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The Relationship and Influences of Organisational Resilience and Open Innovation for United Kingdom (UK) Life Science Small and Medium-Sized Enterprises (SMEs)

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Abstract

This research questions whether open innovation can enhance the organisational resilience of United Kingdom life science small and medium-sized enterprises, by asking how the two concepts are related and influenced. This provides a significant and original contribution to knowledge and practice, to best understand how the two concepts associate, and how practitioners should allocate their limited resources across three factors (internal, demographic, external) to enhance both concepts together.

The rationale is drawn from a gap in the peer-reviewed and grey literature, as it reports that United Kingdom life science small and medium-sized enterprises face a 39% failure rate, with those practicing *closed* innovation being more at risk. These sized enterprises represent 99.9% of the national economy and those operating in the life sciences must become resilient to deliver important social health and economic benefits. This research contributes to the body of knowledge by first considering the concept of organisational resilience, which has a standardised industry definition as an ability to anticipate, prepare for, respond, and adapt to disruption and change. The second concept of this research, *open* innovation, is defined as using external resources for innovation, whilst also allowing any unused resources to go outside of organisational boundaries.

Mixed methods with multi-stage validation of regression and thematic analyses, ensured rigour. Findings show a moderate, positive relationship between the concepts for United Kingdom life science small and medium-sized enterprises. It was, therefore, of value to combine them into an interaction variable, to measure their influences. The foremost contribution is that internationalisation is the most significant influence, implying that a globalised outlook is beneficial. Furthermore, the frequency of significant influences was equal across internal and external factors, indicating that owner-managers should be considerate of both contexts during their resource-based activities.

Declarations

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed: [redacted] Date: May 2024

This thesis is the result of my own investigations, except where otherwise stated. Where correction services have been used, the extent and nature of the correction is clearly marked in footnotes. Other sources are acknowledged by footnotes giving explicit references. A bibliography is appended.

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The University's ethical procedures have been followed and, where appropriate, that ethical approval has been granted.

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Definitions and Abbreviations

Although any initials, acronyms, abbreviations, and statistical lettering, are explained in full when first mentioned, this table also provides a comprehensive list for ease of reference. Please note that the English spelling of organisation is used within this thesis, but sometimes the American spelling ("organization") will be used as it appears in citations.

Term	Explanation
Agritech	Agricultural Technology
Anihealth	Animal Health
Aqua.	Aquaculture
B	Unstandardised Regression Coefficient
β	Standardised Regression Coefficient
Biotech	Biological Technology
BREXIT	British Exit of the European Union
BUCANIER	Building Clusters and Networks in Innovation Enterprise and Research
C1, C2	Concept
CALIN	Celtic Advanced Life Science Innovation Network
COVID	Corona Virus Disease
e1i, e2i, e3i…	Enterprise Interview Participant
e1p, e2p, e3p...	Enterprise Pilot Survey Participant
e1s, e2s, e3s...	Enterprise Survey Participant
EU	European Union
F	Regression Calculation
F1, F2, F3	Factor
FDA	Food and Drugs Administration (USA regulator)
GDPR	General Data Protection Regulations
H_0, H_1	Hypotheses
HM	His Majesty's
IBM SPSS	International Business Machines' Statistical Package for the Social Sciences
IOI	Inbound Open Innovation
IP	Intellectual Property or Internet Protocol (Distinction is made in-text)
Medtech	Medical Technology
MGMT	Management
MHRA	Medicines and Healthcare products Regulatory Agency (UK regulator)
NDA	Non-Disclosure Agreement
NHS	National Health Service
OOI	Outbound Open Innovation
OR	Organisational Resilience
P	Probability
Pharma	Pharmaceutical

R&D	Research and Development
R	Variance
RQ1, RQ2	Research Questions
S	Covariance Coefficient
SIG.	Significance
SME	Small and Medium-Sized Enterprise
STEM	Science Technology Engineering and Mathematics
T	Calculated Difference Represented in Units of Standard Error
TI	Tolerance Interval
UK	United Kingdom
USA	United States of America
VIF	Variance Inflation Factor

Chapter 1: Introduction

This piece of research is conducted within the academic domain of business management, with a specific focus upon the practice of organisational resilience and open innovation activities by small and medium-sized enterprises (SMEs) operating in the United Kingdom (UK) life sciences. This introduction chapter explores the theoretical foundations, and then the research background to understand the field of the investigation, and identify the problem to be solved through this research. Following this, are the aims and objectives of the study, and the identification of two research questions to address the above problem. The significance and originality are then discussed in relation to the contributions to knowledge, practice and methodology that are sought by the research. This chapter ends with a summary for each of the upcoming chapters within the thesis.

1.1. Theoretical Foundations of Systems Theory

At the very start of this thesis, it is appropriate to outline the overall field of organisational theory to provide the background ideas and theoretical underpinnings of this research. Classic organisation theory originated out of the social sciences, from as far back as Smith's (1776/1977) 'Wealth of Nations'. Introducing the idea of the division of labour within a social structure, specifically for industrial efficiency. However, Hatch and Cunliffe (2006) suggest that organisational theory, as a branch of knowledge, was not formally recognised until the 1960s, and that this was with the advent of more modernist approaches. They argue that these modernist influences holistically consider how the organisation is a functional unit within an economic system, removing the emphasis on its people as labour.

Therefore, system theory is claimed by Cole and Kelly (2020) to be a holistic approach, which disregards simplicity and reductionism, and instead embraces complexity. They suggest that this is achieved by focussing attention on the total operations of the system (in this case, the UK life science sector) and the interrelationships of the structure (the SMEs). Systems theory is used as the foundation that this research contributes towards. It's sub-theories of general systems, complex adaptive systems, and contingency, are also related to this investigation regarding organisational resilience and open innovation, discussed next.

1.1.1. General Systems Theory

Although a biologist, von Bertalanffy (1928/1968) theorises that the natural and social world comprises of organisations, and so this theory observes hierarchies from humble atoms and molecules, up to wider complex societies and economies, that are all generalisable across contexts. The wide applicability of this theory across scientific domains justifies the need for it to be labelled a generalisable system of universal study. This theory takes a holistic approach to the 'organism' by considering multiple ways to achieve various goals. and so, for the purposes of this research, it pertains to how open innovation by UK life science SMEs can achieve their organisational resilience. The 'whole' UK life science sector is later defined through the sum of its subsectors (section 1.2., below), and therefore lays the foundation for this holistic general systems theory.

Von Bertalanffy (1928/1968) described the problem with systems today is their "organised complexity" (p. 33), requiring the scientific method[1] and mathematical reasoning to quantify them using a positivist philosophy, which informs the later primary research design. One of the five principles of the general system theory is to develop "unifying principles running vertically through the universe of the individual sciences, this theory brings us nearer to the goal of the unity of science" (p. 37). Hence, the later quantitative findings regarding the relationship between the concepts of organisational resilience and open innovation is later benchmarked against similar research to test if the association is universal across systems, as a contribution to knowledge.

Woodward (1965) observed that multidisciplinary theories were being built on the study of systems, including mathematics, psychology, sociology, and economics. This is said to be resulting in organisations creating a generalisable[2] "common language" (p. 251) for whichever

[1] As first proposed by Taylor (1911/2004, p. 9) in 'Principles of Scientific Management, whereby "the principal object of management should be to secure the maximum prosperity" for the employer and employee, to achieve a "state of maximum efficiency" and productivity. Corroborated by Woodward (1965), who discussed 'management science' as different to the classical approaches - attributing it to the emphasis on empiricism, rather than just on theory.

[2] Hence the name: *general* systems theory.

field they operate within. Woodward proposed that attempts at developing a universal (general) science, utilising "common organizational elements found at all system level as its conceptual framework" (pp. 251-252) is what this research aims to create through a final, accurate empirical model. Firstly, to determine if an identified relationship between the concepts of organisational resilience and open innovation is wide-ranging across systems (countries and sectors). Secondly, to establish which influences of the concepts are significant across the sampled UK life science SMEs, to contribute a generalisable model for the wider UK life science system or population. However, Woodward warned that "it is dangerous to take for granted that organizational elements found at different system levels are of the same nature or operate in the same way" (p. 252), and so these influences are allocated to internal, demographic, and external factors to ensure their contexts are considered within the findings.

Relevant to one of the main concepts of this research (open innovation), the general systems theory is further split into closed and open systems. Daft (2001) makes the distinction by suggesting that closed systems are autonomous, as it "takes the environment for granted and assume[s] the organisation could be made more effective through internal design … The environment would be stable and predictable and would not intervene to cause problems" (p. 14). It is argued by Crowther and Green (2004) that "organisations cannot sit outside of society - they are an integral part" (p. 196), so it is relevant to consider the wider system (the UK life sciences) through systems theory.

In contrast, the open system is described by Cole and Kelly (2020) as organisations being interdependent with the environment for inputs (cited as people, materials, information, and finance). Then, following conversion and transformation of those resources by the organisations, they release their outputs (cited as products, services, ideas, and waste) into it too. In light of this, it is similarly represented later in the open innovation funnel, conceptualised by Chesbrough (2003) but well-utilised and adapted within the academic literature since. Cole and Kelly (2020) make the bold claim that research and development activities tend to work most effectively in open systems, "where they can be aware of, and adapt to, key influences in the external environment" (p. 97) through their permeable boundaries. However, this assertion by Cole and Kelly is unsupported by cited evidence, and so it justifies the need for testing in the upcoming primary research.

1.1.2. Complex Adaptive Systems Theory

This theory develops the above linear system of inputs – conversion – outputs, and adds a feedback loop to make it a circular process. Cole and Kelly (2020) suggest that this allows organisations to effectively adapt to their environment. Driven by learning, evolving, and adjusting their behaviour, based on information, results and their experience, to specifically self-regulate and ensure organisational resilience, which is the other key concept of this research. In their research of teams, Ramos-Villagrasa et al. (2018) propose that entropy is a characteristic of this theory and chaos theory, indicating that complex adaptive systems disorganise over time. Therefore, this highlights the importance of introducing a feedback loop, to ensure that the organisation adapts to ever-changing environmental (or 'market') conditions. Also, specific to this research, it highlights how this investigation is significant and specific for this moment in time, for the UK economy.

In a recent investigation, Daniel et al. (2022) define complex adaptive systems theory as exploring "interactions between the actors and factors, characterized in multi-level, dynamic, adaptive, self-organizing processes of [entrepreneurial ecosystems]" (p. 911). Daniel et al. suggests that the theory is a tool for researchers, practitioners, and policymakers to investigate influences, that extend across traditional systems, such as regions (for example, the UK), sectors (for example, the life sciences), and organisations (for example, SMEs). Therefore, it is applicable for this research to contribute to this theory, through an original framework of multi-factor influences of the concepts. As an extension of systems theory, contingency theory is discussed, next.

1.1.3. Contingency Theory

The idea of organisations being dependent on their internal characteristics and external environment was introduced by Tannenbaum and Schmidt (1958) for the Harvard Business Review. Their study found that successful leaders of teams are acutely aware of their behaviour being contingent upon certain organisational characteristics and 'forces in the situation' and must behave appropriately in light of this knowledge. Therefore, this research has an industry

impact by supplying UK life science SME owner-managers with the significant internal, demographic, and external influences of the two concepts[3] in question.

However, contingency theory was not explicitly conceptualised until Lawrence and Lorsch (1969) observed the ability to understand how the internal state and processes of an organisation is dependent on their external environments, leading them to examine "what characteristics organizations must have in order to cope effectively with different environment demands" (p. 157). In the context of this study, a demanding environment is presented to SMEs in the UK life sciences sector (as discussed in the next section), and so they must be organisationally resilient towards these pressures to survive and prosper. This research firstly measures if open innovation can enhance their resilience, and secondly, what influences the sampled SMEs are contingent upon to practice both concepts. Lawrence and Lorsch found that such organisational variables have complex interrelationships with each other, and the environment that is unique to them. Therefore, contingency theory is relevant as it proposes that there is not one best way to organise within a system.

As discussed by von Bertalanffy (1928/1968), equifinality is a feature of contingency theory, as there are many ways and environmental conditions to both organise and create order from chaos, to achieve homeostasis. It was also asserted that not all ways are equally effective, and so it is important for this research to determine if open innovation is an effective way to achieve organisational resilience. Donaldson (2001) corroborates the above by suggesting that not all modern organisations were considered alike and should therefore not be treated the same. Similarly, Daft (2001) argues that organisations should find a "goodness of fit" (p. 24) to face uncertainty, within the environment upon which they are dependent. Daft states: "What works in one setting may not work in another" (p. 24) and so there is no one best way to operate and manage the organisation, which is the fundamental basis of contingency theory. Even the cited academic (Sullivan-Taylor & Branicki, 2011) and grey (British Standards Institute, 2021)

[3] Organisational resilience and open innovation.

authors consider SMEs to be unique and complex in their own way, so this research is underpinned by this modernist contingency theory.

1.2. Research Background

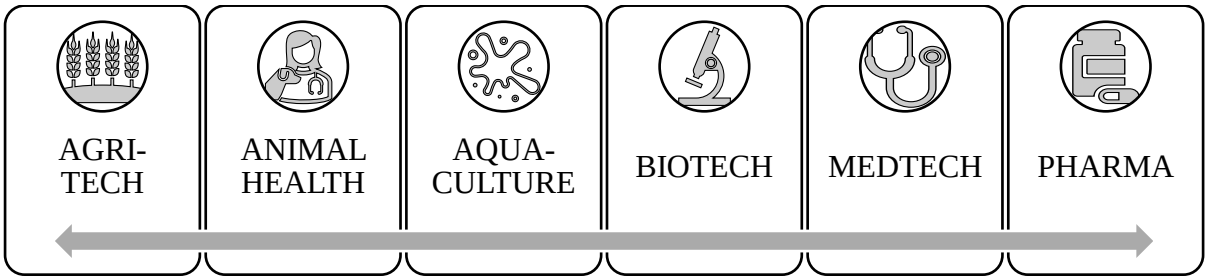
To introduce the UK life sciences in a historical context, Syed (2015) reflects that it has been over 200 years since the first medical clinical trial, yet the sector has a long way to go. Syed proposes that despite the sector's limitations, it has a willingness to evaluate new ideas and learn from its mistakes to increase performance. However, despite promoting the UK's advanced health capabilities contributed by the life sciences, Lettieri et al. (2013) suggests that our "fragmented healthcare [system] delivers poor-quality and high-cost care" (p. 591). It is therefore of value to investigate how the UK life science SMEs can be resilient, collaborative, efficient, and effective in contributing to increasing quality and reducing costs for the downstream healthcare sector.

The current literature lacks a finite definition of the UK life science sector, which is validated by the Fraser of Allander Institute (2017). Suggesting that the lines between its sectors are blurred. They claim that: "a strict definition of activity in the sector is hard to pin down. Gone are the days of the sector comprising firms only working on the development and manufacturing of drugs" (p. 4). In the above General System Theory, von Bertalanffy (1928/1968) suggests that the sciences are "split into innumerable disciplines continually generating new subdivisions" (p. 29), therefore attempts are made to define the UK life sciences by collectivising its subsectors. For example, there are three main scientific subsectors defined by Welsh Government (2013, as cited in Howson & Davies, 2018) for human health: medical technology (medtech), biological technology (biotech), and pharmaceuticals (pharma). However, it was suggested that the UK life sciences are a multi-actor field anyway, with "each playing varying roles to service the combinatorial nature of innovation" (p. 315).

The UK government define the life sciences sector, in their industrial strategy, as the "application of biology and technology to health improvement" (Office for Life Sciences, 2017, p. 3). Later boasting that it is "one of the strongest, most productive health and life sciences industries in the world" (Office for Life Sciences, 2019, p. 2). Interestingly, HM Government (2021) 10-year vision report for the UK life sciences presents no explicit sector definition. Instead, each promoted the significant successes and aims of the sector, but these are likely to contain government bias to encourage UK trade. The subsectors are expanded to

include specialism to support non-human life too, as Life Sciences Scotland (2023) contributes the following subsectors: animal health, agricultural technology (agritech), and aquaculture (Figure 1). Each of these distinct subsectors contribute to the later stratified sampling method, as well as in the testing of enterprise demographics as an influence of the concepts of organisational resilience and open innovation.

Figure 1: UK life Science Subsectors (Life Sciences Scotland, 2023; Welsh Government, 2013, as cited in Howson & Davies, 2018)



Life sciences are identified as a regional strength in Wales (Davies et al., 2020), and, furthermore, according to Howson et al. (2019), the Welsh (and wider-UK) sector is characterised by its highly technical innovations. These can provide solutions to current challenges faced by the downstream UK National Health Service (NHS), which include increased demands and expectations, diversifying public health challenges, and a fragmentation of the system (Aylward et al., 2013; UK Parliament, 2018). Not only are the life sciences aiming to achieve a social benefit, but Howson et al. (2019) further suggest that the sector's SMEs are a catalyst for UK economic growth.

Although Lettieri et al. (2013) cite that the UK has advanced health capabilities, SMEs can lack the internal resources to cater to ever-increasing demographics and medical needs (Ridley, 2011). As a result, they isolate themselves within the system to specialise, rather than collaborate and offer a unified response for wider public health. This consequently creates a fragmented and vulnerable set of subsectors (Lettieri et al., 2013). Even early 'competition literature' by Porter (1998, 2004) cites that any isolated organisations that are disengaged from the system and unconnected within ecosystems face higher costs of acquiring ideas and face higher operating risks. Therefore, relying upon allocating their internal, limited resources to generate those ideas. Whereas, Porter proposes that profitable innovations could instead come from 'outsider' enterprises and industries where the transfer of ideas and other resources across organisation borders occurs. Later conceptualised as 'open innovation' (Chesbrough, 2003,

2019). All these structures justify the investigation into open innovation as the second considered research concept.

It is suggested by Mina et al. (2007) that life science innovations are an international endeavour, unrestricted by geographical boundaries. It is therefore noteworthy that this research is designed as a legacy resulting from two UK life science SME networks, which were both unrestricted by their UK boundaries. Firstly, Building Clusters and Networks in Innovation Enterprise and Research (BUCANIER), and then also, Celtic Advanced Life Science Innovation Network (CALIN). Both facilitated cross-border collaborations, across Wales in the UK, and Republic of Ireland in the European Union (EU). They also facilitated cross-domain collaborations, bridging industry (other UK life science SMEs) and academia. As stated by Davies et al. (2020), the objective of BUCANIER was to *strengthen* enterprise research, development and open innovation through cluster collaborations and knowledge transfers within an ecosystem. Aimed to bolster regional socio-economic strengths, but also address the cited life science sector weaknesses of financial capital and regulatory engagement, which both feed into the downstream challenges of the NHS, above. Whereas CALIN (2023) promoted sustainability (arguably a synonym for resilience) of their member SMEs through collaboration of their network in specific regions across the British Isles.

As SMEs are the focal subject of this research, it is of value to define their boundaries using contextual, grey literature from industry and governmental reports. For example, the UK legal criteria of each size, concerning maximum financial information and employee counts, as set out in the Companies Act (2006, Table 1). There are 5,547,170 UK SMEs, which substantially represent 99.9% of the wider UK business population (Barton, 2023). Barton also reports that the life sciences (included within 'professional, scientific, and technical activities') has the second highest population of SMEs. However, these same activities also report the highest business cessation and deaths (Shaw, 2023), which is reflected in a statistic by the Office for Life Sciences (2011). Formative of this research, they report that UK life science SMEs face a 39% failure rate within their first three years of operating. Consequently, this research considers the first concept of organisational resilience of SMEs, and their ability to provide sustainable social and economic value, despite the occurrence of any external shocks.

Table 1: Defining Criteria for SMEs in UK Legislation (Companies Act, 2006)

Enterprise Size	Act Citation	Maximum Turnover	Maximum Balance Sheet Total	Maximum Employees
Micro	Part 15, Chapter 1, Section 384a	£632k	£316k	10
Small	Part 15, Chapter 1, Section 382	£10.2m	£5.1m	50
Medium	Part 15, Chapter 12, Section 465	£36m	£18m	250

According to Morrison (2021), the UK is an advantageous location for developing medicines, due to having a well-established life science sector. Beside their SMEs, Morrison makes the case that this UK industry also features: (a) globally recognised academic research, (b) commercialisation which spans from pharmaceuticals to data analysis and contract manufacturing, (c) multiple research-intensive NHS hospitals, and (d) an established system of regulatory oversight. So, it makes sense, that the organisational resilience of UK life science SMEs is important for both the social benefit of public health and the UK economy.

The Department for Business Energy and Industrial Strategy (2023) considers SMEs as the backbone of the national economy, so the UK government's current SME action plan (for 2022 to 2025), introduces their commitment to ensuring their enhanced organisational resilience and access to innovation. Yet, there is no mention of *open* innovation to support their endeavours. Therefore, this research is valuable to inform government policy, such as their next UK SME action plan for 2026+. It is also of value for this research to influence industrial policy too, as the current Organisational Resilience Index Report (British Standards Institute, 2021) also does not mention open innovation as a strategy for UK businesses. Therefore, this research could be a vital missing piece to consider for their next index report.

1.3. Research Aim and Objectives

Considering the above, this research aims to provide a significant and original contribution to knowledge by investigating the relationship and influence of the two business management concepts of organisational resilience and open innovation. These themes will be explored in more detail in the next chapter, but to address ongoing debates found in the literature, the objective of this research is to determine if and how open innovation enhances the organisational resilience of UK life Science SMEs. To test this, the following unanswered questions (Table 2) are raised and satisfied through this research.

Table 2: Rationale for Proposed Research Questions

Research Questions (RQs)	Their Rationale
RQ1: How are the concepts of organisational resilience and open innovation related?	Determining if the two concepts have an association, and if so, the strength and direction of that association.
RQ2: How are the concepts of organisational resilience and open innovation influenced?	Factors of varying contexts are analysed against the individual and uniquely combined concepts, to assess what UK life science SMEs should direct their limited resources towards, to enhance both concepts.

1.4. Research Boundaries

This research is bounded by time, and so a cross-sectional approach (Herbane, 2020; Pickernell et al., 2019; Shore et al., 2023) has been applied to provide a snapshot of current levels of organisational resilience and open innovation for UK life Science SMEs. However, due to the adaptability of this research, it could be repeated in the future for a longitudinal comparison. Furthermore, owner-managers are invited to participate, as a single point of contact from each SME. They can offer the best representation of their SME, by being their most knowledgeable of their operations and strategy, to provide accurate and rich answers. Related to the first concept of organisational resilience, this research is bounded by survivor bias (Green et al., 2021; Nikolić et al., 2019) as all enterprises invited to participate in the research will be active. However, this is mitigated by asking the respondents of any past entrepreneurial failures they may have, to capture data regarding business deaths.

1.5.Research Contributions

By accomplishing this primary research, it provides a contribution to the current body of knowledge and methodologies, within the domain of business management. It also has practical industry application for UK life science SMEs, and influence of governmental policy of the Department for Business and Trade, and the Office for Life Sciences (as part of the Department for Science, Business, and Technology). Using a chronological approach through the research process, these contributions are explained below in relation to their significance and originality.

1.5.1. Significance

There is a dearth of UK life science sector definitions within the literature, an so it is meaningful for this research to propose a definition by collectivising its subsectors. This definition is

inclusive, as it not only considers those with *human* health outputs, for example: biological technology, medical technology, and pharmaceuticals (Welsh Government, 2013, as cited in Howson & Davies, 2018). But the definition is also inclusive of *non-human* subsectors too, for example: animal health, agricultural technology, and aquaculture (Life Sciences Scotland, 2023). It additionally encompasses the business support services subsector that specialises in the life sciences.

When evaluating the research methodology, the sampling of UK SMEs from each of the above UK life science subsectors is significant due to the expansive size of the frame applied. By using multiple sources and sampling methods, this research provides a comprehensive, diverse, and representative sample of 2625 UK life science SMEs (Appendix F: Sampling). With 158 survey responses (118 after cleaning) and 16 interview responses, the mixed-method approach also delivers comprehensive analyses for a wide-breadth and in-depth investigation. Furthermore, due to the specificity of the survey and interview questions designed from thorough reading of the literature, this research is important as it is specific to UK life science SMEs, and to now (as a time-period). This means that it cannot easily be repeated in other countries, sectors, or eras, without adaptation. Using such sector-specific measuring tools and data capture, provides truly tailored research. This relates back to the cited theoretical foundations of general systems by von Bertalanffy (1928/1968), because although the subjects of this investigation are the individual organisations, the research is specific to the UK life science eco-system it operates within.

The analyses applied are also noteworthy due to their comprehensiveness. For the quantitative analysis, all variate equations (uni, bi, and multi) were calculated to answer the two research questions. Furthermore, each method of variable selection (enter, stepwise, remove, backward, and forward) was calculated to ensure the most appropriate and accurate regression model. Then, different values were extracted and analysed (P, R, R^2, adjusted R^2, S, T). For the qualitative thematic analysis, not only was a priori coding applied from the quantitative analysis, but also emergent coding too, providing a broad richness to the findings.

This research seeks to transform theory into practice, by summarising the results into two non-traditional research outputs. These accessible industry reports are published with their respective UK life science networks of SMEs for phronesis, through the implementation of the recommendations in their enterprises. The reports are significant as they provide tailored

results, as per the networks' catchment areas, one of which (CALIN) is cross-border. Both reports are written in English, and also translated into Welsh for extra accessibility (Appendix L: Research Outputs).

1.5.2. Originality

To demonstrate originality, this research explicitly included micro-sized enterprises, which is oftentimes not specifically acknowledged within SME literature. Also, the justified measurement tools of each concept are novel in their application. They also provide multidisciplinary but appropriate perspectives:

- **Concept One (C1):** The measurement tool for organisational resilience is specific to UK risk science (British Standards Institute, 2014, as cited in Pescaroli et al., 2020)
- **Concept Two (C2):** The measurement tool for open innovation is specific to life science SME drug discovery (Nilsson & Minssen, 2018)

After discovering a relationship between the concepts, this research then combines them into one interaction variable for measuring their influences in efficient unison. The body of literature reviewed also provides a new, wide-breadth, and diverse range of potential influences, across three different contexts of the SMEs (internal, demographic, external; Mirghaderi et al., 2023), to be measured within the subsequent primary research.

By capturing the influence of specific factors related to the UK and the life sciences, as well as the recent significant events such as BREXIT and COVID, the collection of influences being tested is innovative. However, including the later emergent influence of the Russia-Ukraine War, none of these external threats were found to be significant for UK life science SMEs when practicing organisational resilience and open innovation. Nonetheless, it was topical and novel to consider and measure them, as both the pandemic and the war occurred during the lifespan of this research project. Other disparate themes were not sourced from a pre-existing framework, but identified by the researcher through in-depth reading of the literature, and gaining an expansive knowledge of the ongoing debates and unanswered questions. These then formed models (formative measurement model, Figure 13; and final model, Figure 44) as original contributions to knowledge.

1.6. Overview of the Thesis Structure

Each proceeding chapter of the thesis is described below:

1.6.1. Literature Review

Having identified two research questions in Table 2, this chapter reviews the existing body of knowledge (both academic and contextual) on the concepts of organisational resilience and open innovation, in relation to UK life science SMEs. To not only underpin, but to also inform the research with contemporary theory. The sources are considered chronologically, to track the evolutions of each business management theme, over recent times.

To answer the first question regarding the relationship of organisational resilience and open innovation, literature was first reviewed regarding each of the two concepts independently. They are discussed firstly by their definitions, then how they have each evolved within the academic domain of business management, and then finally, they are supplemented by relevant contextual, grey literature from both industry and government. Only then were the concepts considered in unison. However, due to the originality of this research, literature was sparse, which justifies the need for this investigation.

To answer the second question of what influences the concepts, wide-ranging themes were explored in the literature. For this research to be significant, an emphasis was placed on UK life science SME-specific influences (including UK country of operation, life science subsector, and size of enterprise), and recent significant external forces (BREXIT and COVID) to create a novel framework. These were all allocated to a multi-factor structure which is proven commonplace within such investigations in the literature:

1. **Internal to the SME:** Potential influences related to innovation and management, inside of the enterprise.
2. **Demographic characteristics of the SME:** Potential influences related to the characteristics of the enterprise. Making efficient use of the sample baseline data collected.
3. **External to the SME:** Potential influences related to geographic and events, outside of the enterprise.

1.6.2. Defence of Method

This chapter explores and justifies the use of a objectivist and realist ontology, and a positivist and interpretivist epistemology, through the application of mixed methods to investigate the concepts of organisational resilience and open innovation by UK life science SMEs. A sequential design of quantitative surveys followed by qualitative interviews to collect a breadth and depth of data. These were used to provide a comprehensive and valid understanding of the concepts. Mixed method sampling is also applied to maximise the sample frame from a variety of sources. Ethical approval is separately validated by two schools at Swansea University for rigour. A Gantt chart and audits are also included for transparency of the design process.

1.6.3. Analysis of Findings

This chapter begins by analysing the representativeness of the sample, which includes responses from all the indicators (UK country of operation, life science subsector, size of enterprise, age of enterprise, and leadership of enterprises).

The univariate analysis described most UK life science SMEs as practicing a medium level of organisational resilience, and a partially open model of innovation. A bivariate regression calculated a positive relationship between the concepts (whereby they both increase together), but not in a statistically significant manner. However, this could be attributed to the sample being underpowered, due to not meeting the power analysis target number of responses.

The qualitative investigation is therefore necessary to confirm the strength of relationship between organisational resilience and open innovation. However, a surprising finding was that SMEs only need to practice a partially open model of innovation to achieve a high level of organisational resilience. Due to there being a suggestion of a relationship, this research then uniquely combined the concepts into an interaction variable to answer the second research question. A multivariate regression of backward elimination of variables calculated nine significant influences of the combined concepts.

A thematic analysis of the qualitative interview transcripts followed. Most of the responses confirmed that there is a moderate and positive relationship, indicating a stronger association than the quantitative analysis had calculated. To answer the second research question, the nine calculated influences were used as a priori codes to validate against the qualitative data.

Through an iterative multi-stage validation process, and due to a lack of qualitative evidence to validate their significance, some were disregarded.

To fill the statistically calculated deficit of explanatory power that the above nine quantitative influences had, it was justified to also extract *emerging* influences from the interview transcripts. This better satisfies the model by providing an extra stage of validation, to create a more accurate results. However, for model efficiency, some of these emergent influences did not have enough qualitative evidence to qualify as a significant influence upon organisational resilience and open innovation. Therefore, some were also disregarded.

The final model represents 12 significant influences. It is identified that both the internal and external factors were both equally populated with influences. This can be interpreted that UK life science SMEs must find a careful balance of endogenously and exogenously allocating their limited resources, to simultaneously enhance their organisational resilience and open innovation.

1.6.4. Discussion

The discussion chapter identifies, interprets, and evaluates the findings of the research are positioned within the wider existing body of knowledge; specifically, the literature relating to the concepts of organisational resilience, open innovation, and/or UK life science SMEs. Achieved by representing how it compares or provides an original contribution to the field of business management. To answer the first research question about the relationship between the two concepts, the results were compared against the only two studies that also quantitatively compares organisational resilience and open innovation. Even though the research of Ju (2023) and Mirghaderi et al. (2023) were based in different countries and sectors, it was of value to compare against the P-values of this research. These are plotted within the same range, with a lack of statistical significance, and so it can be interpreted that this is a universal finding.

To answer the second research question about the influences of the combined concepts, the results were compared to the comprehensive literature review against each significant influence that featured on the final model. The resultant 12 influences across the three factors were largely validated by the cited literature, however some finer themes within them are identified as contributions to new knowledge. These include the following subtler discussion points that are influential of organisational resilience and open innovation, listed here as: (a) the high

financial cost of legally protecting their resources, (b) the lack of respect or understanding by other UK life science actors, (c) managements' facilitation of internal communications, (d) their investment in finance and marketing, (e) the inclusion of business support services to other UK life science SMEs, and (f) the government facilitating 'artificial' industry-academia collaborations for funding.

1.6.5. Conclusion

The conclusion begins by revisiting the aim of this research. As a result, the significant and original contribution to knowledge is highlighted and justified within the thesis. Also, the objective to gain a comprehensive understanding of organisational resilience and open innovation for UK life science SMEs has also been fulfilled, through the answering of two research questions. These questions were raised as ongoing debates and unanswered questions within the literature and were tested through the primary research. The research process and results are then summarised as per both research questions, to evaluate how they provide a contribution to the body of knowledge, under the domain of business management. This contribution is then considered as a contribution to the underpinning theory of General Systems, Complex Adaptive Systems, and Contingency Theory. Furthermore, contributions to academia, industry, and government are also contemplated.

This concluding chapter explores what is next in the research agenda, which includes: (a) the quantitative analysis of the emergent influences of the qualitative data, (b) applying more targeted sampling techniques for truer representation across the SME demographics tested, (c) repeating the research in the Republic of Ireland to compare their EU perspectives and experiences, and more. Finally, the concluding remarks of the chapter and entire thesis comments at how increasing both organisational resilience and practicing open innovation can ensure that life science SMEs can continue to deliver social benefits to the NHS and wider public health, and economic benefits to UK trade and industry.

Chapter 2: Literature Review

The objective of this chapter is to critically analyse the existing research surrounding the concepts of organisational resilience and open innovation, within the context of small and medium-sized enterprises (SMEs) operating within the United Kingdom (UK) life sciences sector. Considering that this is to not only establish how this research is positioned within it, but also to identify ongoing debates and unanswered questions. This allows this primary research to provide a significant and original contribution to knowledge. Having established the research background, aims, objectives, boundaries and contributions in the introduction, this chapter focuses on reviewing the literature regarding the two concepts of organisational resilience and open innovation. The aim is to critically assess theory, to identify ongoing debates and unanswered questions, for them to be answered through the primary research. This research takes a holistic approach to investigating the UK life science SMEs, yet there is limited literature upon the concepts for this subject. Consequently, some citations are regarding the closely related health sector, and some are based in countries outside the UK.

To ensure a high quality of journal selection, the Annual Journal Guide of the Chartered Association of Business Schools is referred to for quality ratings. The considered peer-reviewed literature is sourced from esteemed databases (such as Scopus and Web of Science) and reputable publishers (such as Academy of Management, Blackwell, Elsevier, Emerald, SAGE, Taylor & Francis, and Wiley). The following keywords are used to search virtual databases:

- Organisational resilience (including Americanised: ‘organizational’)
- Open innovation
- United Kingdom (UK)
- Life sciences
- Small and medium-sized enterprise (SME)
- Relationship
- Influence

The review of literature primarily cites peer-reviewed sources, with an effort made to also cite open access research, in line with the research concept of openness. This review is also contextualised with ‘grey’ literature, from such credible industry sources of Deloitte and Ernst

and Young, due to their market knowledge of the UK life sciences sector. Also supplemented by relevant UK government sources, specifically the Office for Life Sciences, as a key stakeholder and policy-maker of the sector. A chronological approach is applied to each concept to track their (a) definitions and typologies/taxonomies, (b) evolution, (c) contextual information, and (d) measurements. This begins with the literature regarding the possible relationship between the concepts, next.

2.1. Relating Organisational Resilience and Open Innovation

Concepts are defined by Bell et al. (2022) as "a name given to a category that organises observations and ideas by virtue of their possessing common features" (p. 588). The review of the following body of literature identifies and evidences an ongoing debate and unanswered question regarding the relationship between the concepts of organisational resilience and open innovation. Establishing if and how innovative UK life science SMEs should enact resilient and 'permeable' boundaries (Howson et al., 2019). However, firstly, the concepts are considered independently, before then considering their relationship to each other.

2.1.1. Organisational Resilience (C1)

There are many different typologies of resilience within business management literature (Reinmoeller & van Baardwijk, 2005) with such examples as *entrepreneurial* resilience (Branicki et al., 2018; Santoro et al., 2020), *financial* resilience (Green et al., 2021; Ries, 2017), *infrastructure* resilience (Schabacker et al., 2019) and *supply chain* resilience (Bak et al., 2020; Fearne et al., 2021). Oftentimes, these types of resilience can be ambiguous and correlated so cannot easily be independently examined.

From an industry perspective, the British Standards Institute (2021) offers a comprehensive definition through their standard of organisational resilience (BS:65000), which is expressed as an "ability of an organisation to anticipate, prepare for, respond and adapt to incremental change and sudden disruptions in order to survive and prosper" (p. 4). However, the Office for Life Sciences (2011) reports a 39% failure rate of UK life science SMEs within their first three years of operation. This statistic supports the need for this research to focus upon this first concept of organisational resilience, to not only provide a significant and original contribution to knowledge, but to also providing practical recommendations for strengthening the life science industry.

There has been an identified lack of knowledge upon the organisational resilience of UK SMEs (Herbane, 2010; Niemimaa et al., 2019; Sullivan-Taylor & Branicki, 2011). Niemimaa et al. (2019) propose that it is instead, mainly dominated by the organisational resilience of larger businesses, with plentiful access to resources. Due to the complexity, nuance, and uniqueness of every SME, Sullivan-Taylor and Branicki (2011) suggest that there is no one-size-that-fits-all fail-safe solution for their organisational resilience anyway; this correlates with modernist contingency theory of organisations being individual, dependent on the scenario they operate within (Daft, 2001; Donaldson, 2001; Lawrence & Lorsch, 1969; Tannenbaum & Schmidt, 1958; von Bertalanffy, 1928/1968).

Furthermore, Korber and McNaughton (2018) perceive the organisational resilience to be poorly defined. They describe it as being "used to connote a wide range of concepts" (p. 1130), which was cited to include ideas around business success, survival, persistence, and optimism. Likewise, Jarvis (2019) argues that the indicators for business failure and success can only really be subjectively defined by the owner-managers themselves. Therefore, noting this difficulty and complication to define it, the next section will not only track the evolution and context of this concept, to provide a best-suited explanation for this research, but also demonstrate the lack of literature upon this concept for UK life science SMEs.

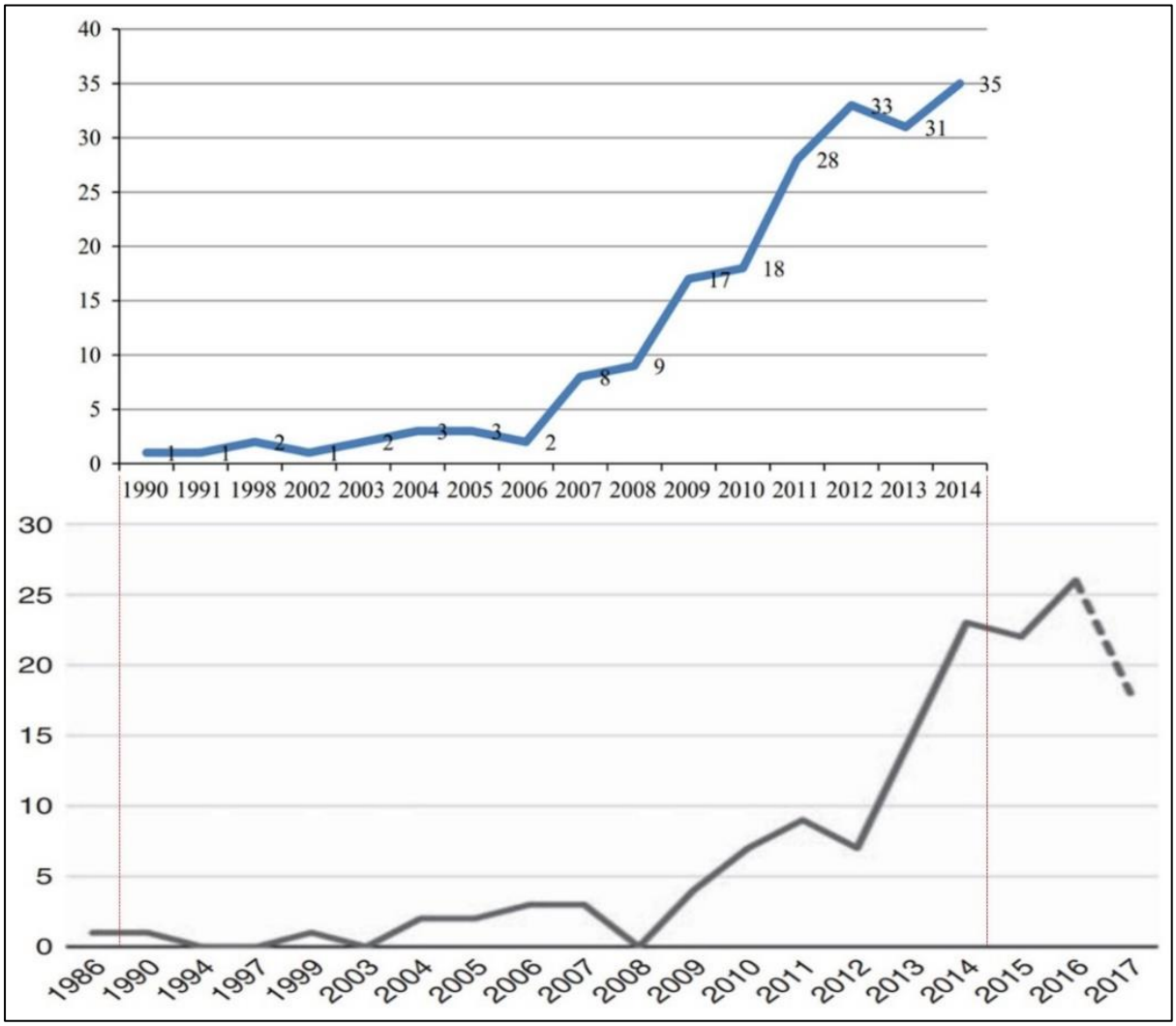
Evolution

Early organisational resilience theory by Meyer (1982) considered "threats, crises, and catastrophes" (p. 515), with each disruption revealing vulnerabilities to health infrastructure. Although a dated and American study, it is still relevant to the life sciences, as "by plunging organisations into unfamiliar circumstances, jolts can … revitalize them, [and] teach lessons that reacquaint them with their environments" (p. 535) to provide end-benefits to the patient. To safely provide these end-benefits, the UK life sciences are characterised by lengthy regulatory safety checks. These can prolong, or indeed prevent, SME innovation getting to market, due to "complex, uncertain and costly nature of transforming basic science" (Rothaermel & Deeds, 2006, p. 440) into a drug that they can commercialise. 95% of their sampled biotech enterprises marketed no new drugs by the end of their study and was 'burning' substantial finances to make accrued changes to their existing products, to attempt to stay resilient, and ahead of competition.

Acknowledging the high failure rate of SMEs in general, Garengo and Bernardi (2007) argued that their lack of resources is what causes an inadequate ability to strategically plan ahead, and therefore, instead, use a reactive strategy. They propose that the temporary chaos of a threat poses an innovative opportunity to learn from. Yet, a fundamental aim of a resilient enterprise is "to engage in organization-building under conditions of extreme uncertainty" (Ries, 2011, p. 38).

SMEs, in general, are noted to have a history of being more likely to be *reactive* to such uncertainty, attributed to their lack of resources to be proactive. This results in an attitude to "muddle through" (Branicki et al., 2018, pp. 1255-1257; Sullivan-Taylor & Branicki, 2011, pp. 9, 11) and make spontaneous decisions, despite this approach being increasingly difficult to sustain. Such external change drivers can offer opportunities to recontextualise and strengthen an enterprise into "a new reality while simultaneously avoiding or limiting dysfunctional or regressive behaviours" (Lengnick-Hall et al., 2011, p. 244). An example of such a threat is that of national recessions, whereby the research of Lai et al. (2016) stressed that it is the SMEs' flexibility and adaptability that helps them thrive through such economic hardships. This was certainly the case during the global financial crisis of 2007-2008, which caused a substantial increase of academic research on organisational resilience, evidenced by multiple systematic literature reviews (Annarelli & Nonino, 2016; Korber & McNaughton, 2018; Figure 2).

Figure 2: Comparison of Organisational Resilience Literature Reviews (Annarelli & Nonino, 2016, p. 9; Korber & McNaughton, 2018, p. 1132)[4]



Yet, despite the progress and evolution of the topic, Duchek (2020) considers organisational resilience as a "complex construct … still in its infancy" (p. 216). In such times of economic recessions as the above financial crisis, it is suggested by Lai et al. (2016) that SMEs have advantages over larger firms, due to their flexibility and adaptability. This allows them to be resilient and thrive during challenging times, despite their lack of resources. It could, therefore, be argued that the significant events of BREXIT and COVID could inspire another increase in

[4] The Y-axis represents the frequency of publications.

contemporary organisational resilience literature, of which this original research will contribute.

Although well-intentioned, Williams et al. (2017) report that post-threat responses by an organisation may be clumsy, with an excess and congestion of people and resources allocated to its recovery. The resilient attitude of "maintaining a posture" (p. 751) through hardship, to keep an 'equilibrium' or 'status quo', may be noble in its cause. However, this persistence could also mean a commitment to a lost cause, as the enterprise may no longer be suited to the new environmental context (marketplace) following the threat. This could lead to several negative outcomes, including major disruption, "delayed decisions to terminate poorly performing endeavours, and [an] inability to readjust" (p. 757).

According to Ries (2017), enterprises frequently fail, but it is wrongfully attributed by Rothaermel and Deeds (2006) to a lack of financial resilience. Instead, a general consensus is that failure is caused by the poor decisions of their entrepreneurial leadership. Countering this, organisational resilience is labelled as a contentious term within the UK life sciences, due to it unfairly creating *entrepreneurial* blame. Rather than accusing the "often over-politicised, understaffed, underfunded, badly-organised systems" (Oliver, 2017, p. 1), reinforcing the aforementioned National Health Service (NHS) challenges (Aylward et al., 2013; UK Parliament, 2018). The same NHS challenges are present within the UK life sciences too. In the years leading up to COVID, it was argued by The Lancet (2018), that the golden era of biomedical research was due to end. 12 global life sciences companies were cited by The Lancet to have reported a decline in returns on their research and development since 2010. This was attributed to the sector catering for ever-increasing complexities and multi-morbidities of the aging population. From a systems standpoint, Tidd and Bessant (2021) argue that innovation prospers when managed holistically. They propose inter-organisational collaboration as a solution to address sector challenges, while still allowing individual organisations to be contingent to ever-changing demands in their environment.

SMEs are described as the backbone of the wider UK economy, through their 99.9% representation, and so they are at the forefront of driving global economic recovery (Beynon et al., 2020a, p.2; Department for Business Energy and Industrial Strategy, 2023). Yet UK life science SMEs, specifically, are met with the challenge of blurred sector boundaries and

identity, as they are distinct from the healthcare sector, but are certainly connected through collaboration (Rees et al., 2021).

Context

To introduce the literature of the wider context, an industry report commented upon the morality of life science commercialisation, by controversially asking if curing patients is a sustainable business model for their organisational resilience:

> *"The potential to deliver 'one shot cures' is one of the most attractive aspects of gene therapy … While this proposition carries tremendous value for patients and society, it could represent a challenge for genome medicine developers looking for sustained cash flow." (Richter et al., 2018, p. 20)*

Yet, giving kudos to "what does not kill me, makes me stronger" (Nietzsche, 1889/1997, p. 6), organisational resilience for UK SMEs is viewed as "a process through which they learn from the experience and become stronger and more capable of withstanding future shocks" (Wishart, 2018, p. 7). This came with a recommendation that SMEs, with their advantageous lack of bureaucracy, should invest in holistically developing a culture that can "navigate adversity" (p. 12), rather than allocating their limited resources to constantly planning for specific, potential jolts.

According to the British Standards Institute (2021), every organisation has a "unique narrative" (p. 7), which reinforces that there is no universal fail-safe solution for UK organisational resilience (Sullivan-Taylor & Branicki, 2011). Nevertheless, the high failure rate of UK life science SMEs reported by the Office for Life Sciences (2011), is later contradicted by the same government department. The Office for Life Sciences (2019) proudly asserts that the UK sector is strong, productive, and a globally competitive industry. Furthermore, it is described as having a competitive ambition to become a global powerhouse of scientific research and technologies (Office for Life Sciences, 2023). Whilst these UK reports promote the robust and resilient nature of the sector, it is likely that they contain government bias to not update, nor draw attention to, the high failure rate. This may be explained by their aim to attract and sustain investment in the sector.

Yet, by interpreting the business demography data, Shaw (2023) reports that the UK 'health' industry is growing with a 9.3% business birth rate, which is higher than their 7.3% business death rate. However, it is quite a pessimistic state for the UK 'professional, scientific and

technical' industry which is shrinking with a 9.9% business birth rate, lower than their 12.2% death rate. With the life sciences spanning both of those industries, it provides a conflicting state of the sector for their SMEs. However, it should be noted that these statistics are regarding business of any size.

Measurement

Using a binary approach, Branicki et al. (2018) found that SMEs "are often walking a knife edge between success and failure due to limited resources" (pp. 1254-1255); reinforced by the Office for National Statistics, who rigidly and dichotomously consider UK businesses as either alive, surviving businesses or a business death whereby they cease to trade (Shaw, 2023) for their reporting of UK business demography. Yet, there are those that consider organisational resilience to be much more nuanced. For example, Bak et al. (2020) suggest that the topic is a complex "multidimensional and multidisciplinary concept" (p. 1).

Due to its comprehensiveness, a Likert scale of definitions by the British Standards Institute (2014, as cited in Pescaroli et al., 2020; Appendix A: Concept Measurement Frameworks) measures the organisational resilience for UK organisations through an industry-standardised ranking scale; the higher the level, the more resilient they perceive their organisation to be. This was published in the Journal of Disaster Risk Science, and so provides a cross-disciplinary and peer-reviewed framework to later be applied within the research design. Likert scales were also utilised in similar research to measure the concept (Ju, 2023; Mirghaderi et al., 2023).

Section Conclusion

This section has provided the theoretical and contextual underpinning of the first concept. It started by recognising the interconnectedness of typologies of resilience, and scarcity of relevant SME literature, both within the domain of business management. This justifies the need for this research to shine a spotlight on organisational resilience. The evolution of the concept traced its origins to within healthcare, which sits downstream of the UK life sciences. The UK's strict and lengthy regulatory checks, combined with the SMEs' limited resources, requires their flexibility to survive and innovate. Using grey literature, the wider context of the UK life sciences was also examined. This included the moral dilemmas around the commercialisation of life science outputs, and the government's juxtaposing account of boasting a resilient sector, whilst also evidencing a high failure rate for their SMEs. This further

justifies this research to provide clarity on the sector's successes and vulnerabilities regarding organisational resilience.

Lastly, different measurement frameworks (both binary and nuanced) were considered for this complex concept. The justified framework of Pescaroli et al. (2020) is later applied within the primary research design to gain a clearer understanding of organisational resilience for the UK life science SME population and provide a significant and original contribution to knowledge. Applying the same structure as this section, the next will critically assess the literature of the second concept of open innovation for UK life science SMEs.

2.1.2. Open Innovation (C2)

This research now independently considers the concept of open innovation, to later determine if it can be used as a much-needed model to enhance the organisational resilience of the vulnerable (Meyer, 1982) and fragmented (Lettieri et al., 2013; Porter, 1998) UK life science SMEs. Innovation has been defined within early literature by West and Farr (1990, as cited in Omachonu & Einspruch, 2010) as "the intentional introduction and application within … [an] organization, of ideas, processes, products or procedures, new to the relevant unit of adoption, designed to significantly benefit the individual, the group, or wider society" (p. 3). In as much as it is particularly pertinent to the public health benefits of UK life science innovation outputs, to improve health or reduce suffering (Faulkner & Kent, 2001), but also benefit the organisation, the sector, and the broader UK economy too. Included in the development of a UK-based technical innovation audit, Chiesa et al. (1996) introduced innovation, as activities which a business "converts its substantive product or process concepts into deliveries for external customers" (p. 107). This is later analogised for the UK life sciences as taking the innovation from:

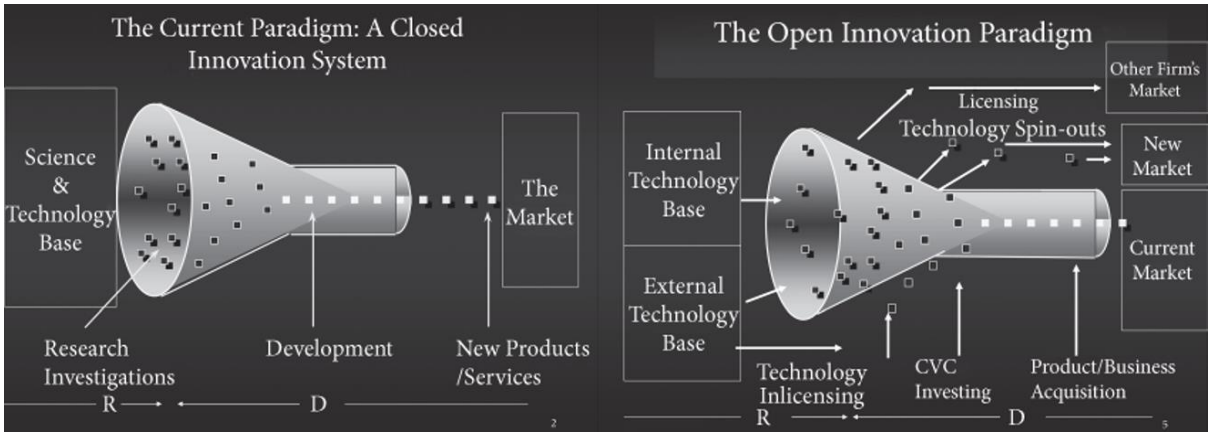
- 'Bench to bedside' (Howson & Davies, 2018), whereby the researchers identify the UK life sciences as being critical to not only ensure sustainability of the service, but also improve patient health outcomes, and driving economic growth.
- 'Mind to market' (Howson et al., 2019) whereby the UK sector is said to be revered for its prestigious history of innovation.

Whilst there is a focus on Howson's published literature (both above and within the wider literature review), it is due to their unique and highly relevant research contributions regarding Welsh life science innovation.

An internationally regarded competition theorist, Porter (2004), introduces the importance of innovation, as it widens the market for industry growth and enhances product differentiation. Porter describes it as "a response to incentives created by overall industry structure and a shaper of that structure" (p. 195). Yet, it is also stated that innovation comes with costs to SMEs, which can impact their organisational resilience. Porter explains that with already limited resources, it can be difficult for SMEs to practice 'rapid product introduction' to their market. Requiring new marketing, manufacturing, and distribution; all at a heavy financial burden which SMEs may not afford to bear.

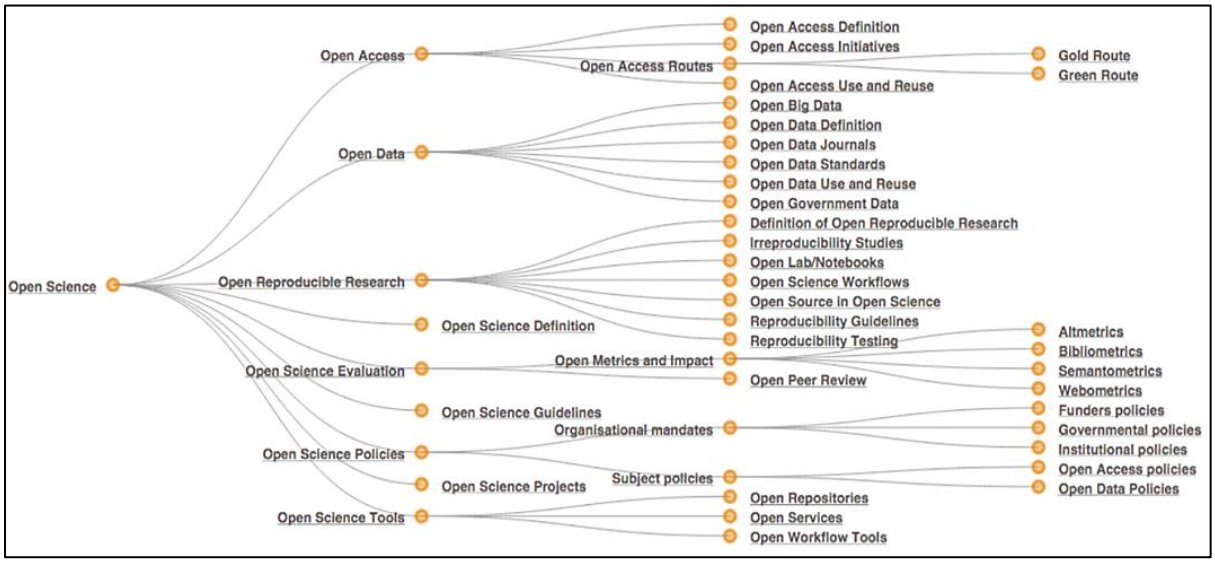
Asserted by Brunswicker and Vanhaverbeke (2015), SME innovation "almost always has an interorganizational and boundary-spanning component" (p. 1243). Therefore, it is suggested to be a way for SMEs to navigate their research and development with limited resources. For this reason, this research now considers the second concept of open innovation for UK life science SMEs. The founder of this concept originally identified that "valuable ideas can come from inside or outside the company and can go to market from inside or outside the company as well" (Chesbrough, 2003, p. 43). In a co-authored article with Chesbrough, Bogers et al. (2018) evidenced the blurring of organisational boundaries. They described those borders as creating "an ecosystem where people, organizations, and sectors can foster co-creation" (p. 10). In an updated definition and model of the concept, Chesbrough (2019) argued that "no one organization has a monopoly on great ideas, and every organization, no matter how effective internally, needs to engage deeply and extensively with external knowledge networks" (p. 28). Chesbrough then promoted open innovation very much as a process, with "purposively managed knowledge flows across organizational boundaries" (p. 30; Figure 3).

Figure 3: Closed and Open Models of Innovation (Chesbrough, 2019, pp. 35-36)



Pharmaceutical enterprises are later identified by Chesbrough (2019), as being fractal. Closing their boundaries to not "export an abandoned compound outside the company for another group to commercialise" (p. 47). Reportedly, due to a fear of looking foolish about being unsuccessful in their own attempts to monetise their ideas. This research is therefore significant, as it will identify if practicing more open models of innovation can assist these such pharmaceutical enterprises. Much like the wide business management typologies of resilience, Pontika et al. (2015; Figure 4) also evidenced the uptake of scientific openness through a wide-ranging taxonomy, as practiced by the European Union (EU), whilst the UK was still a member state.

Figure 4: Open Science Taxonomy (Pontika et al., 2015, p. 3)



Open science was later signed into EU legislation, with the expectation that any government-funded scientific research must be published in open access journals, to encourage the

widespread dissemination of new knowledge (Bogers et al., 2018). Yet, despite its wide application, Lopes and de Carvalho (2018) consider open innovation as a complex topic, and as yet, under-researched for SMEs. Therefore, this research aims to provide a significant and original contribution to knowledge under this topic's domain, by first exploring the evolution and context of the concept in relation to the subject of UK life SMEs.

Evolution

In the early theory of General Systems, von Bertalanffy (1928/1968) described the fragmented and closed nature of the sciences, as "the physicist, the biologist, the psychologist, and the social scientist are, so to speak, encapsulated in their private universes, and it is difficult to get word from one cocoon to another" (p. 29), stifling collaboration and competition for societal and economic benefit. Yet, using a biological analogy, von Bertalanffy describes organisms as open "systems exchanging matter with their environment" (p. 31) - a fundamental aspect of what was later conceptualised as open innovation for organisations.

Porter (1998) pre-empted the advantages of open innovation to enterprises. Porter identified that knowledge can not only come from in-house research and development, but also from 'outsider' actors, industries, or countries. Isolated enterprises, unconnected within the ecosystem, face higher costs for acquiring ideas, as their already-limited resources must be allocated to specifically generate them internally. Porter asked: "What will it take to foster entirely new approaches to disease prevention and treatment?" (p. 409), which began a discussion around more open approaches to life science innovation, to achieve competitive advantage, years before open innovation was to be conceptualised. Later, Porter (2004) commented that the concept was promoted as being bigger than the individual enterprise, as it can encourage industry-wide growth. Despite this stated competitive advantage, *open* innovation is not universally welcomed by SMEs. Enkel et al. (2009) emphasise that "too much openness can negatively impact companies' long-term innovation success, because it could lead to loss of control and core competences" (p. 312). This results in overly cautious entrepreneurs keeping to closed innovation models, due to caution from any previous experience of failure.

There are sacrifices which SMEs must make to be open, including the developer losing freedom and control over their innovations, as choices will instead be made by external "independent firms that pursue their own interests" (Almirall & Casadesus-Masanell, 2010, pp. 27-28). Of

which, even those choices will not be perfectly aligned for both/all partners. Yet in contrast, some suggest that the life sciences are fragmented (Lettieri et al., 2013; Porter, 1998), which is reinforced by Carayannis and Campbell (2011) who describe such fractal ecosystems as "multilayered, multimodal, multi-nodal, and multilateral" (p. 330). They suggest that such social innovators are "continually co-evolving, co-specializing, and co-opeting … [to] form, reform, and dissolve" (p. 337) in diverse areas of the marketplace.

Ridley (2011) suggests that an accumulation of ideas and knowledge is valuable for exchange and specialisation, as no single enterprise is said to know all. Instead, Ridley states that learning from others is vital for ideas to 'cross-fertilise'. This reinforces the previously cited idea of Chesbrough (2003), that no organisation has a monopoly on knowledge. However, Ridley (2011) argues that the concept of open innovation is not new and is actually a rebranding of the historical market process of exchange and specialisation, under the domain of business management. This was agreed upon by Trott and Hartmann (2013), who argued that the concept of open innovation is only a mere relabelling of "old ideas in a fancy tuxedo" and is actually, merely "old wine in new bottles" (p. 359). Equally, Tidd and Bessant (2021) suggest that the concept is no longer new or original, and that some form of collaboration or licencing is always necessary.

Furthermore, Ridley (2011) suggested that scientific innovation and reciprocal exchanges of information lead to a theory of 'collective intelligence', whereby the beauty of knowledge exchange is that the enterprise can simultaneously give it away *and* keep it. Both options can be commercialised, as "human progress consists largely in accumulating recipes for rearranging atoms in ways that raise living standards" (p. 269). This sharing of resources is said by Ridley, to be one of the most important things innovators do, "for unless they share their innovation it can have no benefit for them or for anybody else" (p. 270). Hence, it is vital for the life sciences to create health impact via their outputs. It was further commented that the sharing of resources has got easier and more frequent over the last two centuries, as the modern world has become increasingly interconnected, with ideas meeting, mixing, mating, and mutating.

Yet, caution is heeded over the appropriation of inbound knowledge transfer, as "external ideas and information might be biased and misleading" (Salge et al., 2013, p. 662). Instead, it is better suited for the external knowledge creator, than the enterprise attempting to assimilate it.

With the management of strategic alliance capabilities taking up an SME's precious resources, Salge et al. suggest that although diverse alliances may provide innovative solutions to problems, their ideas "might be too diverse to be integrated into a coherent concept" (p. 662). Furthermore, despite a model by Brunswicker and Vanhaverbeke (2015) holistically promoting ecosystem-wide collaboration, it is actually proposed that enterprises should choose quality over quantity of external knowledge sources. They argued that a "combination of innovation sources rather than their total number is crucial for the success of a firm's sourcing strategy" (p. 1244).

According to Veer et al. (2013), openness is a very en-vogue (*fashionable*) topic. And yet, later they questioned: 'How open is too open?'. Veer et al. lists the dark sides of open innovation as (a) problems regarding appropriability, (b) unintended knowledge drains, and (c) imitation. These cause a double-edged sword, with Veer et al. (2016) later adding to their theory that "tensions between firms' increased tendencies to complement their internal processes with external partnerships while simultaneously focusing on the protection of critical know-how" (p. 1115). This has the implication of the SMEs specialised resources being vulnerable to the dominance of their larger and more-successful partners. Yet, according to Forés and Camisón (2016), to pursue profit, enterprises *must* accumulate both internal and external knowledge. This makes it harder for competitors to imitate, substitute and replicate it for their own commercial purposes, which results in a paradox.

Expanding upon Chesbrough's funnel model of open innovation (above), which was concerned with the transfer of valuable ideas, an updated resource-based model is published by Escoffier et al. (2016). This includes the transfer of technology, people, money, and intellectual property across enterprise borders. This strongly suggests that this is an ever-expanding, applicable concept within business management literature. In the closest related research of open innovation by UK life science SMEs, Marangos and Warren (2017) agreed the importance of insourcing much needed resources and outsourcing their useful ideas beyond their borders for profit. They confess that those UK life science SMEs who do not transfer resources, and instead use a *closed* model of innovation, are believed by them to forfeit their organisational resilience and be more at risk of failure.

Similar to the previously cited systematic literature reviews of organisational resilience (Annarelli & Nonino, 2016; Korber & McNaughton, 2018), a very similar trajectory of

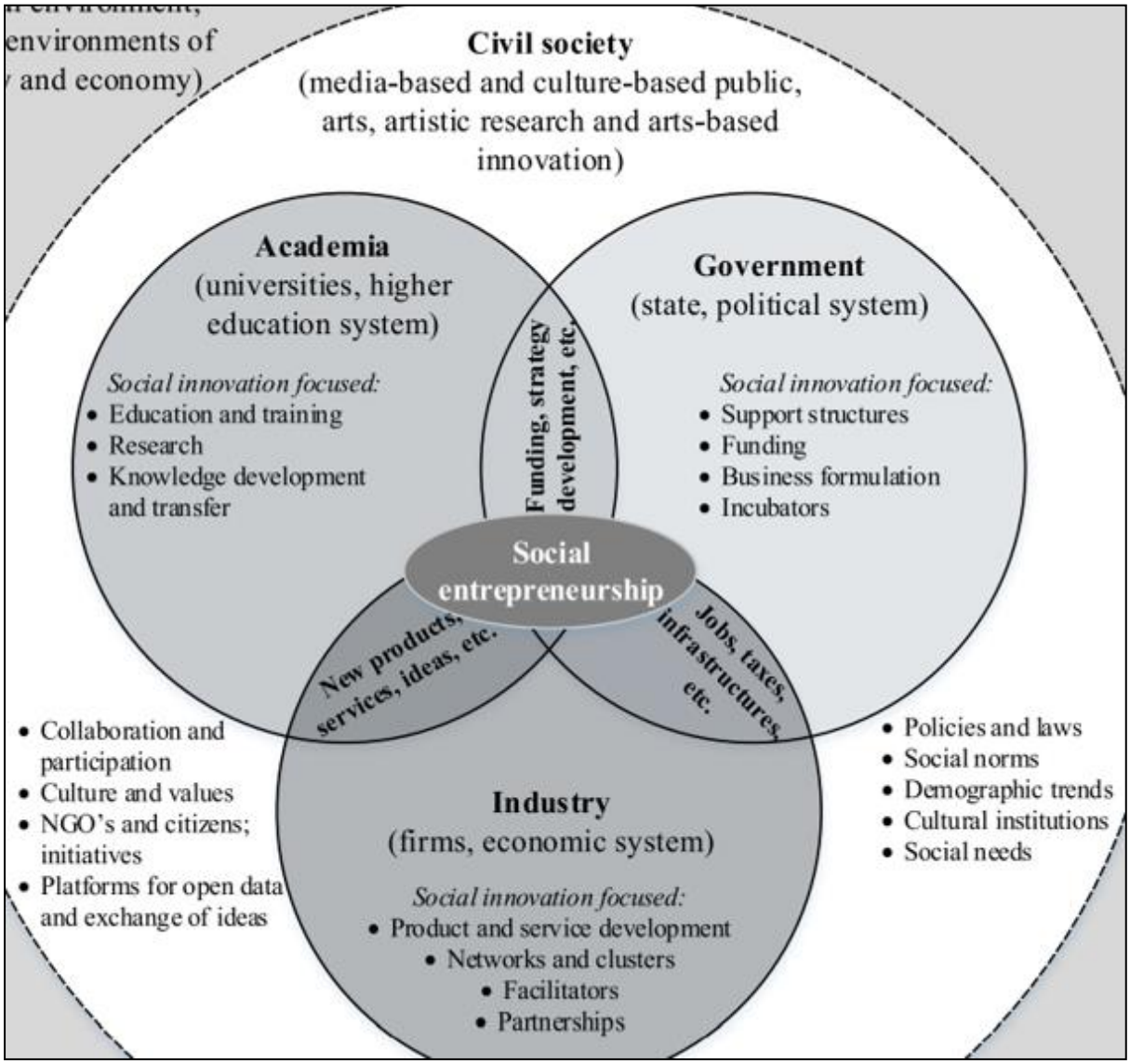
academic interest was also found for open innovation after the 2007-2008 financial crisis (Lopes & de Carvalho, 2018, p. 291), although no link was made to this event as causing the-then upsurge. Despite such recent and frequent academic interest in open innovation, Bogers et al. (2018) acknowledged that openness is known to increase effectiveness and competitiveness, but "at the same time, science is changing, and the way we use science to solve global problems is changing too" (p. 9).

The European Conference on Innovation and Entrepreneurship saw multiple papers in recent years regarding health innovation (Davies et al., 2017, 2020; Howson & Davies, 2018; Howson et al. 2019). Specifically, Howson and Davies (2018) introduce the Welsh health and life science sectors as "inherently inter-connected" (p. 309). This links to the difficulty in finitely defining the sector. However, it could arguably represent openness and blurred boundaries in the wider ecosystem. Syed (2019) considers openness as a 'rebel idea', whereby it is promoted as a combination of the 'outsider mindset' and 'internal expertise' as powerful assets. Syed argues that enterprises need to (a) have a conceptual depth and distance, (b) embody being an insider and outsider, (c) be "conceptual natives and recombinant immigrants" (p. 142), and (d) to both keep and challenge the status quo. Yet it is foolish to do so as "when ideas are shared, the possibilities do not add up. They multiply" (p. 146). This advantageous flow of open knowledge is cited as travelling from:

> *"Engineer to engineer, firm to firm, spilling over all the time. Information didn't merely circulate within institutions, but between institutions … with different perspectives and paradigms. Insiders on one topic or technology were outsiders on another and vice versa, creating vast diversity of thought." (p. 159)*

Asserted by Rees et al. (2021), the UK life sciences are said to be complex, and as yet, uncollaborative and closed. Partnerships are, instead, described as being crucial, for not only economic reasons, but also for other implications such as patient care. In the same year, Carayannis et al. (2021; Figure 5) modelled such collaborative working for social innovation into a 'quadruple helix model of social innovation' which labels government, industry, academia, and civil society as stakeholders. This can be applied to open innovation through the knowledge transfer with each of these helices. For example, using 'reverse exchange' with current patients and wider society to increase reliability of health care organisations (Kumar et al., 2021).

Figure 5: Quadruple Helix Model for Social Innovation (Carayannis et al., 2021, p. 245)



Context

As observed in the EU's open science (Bogers et al., 2018; Pontika et al., 2015), the UK is now also requesting that all health researchers openly publish their trial data. Even whether the results are "positive, negative, neutral or inconclusive [they] should be made accessible in a timely manner" (Health Research Authority, 2021, para. 1). These such results are new knowledge that can then be absorbed, assimilated, innovated, and commercialised by UK life science enterprises, for public benefit. Morrison (2021) argued in an open access government article, that to produce novel medical products and services from the above new knowledge, UK collaboration is needed to translate and transfer knowledge and technologies between "academics, companies, healthcare professionals, regulators, funding agencies, hospital

managers and health economists working together to develop solutions" (p. 1), with the cited NHS challenges (Aylward et al., 2013; UK Parliament, 2018) as a prime example.

Measurement

In a similar way that it occurs in the literature of organisational resilience, there are also disputes over dichotomous or nuanced approaches to measure open innovation. Despite Marangos and Warren (2017) finding that UK life science SMEs are open to collaborations, their open innovation was inconsistent and selective. They suggest that this makes the concept difficult to measure. Lopes and de Carvalho (2018) took a twofold approach, which was later reinforced by the following life science industry report (with notable corporate bias). Goldberg (2020) treated the topic as strictly a choice of either closed or open:

> *"Fluidity versus silos. Data sharing versus data ownership. Process and algorithm versus product. The ecosystem of the future will be connected and open, blurring traditional distinctions among the players in the … value chain. Organizations will focus less on owning and monetizing data and more on connecting and combining it to drive valuable insights that can transform health care." (p. 17)*

However, the above dichotomy is rejected as being unhelpful and unrealistic, and instead it is recommended to "explore the different degrees and types of openness and the extent to which a firm can benefit from external and internal resources and knowledge in the innovation process" (Tidd & Bessant, 2021, p. 438). Nilsson and Minssen (2018; Appendix A: Concept Measurement Frameworks) in 'Drug Discovery Today', standardises and explicitly defines the *levels* of life science open innovation for life science enterprises. This was created with a practical application in mind, to increase the clarity of legal agreements of strategic alliances. Without such a framework, both/all life science parties can be confused about expectations, when they are negotiating their proposed collaborative endeavours. No data was collected against their proposed framework, but it is recognised that the model requires modification before such cross-disciplinary application. The use of Likert scales to measure this concept is typically implemented in similar research (Ju, 2023; Mirghaderi et al., 2023).

Once the relationship between the concepts is later tested in the primary research, it will be of significance to the UK life science SMEs to understand what influences this relationship. Providing practical solutions for them to exercise organisational resilience and open

innovation, to solve the current problems in downstream healthcare (Aylward et al., 2013; UK Parliament, 2018).

Section Conclusion

To conclude, this section has examined the second concept of open innovation, generally and within the context of UK life science SMEs. It started with defining innovation as an intentional introduction of new ideas, which are significant in the UK life sciences for health and economic benefit. Then open models of innovation were defined as the exchange of such valuable ideas, inbound and outbound, across enterprise borders. This was noted to be popular with SMEs, who can be encouraged into practicing open innovation, due to their own limited resources. This section has promoted the advantages of practicing open innovation as having greater competitiveness within the UK life science marketplace, and accumulation of external knowledge to fill any deficits of expertise. However, the disadvantages were also noted, especially around a potential loss of control and vulnerability through partnering with dominant or predatory life science actors.

The evolution of open innovation was examined. This began in the concept's founding, regarding knowledge exchange of valuable ideas, and included the expanded definition, which includes technologies, money, people, and intellectual property being transferred across SME boundaries too. However, some authors debated that the concept was just a mere relabelling of a historic tradition of marketplace exchange. Last of all, measurement frameworks (both dichotomous and nuanced) were considered for open innovation. One of which is later applied within the primary research design to gain a clearer understanding of this concept for the UK life science SME population and provide a significant and original contribution to knowledge.

Having explored both concepts independently, this research will now explore them in unison, to understand what relationship they have upon each other. The study of their interaction is unique to the UK life sciences. Yet, due to the complexity of each of the concepts, it will be of interest to academia and industry alike to illustrate their connection, which holds some prospective optimism for the life science sector's growth and success, with social and economic benefits.

*2.1.3. Their Relationship (C1*C2)*

Having investigated the two concepts independently, above, this section considers their possible relationship within business management academic literature. As the life science sector is constantly evolving to the opportunities and threats it faces, understanding how these concepts intersect is vital from a practical standpoint too. This section reviews the current literature to ask if UK life science SMEs can practice open innovation to enhance their organisational resilience. Due to there being long-standing academic interest in both distinct concepts, especially since the financial crisis of 2007-2008 (Annarelli & Nonino, 2016; Duchek, 2020; Korber & McNaughton, 2018; Lopes & de Carvalho, 2018), some contemporary research considers the relationship of similar business management concepts (Acquaah et al., 2011; Marom et al., 2019; Santoro et al., 2020; Venkatesh et al., 2013), and so this research sits alongside them.

Keizer et al. (2002) suggests that SMEs must be innovative, to overcome their (a) limited resources, (b) vulnerability to uncertainty, and (c) turbulence in business environments, amongst other challenges. This provides an early introduction to the resource-based approach of justifying the investigation of the two concepts, albeit outside the UK life sciences, for this instance. According to Powell and Baker (2011, as cited in Wishart, 2018), SMEs' organisational resilience is closely related to its resourceful behaviours, of which open innovation would fall into that category. According to Kmieciak and Michna (2018, p. 559), SME innovation is widely recognised as the "source of long-term competitive advantage and survival" for enterprises, but this research explores if *open* innovation is as effective for organisational resilience. Likewise, Nikolić et al. (2019) used a resourced-based approach to indicate that SMEs are disadvantaged compared to larger/older counterparts[5], due to having (a) higher operating costs, (b) low-to-no economies of scale, and (c) less stability. To rectify these disparities, Nikolić et al. suggest that SMEs must seek external resources for their innovation needs.

[5] Even though those larger/older counterparts would no longer be categorised as 'enterprises', due to their size and age, as per the academic definition by Márquez & Ortiz, 2020, discussed later.

Tidd and Bessant (2021) found that such inter-organisational collaboration (a synonym for open innovation) and "operational and strategic flexibility deemed to bear a high correlation for bolstering resilience" (p. 437). Yet, over a third of Tidd and Bessant's sample organisations found a poor relationship between the concepts, so there is no consensus. This evidences the need for this research to attempt to garner clarity and unanimity of the association between organisational resilience and open innovation. The following literature considers the potential relationship of the concepts, in terms of strength and direction.

Strength of Relationship

It is suggested by Daft (2001) that open systems needs to interact with its environment to survive, perceiving open innovation as a forced opportunity, rather than a choice to be made by SME owner-managers. According to van de Vrande et al. (2009), the practice of open innovation is a resilience-enhancing activity for enterprises, to "serve customers effectively or to open up new markets, with higher-order objectives to secure revenues and to maintain growth" (p. 435). Irish[6] research by Cormican and O'Sullivan (2004) argued that surviving (and arguably therefore, organisationally resilient) healthcare enterprises are those that are rigorous in their pursuit of efficient, effective, and profitable innovation. This pursuit may, consequently, include open models of innovation. Verreynne et al. (2018) observed limited academic organisational resilience research, specifically upon any "conceptual relationships and dynamic boundaries" (p. 1122), which describes features of open innovation.

In a co-authored paper with leading researchers on open innovation, Radziwon et al. (2022) proposed that due to COVID, many well-established enterprises had to scale back their operations to their entrepreneurial roots. This was to strategize the most appropriate response to uncertainty for their organisational resilience, whilst also assessing their available resources to achieve any refreshed aims under the unpredictable circumstances of lockdowns.

[6] This is noted because although no distinction was made, their Irish sample *may* include Northern Irish organisations, which would therefore be relevant to this UK research.

Yet, since the easing of COVID-related rules, it is a recently emerging theme of investigation to measure the relationship between organisational resilience and open innovation across different contexts. Firstly, according to Ju (2023), both inbound and outbound open innovation activities are calculated to be related to organisational resilience, with only inbound being statistically significant. Likewise, Mirghaderi et al. (2023) quantitively determined a relationship of high intensity for start-up SMEs to "increase resilience against various crises through the acquisition of technology and innovation and its exploitation" (p. 13). Yet, they calculated a moderate but statistically insignificant relationship between organisational resilience and open innovation. The resulting data tables of both Ju (2023) and Mirghaderi et al. (2023) can be seen in Appendix B: Quantified Relationship in Similar Research (P-values). Both findings provide robust literary support that there is a probable relationship between the concepts for UK life science SMEs, which will contribute new knowledge to the body of literature. The differences of the above papers are listed in Table 3, and are later quantitively compared to the results of this primary research within the discussion chapter.

Table 3: Relationship Research of Organisational Resilience and Open Innovation

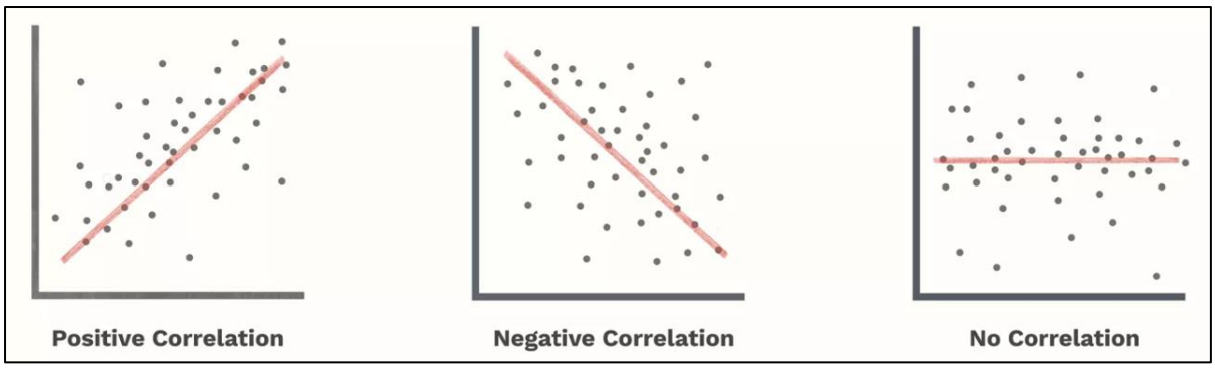
Differences	**This Research**	**Ju (2023)**	**Mirghaderi et al. (2023)**
Country:	UK	China	Iran
Sector:	Life sciences	Information and communication technology	Textiles
Findings:	To be measured through the primary research	Significant relationship between organisational resilience and *inbound* open innovation; but insignificant for *outbound* open innovation	A moderate relationship

Direction of Relationship

The direction of the relationship between organisational resilience and open innovation is a multi-faceted topic of debate within the literature. Some studies suggest a positive relationship, whereby the two concepts grow together. Some indicate a negative relationship, whereby open innovation actually becomes a risk to organisational resilience. Also, there is also the possibility that there is no linear relationship between the two concepts.

This ongoing debate highlights the need for a comprehensive investigation to determine the direction that these two concepts relate to each other. To visualise these options, scatterplots are displayed (Figure 6) to garner a clearer understanding of the potential directions of this relationship within the existing literature. This serves as a springboard for the upcoming quantitative analysis, where scatterplots are used to examine the empirical data collected to explore the concepts' relationship.

Figure 6: Direction of Relationship between Concepts (Nickolas, 2023)



Positive: Both Concepts Increase Together

Identifying a positive relationship, Reinmoeller and van Baardwijk (2005) found that organisational resilience is enabled when enterprises practice a dynamic and diverse innovation strategies. These were cited to include: (a) knowledge management, (b) exploration, (c) cooperation, and (d) entrepreneurship. Aptly, these are pillars of the concept of open innovation. At the time of publication, open innovation had only just been conceptualised by Chesbrough (2003), and so perhaps it was not yet recognised by Reinmoeller and van Baardwijk.

Further promoting a positive association between the two concepts, Varis and Littunen (2010) argue that "in turbulent market economies, innovation is the elixir of life for firms … growth, success and survival, all depend on the ability of firms to innovate on a continual basis" (p. 129). They also argued that although new products reach new customer segments, innovative, and "incremental improvements in products are more associated with improving firm's competitive position in its existing markets" (p. 145), and therefore impacting their organisational resilience.

According to Pal et al. (2014), SME constraints on their resources, control, cash, and time are all considered inhibitors of their organisational resilience, which forces them to outsource and look to external support and synergy for success. They propose future research to consider how organisational resilience and 'dynamic competitiveness' relate, which can be directly associated to open innovation with other industry actors. Within the literature, this is named 'co-opetition' (Carayannis & Campbell, 2011; Kmieciak & Michna, 2018; Porter, 1998). As per Malerba and Orsenigo (2015), the pharmaceutical industry has been continuously evolving due to an "interaction of external shocks and … the internal outcome of the response" (p. 664), which provides rich opportunities for innovation. Malerba and Orsenigo advise that this also presents a high uncertainty for the industry actors, which opens up new approaches, techniques, and markets of life science research and development. Therefore, they promote organisational resilience as much needed within the pharmaceutical subsector, and this can be achieved through open, cumulative, and collective learning (p. 679); this is agreed upon by Ridley (2011) and Syed (2019).

In organisational resilience research of micro-sized enterprises, Dahles and Susilowati (2015) distinguished between (a) those who have simply survived sudden threats to their business, and (b) those that have excelled and thrived by innovating throughout the threat, therefore reducing their vulnerability. They recognised that for enterprise growth and resilience, "intra-sectoral and multi-sectoral business arrangements represent a longer-term adaptive mechanism" (p. 48). This implies that such concepts as open innovation are key for longevity. Equally, Escoffier et al. (2016) assert that failure to innovate jeopardises competitiveness, and yet for SMEs, this is no easy task. Oftentimes, most innovation can "end up in the file drawers … generating no real social or monetary benefit" (p. 20) at their own detriment. Suggesting that it is historical too, as early UK life science SME innovations were characterised by a "linear and internally-focussed or closed process … tending to become more fragmented, leading to an increased risk of market failure" (Marangos & Warren, 2017, p. 211). Yet, the prospect of failure is proposed by Syed (2019) to "spark creativity" (p. 204), and so enterprises should create a culture whereby it is safe to not succeed.

In research of Welsh life science SMEs, Howson and Davies (2018) found that they are likely to fail without: (a) a clear innovation strategy, (b) easy access to resources, (c) plans to acquire resources, (d) project management capabilities, (e) external links, and (f) a flexible and supportive culture. Yet, as an output of the life sciences, they report that health innovation has

a positive impact upon productivity, performance, efficiency, organisational growth, cost efficiency and competitiveness of enterprises (pp. 310, 385). Nevertheless, due to the complexity, nuance and uniqueness of UK life science SMEs, Howson and Davies claim that there is not a one-size-fits-all approach for them to practice innovation across different boundaries.

In research investigating a relationship between performance and collaboration, Bak et al. (2020) suggest that due to their size, SMEs must develop and maintain relationships for visibility in complex ecosystems, such as the UK life sciences. Likewise, using the topical backdrop of COVID, resilience and strategic agility are considered vital for enterprises. Hence their ability to "contribute and collaborate for science" (Liu et al., 2020, p. 278). Furthermore, providing a UK industry case study combining the two concepts, Fearne et al. (2021) researched the open innovation of 'Ventilator Challenge UK'. The consortium of 50 UK industry actors, mainly from the life sciences, designed, built, and implemented solutions, for the urgent supply of breathing apparatus needed at the height of the COVID pandemic. Speed was prioritised over cost for the 'common good', which would otherwise affect an SMEs financial resilience. This resulted in the need for agility "to abandon established processes to make decisions at unprecedented speed" (p. 756). The leading conclusion was that organisational resilience was found through the open culture of shared communication with their co-opetition, regarding challenges encountered and the lessons learnt via daily meetings, which further increased their skillset and expertise in the field.

Negative: One Concept Increases, whilst the Other Decreases

Countering the above research, Rothaermel and Deeds (2006) proposed that the concepts may have a negative relationship. Whilst open innovation may present substantial opportunities for enterprises, they may actually be outweighed by the risks involved to practice it. Therefore, a cost-benefit analysis should be conducted, as it may impact their organisational resilience. In a similar argument, Enkel et al. (2009) argued against open research, development, and innovation. All because of its risks of negatively impacting their "long-term innovation success, because it could lead to loss of control and core competences" (p. 312). This results in vulnerable, and consequently, overly cautious enterprises, who keep to closed models of innovation. Raymond and St-Pierre (2010) suggest that SMEs are trapped in a conundrum, as innovation is the very thing that helps SMEs become resilient and grow. Yet, due to their lack

of in-house resources, SMEs must risk openness to achieve that innovativeness, which can leave them vulnerable to imitation.

Comparing the closed versus open models of innovation, Almirall and Casadesus-Masanell (2010) highlighted the compromises that enterprises must make. This includes the innovating firm losing freedom and control over their research and development, as choices will instead be made by "independent firms that pursue their own interests" (p. 27). Of which, even those "will not be perfectly aligned" (p. 28). For this reason, at least closed innovation offers SMEs full internal control. Moreover, Veer et al. (2013) claims that open innovation is deemed "a risky strategy as critical knowledge may spillover to outsiders" (p. 9). Consequently, due to fear of missing out on commercialisation from such a knowledge drain, Veer et al. found this to increase an "obsessiveness with ownership" (p. 9). According to Conz et al. (2017), SME organisational resilience is dependent on internal resources and capabilities (alongside external factors). As a consequence of seeking stability through any uncertainty, Conz et al. argues that an SME's "strong connections ultimately serve to reduce [the] agent's adaptability". This implies that there is "a trade-off between connectedness and resilience" (p. 189).

Neutral: No Relationship

Although it is entirely possible that the two concepts are completely independent of each other, there is a lack of any literature to assert this, even with concepts that are closely related. This suggests that it is an unlikely scenario, but it is a possibility to consider when hypothesising the primary research nonetheless.

Context

Due to the fragmented nature of the life sciences, collaborative activities within a "connected ecosystem of stakeholders" (Goldberg, 2020, p. 2) are promoted within an industry report to strengthen the sector. Such stakeholders in the sector are cited by Goldberg as: (a) patients, (b) healthcare providers, (c) health service companies (including life Science SMEs), (d) insurers/payers (for the UK, this will largely refer to the taxpayers funding the NHS), and (e) the wider biopharmaceutical industry. Goldberg suggests that we are currently living through a transformative period for medical innovation, by it becoming more open. Owing to "an unprecedented level of cooperation, a willingness to share information and a high degree of trust … a recipe for resilience" (p. 2). It was said that no-one can achieve anything alone, and

so the following aim of the life sciences is "to become a more responsive, flexible and resilient ecosystem that allows each member … to be more proactive and be better able to forecast needs rather than reacting to them" (p. 17). This, therefore, presents a positive relationship between the two concepts of organisational resilience and open innovation in the contextual literature.

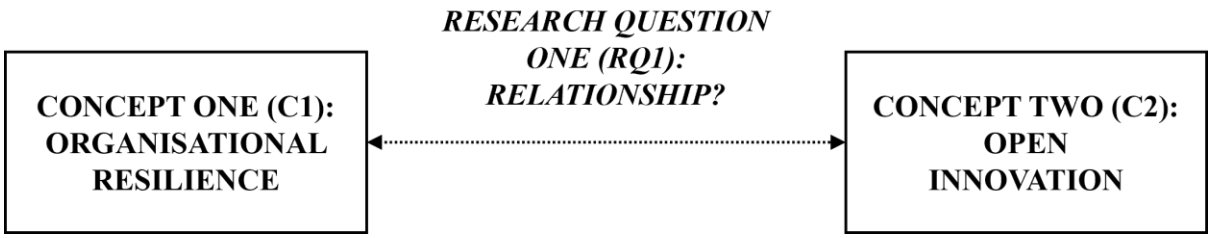
2.1.4. Conclusion of their Relationship as Presented in the Literature

For the success and growth of UK life science SMEs, who experience a high failure rate, it is vital to determine if open innovation can enhance their organisational resilience. This section has reviewed diverse and peer-reviewed sources of information to understand what the current literature has concluded about such a relationship between the concepts (directly, or similar ideas). There was not a clear consensus, although there was more literature in favour of a moderate and positive relationship. That being said, it is evidently a complex topic requiring further investigation through the primary research. Before probing further literature regarding the influence of the concepts' relationship, this research first proposes the following ongoing debate and unanswered question to provide a significant and original contribution to knowledge:

- **Research Question One (RQ1):** How are the concepts of organisational resilience (C1) and open innovation (C2) related for UK life science SMEs?

Formative measurement models (Bagheri, 2021; Coltman et al., 2008; de Vaus, 2014; Jarvis et al., 2003; Ju, 2023; Mirghaderi et al., 2023) do not assume that the factors may not *cause* a concept, instead they *influence* a concept, and so the direction of flow between connections differs from that of a 'reflective' measurement model. Therefore, as we are measuring the relationship between the two equally-loaded concepts, the flow of influence is bi-directional for RQ1, represented in the following formative measurement model (Figure 7):

Figure 7: RQ1: Formative Measurement Model



2.2. Influences of Organisational Resilience and Open Innovation

Considering contingency theory (Daft, 2001; Donaldson, 2001; Lawrence & Lorsch, 1969; Tannenbaum & Schmidt, 1958; von Bertalanffy, 1928/1968), it is observed that organisations are individual, and dependent upon its many influences. Investigating those such influences is popular within the cited business management research (García-Vidales et al., 2019; Nikolić et al., 2019; Venkatesh et al., 2013). This section probes business management literature that considers the multiple influences of the concepts of organisational resilience and open innovation, separately. Then, to make an original contribution to knowledge, this research reviews the factors that influence the concepts combined.

Firstly, the influences of organisational resilience (C1) are independently considered. Given enough notice, Porter (2004) believes that an enterprise can anticipate and prepare for external threats (arguably a synonym of negative influences). Yet, they should also reframe the threats, as "industry evolution should not be greeted as fait accompli, to be reacted to, but as an opportunity" (p. 188). According to Burnard and Bhamra (2011), SME organisational resilience can be enabled through both their internal *and* external situational awareness, so it is important for this research to look at both endogenous and exogenous influences. Burnard and Bhamra also argued that due to an SMEs' lack of bureaucracy and infrastructure, they have increased agility to threats than their larger competitors. Whilst also being "responsive to market demand and innovative in their ability to meet customer needs" (p. 5594), and so it is relevant to measure the influence of enterprise size and other demographical influences too.

For SMEs to survive and be organisationally resilient in this 'contemporary business age', Conz et al. (2017) argue that they must develop strategies to face any uncertain internal and external influences. With the primary goal to retain their prosperity within the marketplace (in this instance, the UK life sciences). This resilience to uncertainty was also picked up by Niemimaa et al. (2019), who found that oftentimes, businesses are overwhelmed with the sheer scope of possible influences to consider. Arising from "identifying uncertainties requires determining the potential challenges that may compromise the current business model or parts of it" (p. 211) with it being unfeasible to identify and analyse them all. Likewise, justified by a lack of current literature, Herbane (2019) emphasises the importance of SME research upon "factors that are known to influence the adoption of resilience enhancing activities" (p. 482).

Secondly, the influences of open innovation (C2) are independently considered. Chesbrough (2003) found the following *original* influences that led to the end of closed innovation, or "knowledge monopolies" (p. 45). These were (a) an increase is research excellence and its diffusion, (b) an increase in distribution of patent awards, (c) an increase in knowledge diffusion beyond national borders, (d) a decrease in size of enterprises which generate most knowledge (which is directly relevant to this SME research), and (e) an increase in graduates entering the workforce. More recently, Marangos and Warren (2017) listed negative influences of open innovation for UK life science SMEs, including: (a) time pressure, (b) payments/cash flow, (c) regulatory hurdles, (d) finance and funding, (e) product failure, (f) operational governance, (g) loss of contracts, and (h) commercialisation hurdles (p. 219). Unfortunately, for contrast, there was no such list for positive influences of open innovation. The 'multiple facets' of open innovation are said to require thorough consideration, due to the breadth and depth of their scope, as seen in the following citation. This quote also justifies the need of the previous question of their relationship:

> *"Identifying the key variables and factors affecting open innovation is still a research challenge. Innovation openness can involve several features … [but] understanding the key aspects is not enough. It is also important to understand the implications of open innovation on performance." (Lopes & de Carvalho, 2018, p. 284).*

The influences of both concepts have now been discussed independently, but for this research to provide a significant and original contribution to knowledge, they are uniquely combined into a single interaction variable. As a consequence, this primary research tests what influences them in unison, considered next.

Each concept of organisational resilience and open innovation has a broad typology and taxonomy to consider, and so a comprehensive model is required to understand the complexity of the relationship between (Pontika et al., 2015; Reinmoeller & van Baardwijk, 2005). The turbulent and uncertain nature of the business means that many diverse influences must be reviewed (Burnett & Danson, 2017; Keizer et al., 2002; Nikolić et al., 2019). This is to ensure a complete snapshot of the current UK life science sector.

Multi-factor structures are popular within the cited literature (Alberto et al., 2022; Branicki et al., 2018; Galbraith et al., 2017; Lengnick-Hall et al., 2011; Marangos & Warren, 2017; Rees et al., 2021). Even a contextual source adds that every organisation has "to balance the

challenges of both internal and external factors" (British Standards Institute, 2021, p. 7). Furthermore, Stucki (2009, as cited in Mirghaderi et al, 2023) proposed a three-factor framework to structure their investigation into the influential factors of organisational resilience and open innovation, so it is apt to apply it to this research too: (a) internal factor, (b) specific external[7] factor, and (c) external factor. The use of demographic data is considered as a factor to make efficient and effective use of the sample baseline data that is also collected. This baseline dataset has a potential influence upon the concepts, beyond only understanding the sample representativeness. Therefore, this justifies the collection of disparate themes, allocated into three contexts of factors.

There is a lack of existing frameworks in the existing literature that are significant to UK life science SMEs. Therefore, an innovative approach is applied by the researcher to identify individual influences of either concept within the literature, to later measure against the interaction variable of the two concepts in the primary research. Avoiding a singular focus, such a multi-factor framework contributes a holistic approach to the complexity of the UK life science sector, which relates back to the systems theory that underpins this research. It also provides a comprehensive and nuanced approach to understanding how different components of the enterprises, across each context (factor), influences the two concepts.

This review of factors is advised by Beynon et al. (2020b), as perhaps being insufficient for SMEs to support enterprise growth and innovation alone. Instead, Beynon et al. argue that it will actually require a *combination* of them to influence open innovation. Yet, these influences can be complex, as every enterprise is unique (British Standards Institute, 2021; Daft, 2001; Donaldson, 2001; Lawrence & Lorsch, 1969; Stokes, 2011; Sullivan-Taylor & Branicki, 2011; Tannenbaum & Schmidt, 1958; von Bertalanffy, 1928/1968). Therefore, this novel framework is twice-justified due to a lack of existing frameworks that are specific to UK life science SMEs, and also regarding the unique combination[8] of the concepts.

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[7] Renamed to 'demographic' for the purposes of this research.

[8] Combined, if a relationship is identified through the quantitative testing of RQ1.

Therefore, the identification criteria of the individually identified influences in the existing literature is that of either (a) influences of organisational resilience, (b) influences of open innovation, or (c) influences significant to the UK life science SMEs. Each of the identified influences, under each factor, will then be measured against the combined concepts in the proceeding primary research. This not only adds to the originality of this research, but also the significance for capturing influences that are significant to the UK life science SMEs (by measuring UK country of operation, subsector, and enterprise size) and to this point in time (by measuring recent external events of BREXIT and COVID). These influences are broad ranging, to ensure that factors are not marginalised or overlooked (Stokes, 2011).

With a prioritisation of the academic body of knowledge, it was not necessary to separately review the contextual (grey) section of literature. Instead, the sparse grey literature is infused, but explicitly identified as contextual, within the review of literature. To start, the first factor (F1) considered is that of internal influences, next.

2.2.1. Internal Influences (F1)

The Principles of Scientific Management by Taylor (1911/2004) argued for the standardisation of work processes, and so this can be a foundation for identifying and considering the internal influences of organisational resilience and open innovation. Understanding the influence of innovation and management is of utmost importance for optimisation of the two research concepts. Enterprises will have the ability to control such endogenous factors, to steer them into being beneficial to their survival and prosperity. Mirghaderi et al. (2023) defines this factor (F1) as internal influences. This includes such diverse and comprehensive facets as innovation and management diversity, speed of innovation to market, and the background of the owner-managers (within industry, entrepreneurialism, and academia), to understand if they influence the combined concepts.

Innovation Diversity

Regarding the SMEs' diversity of innovation, in the form of their portfolio of products and/or services, Porter (1998) states that "innovation may occur as a company diversifies" (p. 164). Furthermore, "openness can stimulate innovation by combining the efforts of a large and diverse pool of complementary firms, leading to increased product diversity" (Almirall & Casadesus-Masanell, 2010, p. 27). A lack of a product portfolio was deemed by Pal et al. (2014)

to be commonplace for vulnerable SMEs, only to be worsened by the 2007-2008 financial crisis, resulting in improper market entry issues. In their study of research and development intensive UK life science SMEs, Marangos and Warren (2017) promoted that open innovation is a way to diversify portfolios, by allying new ideas with their collaborators. To "save valuable time in the development phase and also bring in expertise that can take the firm forward" (p. 216). Given these varied perspectives, it is of value to measure if the diversification of innovation portfolios is influential of organisational resilience and open innovation. Next, the innovation's speed to market is considered as a potential influence of the two concepts.

Innovation Speed to Market

With patient safety in mind, Porter (2004) suggested that life science innovations undergo long periods of testing and trials by regulatory agencies, to gain approval for new medical products and services. Yet, open innovation can slow down the products' route to market, by congesting innovation pipelines through the incorporation of additional inputs and outputs. Therefore, it is recommended by Euchner (2011) that enterprises should only consider open innovation across the "ideation stage into the market" (p. 17). Furthermore, Marangos and Warren (2017) recommend UK life science SMEs to save time and resources, by being open to outsource the test phases, and therefore easing their route to market.

In an industry report by Steedman and Taylor (2019), they suggest that novel drug approvals are increasingly granted to SMEs. This allows for higher market shares and pricing, as they are becoming less reliant on big-pharma, and therefore increasing their organisational resilience. The UK life science approval process averages between six to seven years, with an increase of six months from 2014 to 2019. Steedman and Taylor state that the UK pharmaceutical regulations do create long clinical trial cycle times, but it does guarantee high quality of scientific outputs. For the benefit of society, even if it can be costly of the SMEs' limited resources.

Therefore, in this volatile, uncertain, complex, and ambiguous world, Xing et al. (2020) emphasise the value of an organisation's need for speed, and so combined with dynamism, SMEs can become truly resilient. As a real-world example, the urgency of COVID motivating UK life science businesses to innovate with the consortium of Ventilator Challenge UK quickly and openly (Fearne et al., 2021). This was for a social benefit, but also rapidly increased the

skills and expertise of the participating SMEs, which advanced their organisational resilience and agility.

In their 10-year vision report for the UK life sciences, HM Government (2021) reported feedback from industry. The sector is said to experience a slow speed to market, which is a barrier to the prompt diffusion, transfer, and assimilation of innovative technologies across the sector. With the help of the Medicines and Healthcare Products Regulatory Agency, the UK can offer safe and effective testing; recently substantiated by the quality and speed of the regulatory response to the rapid innovation of COVID diagnostics, treatments, and devices.

Tidd and Bessant (2021) argue that enterprises can be innovative in their approach to regulations. This can be done by finding solutions to bend, or get around, imposed rules, which could arguably mean practicing open models of innovation. In their decade-long longitudinal study of 73 pharmaceutical enterprises, and their collective 7524 drug products, it was found that quick launch rates of innovation had a negative association with firm performance. It was also recommended that emphasis should be upon striking a careful balance of the breadth and depth of their product portfolios, rather than rushing them to market. This evidences the need to test this influence, and the previous. However, next, it is explored how having in-house innovation staff can influence the concepts of organisational resilience and open innovation.

Innovation In-House Staffing

Applying the classical organisation theory of Smith (1776/1977) regarding efficiency, an emphasis is placed on the division of labour to ‘employees’ within the social structure of enterprises. Therefore, this influence examines the literature to see if having in-house innovation staff is significant to the two concepts. Due to SMEs having a small or no research and development departments, Escoffier et al. (2016) suggests that they are further impeded due to their limited resources of time, money, and business expertise. Consequently, this is only to operate their enterprise, let alone innovate too. Therefore, SMEs are reliant on external resources to support commercial endeavours. Internal employees are deemed a facilitated ‘social network’ (Barão et al., 2017; Williams et al., 2017), which could be tapped into for innovation. However, enterprises applying open innovation, means a decline of in-house research and development, by sensing, seizing, and transforming opportunities from outside (Bogers et al., 2018).

Internal networks of knowledge-sharing are seen as a way of addressing the problem of SME skills-shortages. Represented in their often-limited employee-bases, which motivates them to absorb external knowledge. Yet, to improve innovativeness, SMEs with their limited resources, must urge their employees to "look for original, unconventional solutions, to try different ways of doing things, and to use new or unexpected events and situations for learning" (Kmieciak & Michna, 2018, p. 569). Because of this, their various channels of knowledge management orientation feeds into their innovativeness. However, Kmieciak and Michna's research was cross-sectional and therefore unable to test the sustainability of SME innovation long-term.

In-house research and development functions are still argued to be critical to generate knowledge for outbound transfer. However, due to their lack of resources and commercialisation skills, SMEs (with their expert specialisms) are often left unable to successfully convert their knowledge into marketable innovation (Beynon et al., 2020a).

From a systems theory standpoint, an interrelation is found between the intensity of an SME's research and development, and their inclination to collaborate, whereby Tidd and Bessant (2021) relate to the life sciences. They argue that due to the technical nature of the sector, it is just not realistic to solely use in-house expertise, especially as many of the ideas (knowledge) and technologies being used are increasingly interdisciplinary, with blurred sector boundaries. Interestingly, Tidd and Bessant claim that enterprises which have experienced past in-house research and development success, may become arrogant and not consider technologies that were created externally; classified by other academics as 'not invented here syndrome'. Yet, other, more-open SMEs will promote a humble culture of understanding that innovative technology can come from anywhere. With employee actively scouting for technologies beyond their enterprise borders. An SME's intent to collaborate is said by Tidd and Bessant, to be cemented into Human Resource policies. Therefore, such alliances should be considered as opportunities to develop staff, instead of merely increase profits. An enterprise is, therefore, described as a collective of staff capabilities, as "the primary purpose of collaboration is the acquisition of new skills or competencies, rather than the acquisition of technologies or products" (p. 424), which again reinforces the classic organisation theory of Smith (1776/1977). Furthermore, the next influence explored also considers the influence of human resources, in the form of family members.

Management: Family

In the early 2000s, the involvement of families within the business structure was said to have a positive influence upon product innovation success (Cormican & O'Sullivan, 2004, p. 820). Yet, using interviews of family-businesses, it was found that family members, whilst motivational, would restrict change and therefore impede any novel innovation. Even if they "might improve the efficiency and profitability of the firm" (Hausman, 2005, p. 780). The common phrase of 'blood is thicker than water' may be true for SME organisational resilience, with family businesses having stronger bonds than colleagues, creating a more unified approach. In a mixed sample of SMEs and larger firms, with family and non-family ownership, organisational resilience was tested using benchmarking of such factors as manufacturing strategy, competitive strategy, and firm performance. Hausman found that the tight-knit family relationships aided their ability to build networks and have quality relationships with customers and suppliers. Consequently, this allows them to cater to demand, however, it is also reported to make them rigid, and less agile. Non-family enterprises were able to be more responsive to customer demand, as they are not restricted by internal relationship expectations or dynamics. It was Acquaah et al. (2011) who found that family businesses are often located closer to their customers, decreasing delivery costs, and increasing loyalty. With much more neutral findings, García-Vidales et al. (2019) did not find any significant difference between family and non-family SMEs, regarding both inbound and outbound open innovation. Without a consensus, it is of value to determine if family members within management are influential of the combined concepts of organisational resilience and open innovation.

Management Team Size

The size of teams has been influential from the earliest of the examined organisational theories considered, with Smith (1776/1977) arguing that for an efficient division of labour, the number of workers assigned to each task should ideally be a small. However, this was in regard to manufacturing teams, rather than the management, and so this section specifically considers the size of the *management* team, or 'board'. From the later point of view of systems theory, Tannenbaum and Schmidt's (1958) work on leadership patterns identified that there is a *general* theory of the social sciences, that group dynamics has a focus on the participation and human relations of members within the management group. Rather than emphasis on one leader of the organisation, "to reduce their own power and to make group members as responsible as

possible for [democratically] setting their own goals and methods" (p.95). Tannenbaum and Schmidt then asked how they each decide how to manage, contingent on three-tier factors and forces, similar to the factors of this research. Therefore, this internal influence quantifies this by asking if the size of the management team (as in the number of group members) is influential of organisational resilience and open innovation.

With a large sample of 700 micro-sized enterprises, Romero and Martínez-Román (2012) found that it was neutral as to whether single owner-managers are influential of their open innovation. This was in comparison to enterprises with multiple owner-managers. A thorough literature search was conducted to see if the size of the management team (or even loosely connected search terms of 'governance', 'board', 'directors') is influential of the research concepts. A lack of literature was found upon this topic, which means that there is a distinct ongoing and unanswered question as to whether the size of management team is influential.

It could also be argued that the more owner-managers the more resilience expertise there will be, and the more contacts they will have to perform open innovation activities. However, the more decision-makers, the higher the likelihood of conflict. Gray and Jones (2016) recognise that owner-managers of micro-sized enterprises in Wales can lead a solitary working life. It is only through business coaching to pursue collaboration, that they can find a positive impact on the resilience of their ventures. Achieving access to a "supportive peer learning community" (p. 476) can help to detect potential 'business frailty'[9] and failures to develop entrepreneurial skills. The next influence remains on the topic of management, but the literature considers if their diversity is influential of the two concepts of organisational resilience and open innovation.

Management Diversity

As a company diversifies, Porter (1998) argues, it brings new resources, skills, or perspectives from and to other industries, but this section considers the literature of whether a diverse

[9] Gray and Jones (2016) defined this frailty specifically for SMEs as: "risks of downsizing and redundancies, and/or business closure is greater" (p. 481).

management team is influential of organisational resilience and open innovation. Ries (2017) suggests that start-ups need to train and retain diverse leaders, as they can trailblaze with high-risk and high-reward innovation projects. This can be beyond standard innovation labs and research and development functions, to provide "something distinct from the secretive skunkworks projects of old" (p. 45), a characterisation of closed innovation. Santoro et al. (2020) calculated gender diversity as of low significance for SME organisational resilience. However, age diversity was significant, with Santoro et al. reporting that "older entrepreneurs are more likely to have weaker perceived success" (p. 146).

From a contextual perspective, there are many protected characteristics (Equality Act, 2010, part 2, c. 1; Equality & Human Rights Commission, 2021) that can make for a diverse management team: (a) age, (b) disability, (c) gender reassignment, (d) marriage and civil partnership, (e) pregnancy and maternity [and paternity], (f) race, (g) religion or belief, (h) sex, and (i) sexual orientation (Figure 8). With a noticeable lack of academic literature upon such identity-based diversity within in UK science, technology, engineering, and mathematics (commonly known as 'STEM'), the influences of two protected characteristics (sexes and ages) will be measured within the subsequent primary research, to provide an original contribution to knowledge. The next considered influence is that of the experiences of UK life science SME owner-managers, as prospectively significant for the two combined concepts.

Figure 8: Protected Characteristics of the Equality Act 2010 (British Broadcasting Corporation, 2024)

Management Entrepreneurial and Industrial Experience

The various experiences of UK life science SME owner-managers are now considered if influential of the concepts of organisational resilience and open innovation.

Nascence

Nascent entrepreneurs are those that are new to entrepreneurialism, for example, either coming from previous employment or entering straight into a venture from academia. It is suggested by Porter (1998) that innovation may come into an existing company through management who are new to a particular industry. Thus, the new owner-managers of SMEs are more able to perceive opportunities, and pursue them. Using an unconventional research method, Caliendo et al. (2009) studied nascent entrepreneurialism and reported that with previous employment, the sampled owner-managers are more likely to take on risk. Due to them being used to stability within their career history. This risk could arguably include practicing open innovation with larger actors in the UK life sciences. Additionally, Ries (2017) found that a nascent entrepreneur's lack of business finance knowledge is identified as the main reason why start-

ups fail so frequently. Attributed to a lack of adequate monetary decisions being made, and this is even before the SME has become profitable. With a lack of investors, compounded by their limited resources, they are unable to raise capital to save themselves. They are then faced with vulnerability to failure, and so it is of value to understand if entrepreneurial nascency is influential of the combined concepts.

Renaissance

Renascent entrepreneurs are those that have return to entrepreneurialism after experiencing previous failure. There is an appreciation by Cormican and O'Sullivan (2004) for the high risk and expense of innovation ventures conducted by senior research and development managers. Those such managers are facilitating projects with low levels of success, and high levels of termination and failure, as reportedly commonplace in healthcare and pharmaceutical industries. Yet, Ries (2011) considered learning from failure as a "pre-requisite to learning" (p. 154), which was described, as well, as a cliché, prosaic, and profound. Successful and renascent entrepreneurs are said to often use the analogy of their enterprise coming to the end of an airport runway, whereby their start-up must either lift-off or fail. To extend the analogous runway, SMEs are advised by Ries to: (a) cut costs, or (b) raise additional funds. Nonetheless, caution is also heeded for cutting costs indiscriminately, as it may consequently mean that they fail more slowly. Ries argues that a balance must be found as too high of a budget is just as dangerous in the wrong hands as too low. Such unconnected, and perhaps 'closed' "independent startups are run with little margin for error. Thus, startups are both easier and more demanding to run" (p. 254).

The life science sector is believed by Syed (2015), to have a long and rich history of evading learning from failure, which is "a cornerstone for success for any institution" (p. 12). Syed proposed that confronting this is beneficial for the society and economy alike:

> *"Nobody wants to fail. We all want to succeed, whether we are entrepreneurs … [or] scientists … Success can only happen when we admit our mistakes, learn from them, and create a climate where it is, in a certain sense, 'safe' to fail." (p. 15)*

Specifically in turbulent times, Iborra et al. (2020) indicate that an entrepreneur's venture can become more resilient when "relying on their past success at investing in risky projects" (p. 2), which will have uncertain outcomes for them. Once failure is experienced (or at least, the

prospect of it), then open innovation may not be such an exciting prospect for them to partake in, due to being too much of a risk. More recently, Shore et al. (2023) explores how entrepreneurs face such grief of their failed enterprises. They found that grief has a significant negative impact upon their ability to learn from failure and re-enter the market. Despite the experience providing them valuable information and lessons to educate themselves for later success. Shore et al. also proposes that entrepreneurs who have failed are more likely to take fewer risks in the future. It is therefore of value to measure if such risks could influence the practice of organisational resilience and open innovation in any future ventures.

Successful or Concurrent Enterprises

In the investigation of concurrent enterprise ventures, Williams et al. (2017) proposed that surviving and successful organisations, and those recovering after a threat, can provide a learning curve for businesses. Survival through a threat may lead to "(overly) positive self-conceptions" (p. 756) and falsely assumed natural immunity to such jolts. This pride by the leaders may lead to a lack of ability for the business to reflect and learn from the experience, leaving them unaware and vulnerable to future disruptions. Williams et al. continued by suggesting that overcoming adversity may lead to narcissism. This can become a liability and have a profoundly harmful impact on the ability to build interfirm relationships for open innovation. Due to scepticism from current or prospective alliances as to how they may be exploited by the 'narcissist' entrepreneur, for the further survival of their enterprise.

Economists, Gauriot and Page (2019), asked if success breeds success in business. They used unique data modelling technique within the context of professional tennis matches, to understand the relationship between the number of balls bounces and the random variations of winning probabilities. They found that context and incentive matters to success momentum:

> *"This effect on agents' behaviour critically depends on their ability to identify and react to their incentives during the competition … Agents have to adjust their strategies depending on the evolution of their relative place in the contest [market], which affects their expected final rewards." (p. 3132)*

Gauriot and Page also found their results to be contingent upon gender, which relates back to the explored influence of management diversity. A success momentum is found for men, whereby winning has a positive causal impact on the probability of winning the next, but this was not the case for women, and so it will be of interest to see if the gendered leadership is

influential of organisational resilience and open innovation. Next, the previous employment of the owner-managers is considered as a influence of the concepts.

Previous Employment

Recognised by Porter (1998), innovation may come from a new company, whose founder has a non-traditional background, or was simply not appreciated in previous employment of an older established company. Later, in research about university knowledge spillovers, Wennberg et al. (2011) found that knowledge-intensive entrepreneurship (such as the highly technical knowledge of the life sciences) is much more likely to be grown out of corporate employment. Furthermore, such enterprises perform more effectively in both survival (organisational resilience) and growth, than those borne out of academic spillovers. It has also been reported by Romero & Martínez-Román (2012) that if an owner-manager has previous employment, even outside of the life sciences, then they will be more inclined to innovate. They went on to suggest that a management style of cooperation significantly increases SME innovation. This evidences the need for this research to explore if previous employment is also influential of *open* innovation.

Each SME owner-managers' diverse experiences in the UK life sciences sector creates a multifaceted variable to be measured. Their entrepreneurialism and industry experience can reveal how their professional backgrounds can influence the concepts of organisational resilience and open innovation. The next influence considered is the last within F1 and is regarding the academic knowledge present within the management team of UK life science SMEs.

Management Academic Knowledge

Audretsch et al. (2004) evaluated if natural (life) or social[10] science matters more to knowledge spillovers and enterprise creation. They argue that due to the codified and explicit knowledge

[10] This is relevant, as the domain of business management sits within the social sciences. For example, as the funder of this research, Swansea University's School of Management is placed under the Faculty of Humanities and Social Sciences.

of the natural sciences, and the tacit knowledge of the social sciences, the geographic proximity to universities is important for spillover effects to occur. This influences cross-domain (industry-academia) open innovation. Investigating absorptive capacity, otherwise known as inbound open innovation, of enterprises. Subsequently, Audretsch and Belitski (2013) similarly found that its spillovers are influenced by the combination of scientific and business skills by entrepreneurs to exploit and commercialise knowledge.

O'Gorman et al. (2008) reports that scientists can be aware of the commercial value of their highly technical knowledge. However, oftentimes, this is only when business management and entrepreneurship is embedded within their taught or research scientific programmes in academia. Otherwise, they can also be made aware of such marketable opportunities through their existing external industry contacts, outside of their research institution, which can encourage knowledge exchange regarding future organisational resilience and open innovation strategies with them. Including the co-authorship of a UK-based researcher, Wennberg et al. (2011) found that a combination of industry (business management) experience and academic (scientific) knowledge is influential upon enterprise creation and ongoing performance too. Arguably a contributor to their organisational resilience too.

Ghio et al. (2015) affirmed that entrepreneurs (such as those in the life sciences) are not necessarily the 'creators' of technical knowledge, but are actually the 'agents', who are "transforming knowledge into marketable products into new markets" (p. 14). This implies that scientific knowledge may not be required for organisational resilience and open innovation, but business acumen is certainly needed for commercialisation. Agreeing with this, Treanor et al. (2021) argue that through initiatives to increase the entrepreneurial capabilities of early career biotechnology researchers in the UK, teaching of such business management skills to life scientists encourages later commercialisation and knowledge transfer within the industry. There is a marked difference of business management skills between those studying exclusively life sciences, and those that are supplementing it with entrepreneurial modules. This has the implication that these combined scientific-business students are better equipped to practice organisational resilience and open innovation of any future entrepreneurial ventures. This is the final internal influence (F1), and so the next section introduces and explores the potential demographic influences (F2) of the two concepts.

2.2.2. Demographic Influences (F2)

Lawrence and Lorsch (1969) assessed how business demographics, cited as ‘formal versus informal structures’ (p. 10) and ‘differentiation’ (p. 11), can influence the ability to be organisationally resilient by adapting to change, and practice open innovation by embracing external ideas. Having considered potential internal influences (F1) of the concepts, this section now turns attention to demographic influences. Again, both the academic and grey literature is reviewed, and covers enterprise size, type, age, and subsector. Mirghaderi et al. (2023) define this factor (F2) as ‘specific external’. However, it has been relabelled as ‘demographic’ to better describe the exploration of the characteristics of the enterprises as prospectively influential of the combined concepts. The review of current knowledge begins with enterprise size, next.

Enterprise Size

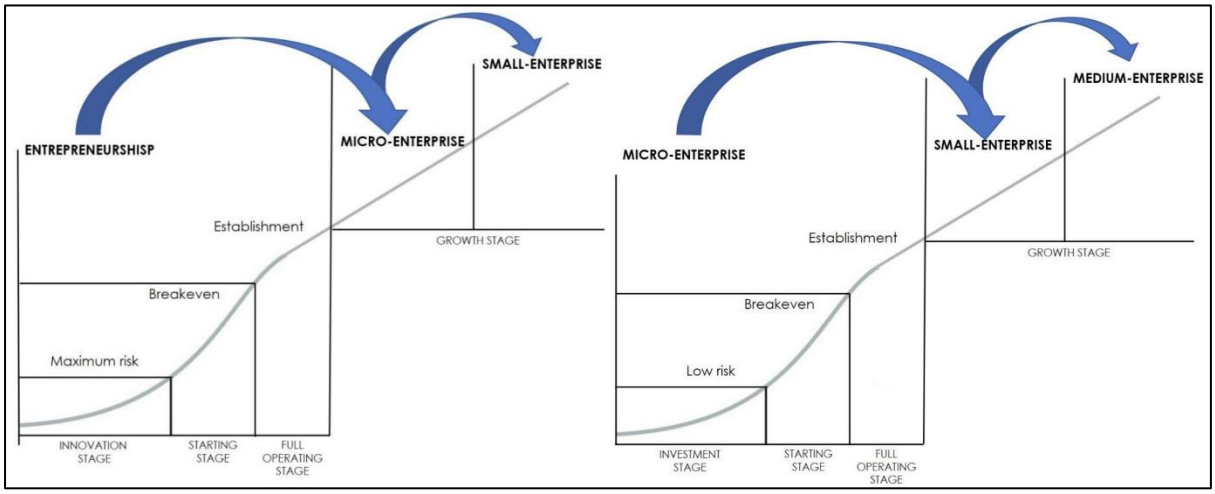
Enterprise size is well-cited within the literature as being influential of organisational resilience or open innovation. Some SMEs deploy a no-growth policy to stay small by design and are still successful in their own ways (Garengo & Bernardi, 2007; Jarvis, 2019). Yet, some enterprises can “become victims of their own success: as they grow and become successful, they lose some of their adaptive capacity” (Doz & Kosonen, 2008, p. 6). Moreover, Doz and Kosonen believe that an enterprise’s pursuit of efficiency can reduce flexibility, leaving them rigid and vulnerable to threats. In their research regarding open innovation practises in different sized organisations, van de Vrande et al. (2009) found medium-sized enterprises more frequently used their scale, extra resources, and larger knowledge repositories, to practice open innovation. More-so than their smaller counterparts. Despite that, smaller enterprises are said to lack the resources and skilled workforce to do such activities, hampering their potential to (openly) innovate, resulting in smaller innovation product and service portfolios – which ties back to the influence of innovation portfolio diversity.

Due to the smaller size of SMEs, there is easier internal communication of knowledge (Li et al., 2011). However, in stark contrast, it is suggested that fewer employees can impact the internal “skills spread of the enterprise” (Jones et al., 2014, p. 48). Causing sporadic development activities, justifying their need to look externally for resources to aid their innovation. In support of this finding, both Forés and Camisón (2016) and Santoro et al. (2016) assert that larger enterprises, who are deemed too big to fail in their innovation, have more

capability to create knowledge in-house. Likewise, Marangos and Warren (2017) observe a trend for larger UK life science actors to "draw more extensively on discoveries, tools and target compounds which have been licensed-in from smaller firms" (p.212). This predatory collaboration is justified to access the SME's specialist expertise and intellectual property, to "evaluate, utilise and acquire [their] knowledge" (p. 212). Investigating the correlation between enterprise size and risk, it is stressed by Marom et al. (2019) that there is a lack of homogeneity within the SME bracket. There are even differences in innovation activities per size, leading owner-managers from larger SMEs to "pursue a strategy that tends to be higher in innovation but with reduced risk, while in smaller firms the owners pursue a strategy that is higher in risk but lower in innovation" (p. 40).

Márquez and Ortiz (2020) explicitly defines such 'entrepreneurship' as being innovative to satisfy a market-need. Due to the offering of new-to-market products and services, Márquez and Ortiz argue that entrepreneurialism is characterised by a high risk of later being rejected by the marketplace. Therefore, they require organisational resilience. They additionally defined micro-sized 'enterprise' as distinct from entrepreneurialism, as a later-stage, subsequent economic activity. This activity supplies the existing and new-to-market products and services, which are accepted by the marketplace, and obtains a profit after covering manufacturing expenses (Figure 9).

Figure 9: Development Stages of Entrepreneurship and Enterprise (Márquez & Ortiz, 2020, pp. 3-4)



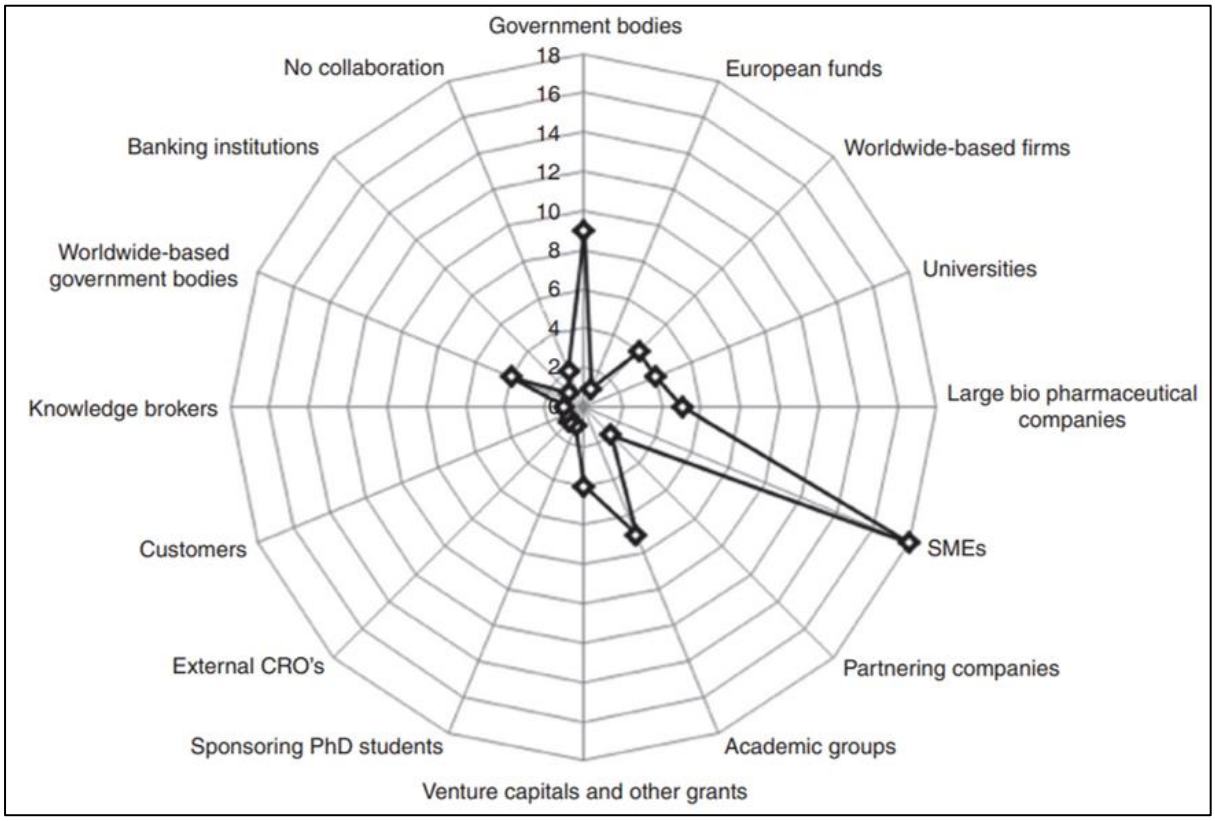
Xing et al. (2020) add that as enterprises grow in both size and complexity, they require a balance of skills and talents to improve their competitive performance. Meaning that micro and

small-sized enterprises are more justified in seeking external resources, than their medium-sized counterparts, all under the SME umbrella. With such a large body of knowledge upon the influence of enterprise size upon the concepts, it will be of value to make this significant and original contribution to knowledge. The next considered influence is regarding enterprise type.

Enterprise Type

The literature will now be reviewed for private limited companies, public limited companies, and non-profit enterprises, to explore if these types of enterprises are influential of the concepts of organisational resilience and open innovation. The transition from a private limited company (LTD) to a public limited company (PLC) is reported by Bernstein (2015) to be a "complex trade-off" (pp. 1368, 1398) between private and public-sourced capital. Evidenced by a 40% reduction in internal (closed) innovation once public. It is impeded further by an exodus of skilled inventors. However, with increased capital, they can more-easily look for external sources of innovation and recruit-in new skilled staff. Despite a comprehensive measurement of collaborators with UK life science SMEs, conducted by Marangos and Warren (2017; Figure 10), non-profits and charities do not even feature as a possible open innovation partner.

Figure 10: Polar Plot Analysis (Marangos & Warren, 2017, p. 217)



Continuing from that point, in a co-authored article with Chesbrough, Bogers et al. (2018) suggested that non-profits were increasingly being considered within open innovation literature. However, there was no further comment on them being influential of either concept. This contributes to the originality of this research, to measure if the pursuit of social impact is influential, rather than profit. A grey, UK life science industry report recommends a hybrid culture for the sector, whereby "profit meets purpose, talent trumps technology, and the social enterprise reigns supreme" (Steedman et al., 2019, p. 18). In reference to each of these enterprise types, Reid (2020) argued that open knowledge transfer through "collaboration between universities but also with private, public and third sectors" (p. 17). Additionally, through a study by Green et al. (2021) of financial resilience and organisational survival of UK charities, it was observed that the sample of mainly SMEs, were able to survive an unstable economy. This was due to if they privately generated their own income through internal sources (a *closed* model). However, high-paying grants increases an enterprises likelihood to fail. Although such grants offered a substantial income, to support their organisational resilience, enterprises can become reliant without a contingency plan. So, when or if that source of capital is removed, Green et al. bleakly suggest that the charities fail. Moving on to the next

demographic characteristic, the influence of enterprise age is considered in relation to the two concepts of organisational resilience and open innovation.

Enterprise Age

Supplementing the previously cited 39% failure rate of UK life science SMEs within their first three years of operation (Office for Life Sciences, 2011), Caliendo et al. (2009) reported a slightly longer time before failure. In comparison, they reported that "unsuccessful entrepreneurs usually close their businesses within the first five years after starting" (p. 162). This evidenced a longer need for start-up enterprises fundamentally needing organisational resilience. Due to an immaturity, Malerba and Orsenigo (2015) state that young life science enterprises in the biological technology subsector do not yet have the financial capital to innovate in-house. Instead, it is claimed that they should sell their knowledge, especially to older and well-established businesses, for them to survive and grow beyond their early vulnerable years of operating. In contrast, Ries (2017) suggested that although a lack of resources is indeed a concern for young SMEs, it is argued that start-ups are at an advantage as their innovation is not yet restricted by the "archaic, inflexible structures and protocols in place" (p. 122) for larger organisations.

Young UK life science SMEs are said, by Marangos and Warren (2017), to bring fresh science to market. Cited examples include drugs, medical devices, and clinical processes. However, these same enterprises are cautious of collaboration with larger, more-established UK life science actors, owing to a feeling of inferiority, due to the SMEs' immaturity and inexperience. Therefore, their age has a negative influence on open innovation. It is proposed by Marom et al. (2019) that younger enterprises must be higher risk-takers, which is "one of the many reasons for the low survivability of firms within the SME sector" (p. 41). Even innovation is found to be low in such start-up enterprises, especially during the time when they establish themselves and gain resources. But, it is recommended that this can be overcome by building networks with other SMEs and small-sized actors within their ecosystem. This allows them to harness resources through teams, partnerships, and stakeholders, within and outside the enterprise boundaries.

Equally, Nikolić et al. (2019) calculated a positive correlation between enterprise age and performance. The older an enterprise, the more access they have to resources. They also have a better knowledge of their business environment, providing them with a readiness to handle

uncertainty. Although, they also identify that more mature enterprises are vulnerable too, due to being less flexible to adaptation within their environment. With such disagreement across the above theorists, it will be of interest to see how age influences the concepts, specific to UK life science SMEs. The next influence considers how or if the life science subsector that the SMEs operate within influences the concepts of organisational resilience and open innovation.

Enterprise Subsector

The final demographic influence considered is that of the UK life science subsector. Using the previously cited 'general systems theory' of von Bertalanffy (1928/1968), it is necessary to identify and measure the subsectors. They each form part of the holistic system it sits within, the UK life sciences. As a reminder, the sectors have been identified by Welsh Government (2013, as cited in Howson & Davies, 2018) as: (a) medical technology, (b) biological technology, and (c) pharmaceuticals. Expanded by Life Sciences Scotland (2023), with: (d) animal health, (e) agricultural technology, and (f) aquaculture (Figure 1). Furthermore, a final subsector is added to the collective: (g) life science-specific business support services is added as a subsector. Porter (2004) suggests that evolution of any industry is accompanied by a shift in structural boundaries, with innovation expanding sector limits to include more competition. Porter suggests that SMEs approach their innovation with much less commitment to the formal structure of the sector, than their larger competition. Yet, Pisano (2011) argues that definitions of the life sciences are misleading, as it's subsectors are only collectivised for convenience. It is actually multi-disciplinary in scope and requires integration of a wide constellation of scientific knowledge and tools to create scale for the enterprises. With the sectors encompassing broad elements of the life sciences, it is insightful to determine which of them influence the two concepts of organisational resilience and open innovation. Next, the external influences are explored in relation to the two concepts.

2.2.3. External Influences (F3)

The 'Industrial Organization' by Woodward (1965) analyses how external influences pressures like shifts in technology, for example, can influence the structures of organisations. By understanding how different systems respond to external pressures, Woodward promoted *flexible* structures to keep pace in adapting to an ever-changing environment for organisational resilience, and to foster open innovation. Therefore, in the last of the three factors (F3), a comprehensive exploration will now consider influences that are external (Mirghaderi et al.,

2023) to the UK life science SMEs. This includes geographic components including where they operate from, if they practice internationalisation, and their locational setting. Also, the position on the life science supply chain, and the external forces of BREXIT and COVID are also considered. This exploration begins with the UK country of which they operate from, and if this is influential for the practice of organisational resilience and open innovation.

UK Country of Operation

The first external influence explores if the whereabouts of the SMEs' operations within the UK. Afterall, location as a competitive factor has been well-researched, especially within competition literature. Porter (1998, 2004) considers the setting of a business to be important due to local, closed economies. Although this is increasingly changing due to enterprises now operating on a global, open economy. Conz et al. (2017) argued that geographic location is heavily linked to entrepreneurial performance and is particularly important for technology acquisition. Because such procurement is what binds the link between local enterprises and domestic (national) alliances. Conz et al. explain that the difficulty when it comes to internationalisation is that understanding and communicating with other national cultures is a barrier for cross-border alliances and acquisitions to take place. Instead, SMEs are allocating their limited resources to collaborate with those enterprises in locations familiar to the entrepreneur, as it is a simpler process. Furthermore, it was identified that the link between place and perceived resilience for UK SMEs is underexplored (Herbane, 2020), evidencing the novelty of this research. Literature regarding operating in England is the first UK country of operation to be reviewed, in connection with its influence upon the two concepts of organisational resilience and open innovation.

England

The Lancet (2018) describes the English zone of London, Oxford, and Cambridge as the 'golden triangle' of the UK's scientific research, development, and innovation. These locations are highly productive due to the influence of the knowledge spillover and spinoffs of their local internationally recognised universities. However, emphasis on those locations alone, means an increasingly uneven regional disparity for life science innovation across England, with "research agendas in the hands of too few and not making optimal use of all the research talent in the UK" (p. 187). Whilst examining the adoption of medical technology from the life sciences, by the NHS, it is suggested that although their English trusts are more responsible for

"policy setting, regulation frameworks and information governance there is considerable fragmentation" (Asthana et al., 2019, p. 2). This, supposedly, creates a complex landscape to navigate, compared to the other UK nations' counterparts, and so deters the successful distribution of innovation into the service. The implication of this is that it may be too complicated and difficult for UK life science SMEs to practice open innovation with NHS research centres, despite them being major actors in the health ecosystem.

Pickernell et al. (2019) found the innovation performance of 39 English 'Local Enterprise Partnerships' to be of a stark contrast between the highly innovative outputs of the often-clustered South-East[11] and the relatively low outputs of the scattered enterprises in the rest of England. Pickernell et al. argue that "geographical concentration potentially facilitates long-term relationships and face-to-face contact, allowing firms to identify new technological possibilities through improved access to information, knowledge and supporting institutions" (p. 83). In a later article with many of the same authors, Beynon et al. (2020b) highlighted that different English regions may require (and receive) inconsistent levels of support from their local authorities. They supplied a very clear aim of the 'Local Enterprise Networks' as energising "local communities and businesses to provide the vision, knowledge and strategic leadership to fulfil their potential through effective economic growth and regeneration policy" (p. 84). Interestingly, despite the inclusion of Oxford in the 'golden triangle' (The Lancet 2018), the city is present within the weakest partnership regions, and London is not even present in their strongest partnership regions.

Northern Ireland

Arguably a resilient nation following the resolution of their internal conflicts, Neale et al. (2007) notes that Northern Irish government intervention has facilitated economic growth for socio-political cohesion through collaboration in the region. They assert that "focus must be on the high-value end of each sector suggesting growth in … health technology/biotech" (p. 449). This focus was encouraged to be rolled-out across all of Ireland, in both the Republic and

[11] Inclusive of the 'golden triangle' of London, Oxford, and Cambridge (The Lancet, 2018).

Northern. However, many regional challenges and deficiencies of the life and health sciences were identified by Scott et al. (2015), which may have a negative influence upon the concepts of organisational resilience:

> *"Adverse events, poor adherence, increasing numbers of medication incidents and inadequate communication at transitions of care … inefficient procurement, lack of compliance with prescribed therapies, morbidity and mortality, wastage of medicines, medication errors, adverse drug reactions, intrasector and intersector transitions of care, multidisciplinary teamwork and pharmacy skill-mix." (p. 222)*

Therefore, to improve organisational resilience, efficiency and effectiveness, Scott et al. (2015) proclaims that Northern Ireland has created an optimisation project within the pharmaceutical subsector: 'Integrated Medicines Management'. However, it is still in-progress and complex, with technology acquisition required. This requirement for technology could, therefore, be a positive influence for the practice of open models of innovation to procure it.

Northern Ireland is considered a peripheral region by Galbraith et al. (2017), which negatively affects SME innovation, and perhaps arguably, *open* innovation too. Despite such-sized enterprises being better-represented within such rural and remote geographical areas. Justification for this is explained by their SMEs' restricted access to "financial, human, physical and technological resources" (p. 670). This reduces the ability to innovate in-house, and to source external ideas (knowledge) and technologies too. Instead, the SMEs rely on large companies to target and initiate niche collaboration, and the government to support and facilitate any innovative ventures, which could be a positive influence on cross-domain open innovation.

Scotland

Henderson (2015) discussed the Scottish vision to anchor life science SMEs there, to boost the number of resilient companies in the region. Henderson discussed that the Scottish life sciences "struggle to maintain their product pipelines … to meet the increasing demands of shareholders to maintain growth margins" (p. 30). Enterprises are being advised to become more resilient through partnering and licencing, which directly links the two concepts. Although afar from England's 'golden triangle' (The Lancet, 2018), the main source of innovative start-ups in Scotland is from the academic institutions, which each feature in the top five for UK university spin-offs, and top 100 global universities for life science and health. It is claimed that "this is

testament to the excellence of Scottish research institutions and their collaborative partnerships with leading companies worldwide" (p. 33). The sheer breadth of life science activities is demonstrated by the Fraser of Allander Institute (2017), who suggest that the Scottish nation is a global leader in its research and development, manufacturing, sales, marketing, and management of the sector. From the perspective of Scottish Government (2020) in their planning policy, health innovation is deemed as "potentially transformative" (s. 6.10.5.). However, they confess that they are limited by a lack of digital connection in peripheral regions, stifling the research and development of remote medical innovations.

Scottish enterprises experience barriers to their growth, due to their historical socio-economic challenges of attracting and recruiting specialised personnel. Especially the case in areas of low population and weak labour markets. However, an upsurge in the national vision to empower local communities has resulted in "expanding enterprise and economic confidence" (Burnett & Dansen, 2022, p. 178). It was later professed that Scotland's rural areas are said to be represented in policy and cultural literature, as being too tough for innovation and enterprise to prosper (and therefore be resilient), even though they offer raw natural environment resources. In contrast, their urban areas are filled with "creative innovation and entrepreneurial success" (p. 180). It is therefore unclear what influence Scotland has upon the concepts.

Wales

Gray and Jones (2016) observe that since the 2000s, the Welsh government have turned to innovation and the knowledge to boost the regional economy. This includes the life science sector. Yet, Gray and Jones suggest that Welsh micro-sized enterprises often find themselves isolated. It is suggested that the creation of a supportive peer network could help such individuals develop their confidence, exchange knowledge, and develop business skills. Increasing their interconnections to collaborate, implying a positive influence on open innovation. Davies et al. (2017) express that south Wales has an established tradition of such collaborations, especially between industry and academia. Through becoming 'knowledge hubs' with universities "playing role of anchor tenant" (p. 187) to local enterprise. Yet in contrast, a Welsh life science enterprise reported that these university–industry programmes are a "waste of time and not valued at all by businesses" (Pugh, 2017, p. 989).

Returning to Davies et al. (2017), the origins of the Welsh life sciences were described as a nascent cluster of biological and medical technology enterprises in Cardiff and Swansea, at the

turn of the millennium. However, they identified a concerning lack of sustainable Technology Transfer Officer activities between Welsh universities and the sector. This resulted in Davies et al. suggesting more open solutions of integration and sharing of services, but later agree that such opportunities take time to develop. The Welsh life sciences are a means to beat the devolved nation's many socio-economic problems, and so Howson and Davies (2018) admit that there is an effort to exemplify open innovation efforts in the country, through a "trans-disciplinary, cross-sectoral approach to health innovation" (p. 317). This concludes our consideration of the individual UK countries of operation, as influential of the two concepts. Next, internationalisation of UK life science SMEs is explored as a possible influence.

Internationalisation

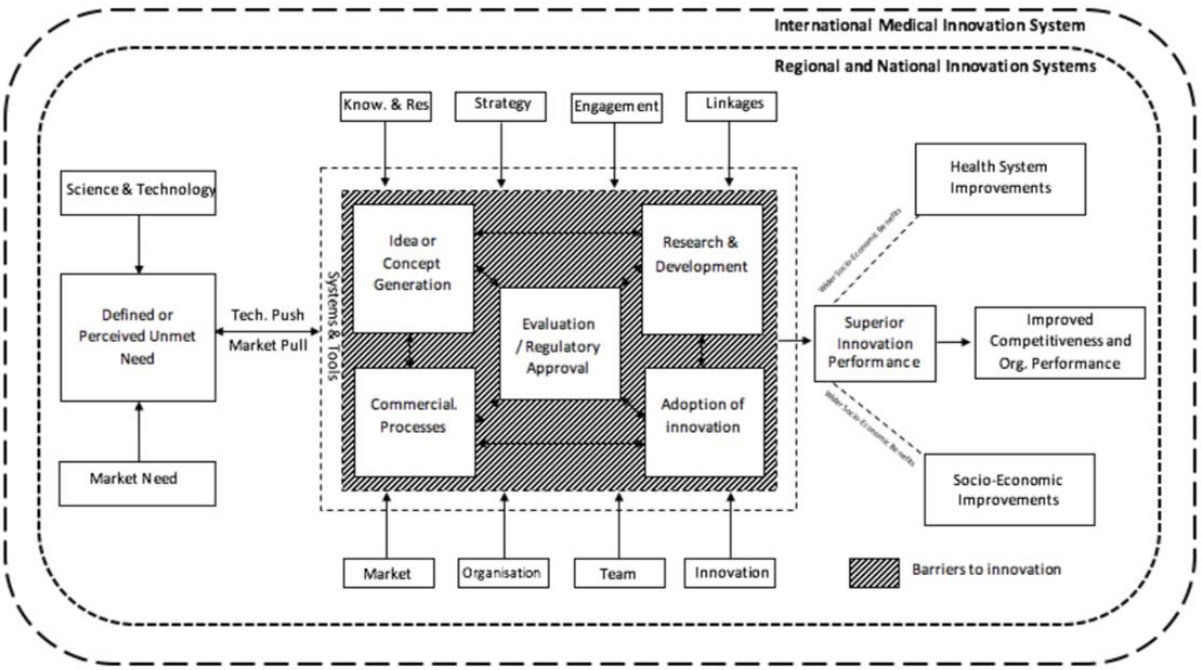
Innovation may come from another nation with different circumstances or different ways of competing (Porter, 1998). Nevertheless, Nummela et al. (2006) suggests that UK SMEs are increasingly operating globally due to improved technological and communication advancements and deregulation. However, it was also emphasised that it is not a simple transition from domestic to international operations. SMEs are instead having to (a) reassess their financial position, (b) restructure and diversify personnel, (c) effectively plan time due to exports having an extended period before profit, and (d) cooperate with vertical and horizontal alliances. All of these strategies are to obtain the skills and resources needed to have worldwide partnerships. Language is blamed as a major problem for open, international communication, with intercultural problems also contributing to the failure of these alliances (Fortuin & Omta, 2008; van de Vrande et al., 2009). In comparison to larger enterprises, SMEs lack the ability to reach and enter new geographical markets, and therefore, they are severely under-exposed to external sources of ideas (knowledge) and technologies. These would otherwise enhance their own business via open innovation. Furthermore, SMEs do not have the resources to increase internal capabilities, to process transfers across enterprise, and indeed geographical, boundaries (Varis & Littunen, 2010).

Open innovation is an inevitable way of working due to globalisation and the internet (Euchner, 2011). In agreement with the unavoidability of openness, Ridley (2011) that "the interdependence of the world through trade is the very thing that makes modern life as sustainable as it is" (p. 42). Ridley, who rejected self-sufficiency as leading organisations away from prosperity, also proposed the theory of a collective intelligence. Whereby organisations

accumulate intellect across enterprise and geographical borders through knowledge exchange. It can therefore be speculated that internationalisation does, in fact, influence open innovation. However, Salge et al. (2013) suggest that such efforts to go global can use up an SME's limited resources, including that of their attention, time, and money. Especially owing to the "greater geographical, cognitive, and cultural distance that needs to be overcome" (p. 661) for internationalisation to occur. There is also an expectation that SME owner-managers must simultaneously manage multiple alliances, with diverse partners, in different countries, to strategically innovate (Hoang & Rothaermel, 2016).

By engaging in international collaborations and expanding their presence in other markets, UK life science enterprises can "capture potential know-how and leverage their investment portfolio" (Marangos & Warren, 2017, p. 218). This asserts internationalisation as influential of their open innovation, especially due to the ease of which it has increased due to digital technologies (Bogers et al., 2018), arguably the internet and social media. The universal application of medical innovation means that it has been considered an international endeavour, crossing both regional and national boundaries. Represented in the outer rings of a conceptual model which represents the permeable external boundaries of regions, nations, and sectors (Howson et al., 2019, Figure 11; Zobel and Hagedoorn, 2020).

Figure 11: External Permeable Boundaries (Howson et al., 2019, p. 386)



Specifically citing *large* UK pharmaceuticals, Tidd and Bessant (2021) state that they do not hold themselves captive to their in-house capabilities, but instead gain from their "different cultural and scientific approaches" (p. 420). From their advantageous positioning in many different international markets, but this research investigates if this is the case for SMEs too. Tidd and Bessant later add that most biotech and pharmaceutical international collaborations occur in a triad of Europe, Japan, and North America. The main reason for such activities is access to their markets and monitoring of their technological advancements, to be disseminated with speed by the life science enterprises. Agreeing with the above, cultural and language differences are also said by Tidd and Bessant to be a significant barrier to cross-border alliances, affecting both the intent and ability for the organisation to learn. To conclude, there seems to be a large body of literature indicating that internationalisation influences open innovation, but a dearth of knowledge regarding its impact on organisational resilience. The next influence considers the geographical setting of the enterprise, specifically in relation to the locational setting of the UK life science SME.

Locational Setting

Within the early text of Smith (1776/1977) argued that the power of exchange (a fundamental aspect of open innovation) is limited by the extent of the market. It is therefore relevant to examine the influence of how each locational setting upon organisational resilience and open innovation. For example, Smith spoke of even the smallest of industries must operate in urban areas in order to find employment and resources, with rural locations being "too narrow a sphere" (p. 15). However, SMEs can be close to others within industry clusters, which are defined as "geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities" (Porter, 1998, p. 199). Yet, Porter noted that single-industry clusters (such as life sciences collectives) overlook cross-industry interconnections, which would otherwise influence competitiveness and open innovation. Such competition and cooperation within a cluster increases knowledge of buyer trends, access to evolving technologies, flexibility, and capacity. Conversely, they can also be a negative influence:

> *"When a cluster shares a uniform approach to competing, a sort of groupthink often reinforces old behaviours, suppresses new ideas, and creates rigidities that prevent adoption of improvements. Clusters also may not support truly radical innovation, which tends to invalidate the existing pools of talent, information, suppliers, and infrastructure." (p. 222).*

In contrast, North and Smallbone (2000) found that rural SMEs who are geographically distant from resources, are less likely to innovate with external sources, with both product and service innovation. They discovered that two thirds of English SMEs who are both innovative and rural are completely self-reliant (and 'closed'). Because: "their innovations were developed internally without any involvement from other individuals, firms, or agencies and service firms" (p. 102). The remaining third of their sample had *some* external input, but only 3% were dependable on external sources. However, North and Smallbone provided no justification for this. Their research implies that rurality and remoteness is a negative influence upon open innovation.

Referring to knowledge flows between three of the aforementioned helices of social innovation (Carayannis et al., 2021; Figure 5), Pickernell et al. (2009) argued that specifically-*tacit* knowledge between UK SMEs and academia, industry, and government does not travel well. Therefore, it is "embedded in a regional context" (p. 81) affected primarily by their geographical proximity. They found that despite UK SMEs more frequently having local links, their relationships for knowledge transfer was stronger in 'cross-local' (geographically wider) collaborations, with a statistical significant benefit of 'national' partnerships.

Contrasting this, Plummer and Acs (2014) find it beneficial for UK life science SMEs to be located close to universities. Because their academic knowledge has always had a spillover effect, beyond their university boundaries, which enhances local economic activity, especially when there is a commonality of specialities (such as the above life science clusters). Opportunities for knowledge spillovers "decay with distance" (Ghio et al., 2015, p. 3), and so proximity to resources is deemed influential, especially for cross-domain collaboration (industry-academia). They also suggested that the "regional diversity [of resources] positively affects new firm creation in neighboring counties" (p. 12). Urban areas, for example, with close proximity to resources, allow "disparate people, and therefore ideas, to bump into each other, is so conducive. They facilitate the association of diverse ideas, and bring people face to face with dissent and criticism" (Syed, 2015, p. 215).

Entrepreneurism is suggested by Burnett and Danson (2016) to be difficult in remote, rural locations (such as the UK's peripheral islands). Due to high costs of operation, particularly transport costs for exportation. Combine this with low levels of competition within their immediate marketplace, and it again implies that rurality is a negative influence, but this time, upon organisational resilience. Encouragingly, innovation is still present in these peripheral locations, but they are more the *acquirers* of research and development, rather than in-house. This suggests that at least inbound open innovation activities are occurring. In a later article, the same co-authors confessed that rural SMEs "face different, additional and exaggerated problems … with the harsher business environment" (Burnett & Danson, 2017, pp. 25-26).

With limited market and employment opportunities in remote regions, young people 'out-migrate' to metropolitan areas to seek academic, industry or social opportunities, leaving a limited "pool of talent and availability of skill and expertise to drive innovation" (Galbraith et al., 2017, p. 670). Corroborated by Florida et al. (2017), who investigated "the geographical distribution of innovation, the spatial correlates of innovative regions, and the local processes that shape these geographical patterns" (p. 88). They argued that cities are innovative machines, as they are more dense and diverse, implying that it is a "conducive environment for generating the human creativity that underpins innovation, entrepreneurship and economic growth" (p. 93). Making the locational setting of UK life science SMEs to be of value to measure if it is influential of organisational resilience and open innovation. The following influence that is considered is that of the position on the supply chain, and whether it can be a significant for organisational resilience and open innovation.

Supply Chain Position

Customers and suppliers can collaborate to generate new ideas for an organisations' products or services (Dahlander & Piezunka, 2014). In particular, the suppliers can provide, not only technological solutions to SMEs, but also advice regarding enhancing their processes and short-term commercial value (Brunswicker & Vanhaverbeke, 2015). Distributers are often the first port of call for buyers and end-users alike, to share feedback about products and services by acting as 'problem informers' and pass this information to the life science enterprise to create novel innovations. They are therefore deemed influential of competitive advantage and future innovation of new product development (Restuccia et al., 2016). A positive relationship was calculated by Yawson (2017), between supplier alliances and open innovation success:

> *"Firms know that they need to depend on partner organizations inside their supply system to innovate efficiently and effectively. Cooperation from suppliers allows the exchange of explicit and tacit knowledge which enhances the creation of knowledge and overflow of innovation from the supplier." (pp. 87-88)*

Supply chains have become more interconnected and complex, leaving them with a need for the individual actors to achieve organisational resilience to counter threats, even though "there is still no comprehensive definition and consensus on a roadmap to achieve resilience" (Bak et al., 2020, p. 1) within the supply chain. To improve innovation under vertical partnerships, relations with suppliers should instead be longer-term and more integrated, for them to communicate their expertise, contributing to the enterprise's product development. Advantageous to the enterprise as it can then reduce the time to market (Tidd & Bessant, 2021). Without a consensus, this research will be novel to understand if holding a particular position on the supply chain is influential of organisational resilience and open innovation. The penultimate external influence is that of BREXIT, and whether it is significant for the combined concepts.

BREXIT

The UK leaving the EU (commonly known as 'BREXIT') has introduced uncertainty into the national economy and regulatory landscape in recent years. Much before the 2016 BREXIT referendum, EU knowledge transfer across their geographical and political borders was considered by Belussi et al. (2010). They used the 'Open Regional Innovation System' model which validates the benefits of open innovation for their life science enterprises. Because knowledge transcends, not only organisational boundaries, but spatial ones too. A limitation of their research is that they only studied one European region. This means it is arguably not representative but does imply that open political borders can encourage open enterprise borders too. BREXIT also impeded the freedom of movement for individuals with highly technical life science knowledge to be available to and from the UK. It is, therefore, relevant and valuable to understand how this impacts the organisational resilience and open innovation of life science SMEs.

However, there is debate within the contextual literature. One source, Moore (2016), considered the UK as a resilient, open, innovative, and standalone country, which can thrive outside of the EU by forging global partnerships. Whereas, according to Dayan (2020), the UK

will no longer be alerted by the EU, regarding safety and pharmacovigilance. The UK is then less knowledgeable about potential, emergent, or current problems with scientific outputs on the market, which could have an untold effect for the end-users (patients). Furthermore, a peer-reviewed medical journal was honest about their impartial dismay over BREXIT, identifying the isolation and vulnerability of the island nation, encouraging the need for international connectivity (The Lancet, 2020). In this post-BREXIT economy, it will be of value to measure how the UK leaving the EU has influenced organisational resilience and open innovation. Finally, the last influence to be explored, is that of COVID, to evaluate if it is of significance to the combined concepts for UK life science SMEs.

COVID

It was unprecedented of how much COVID pushed UK SMEs to the limit of their organisational resilience. This was in order for them to survive through the social and economic restrictions and disruptions, placed by UK Government, to safely navigate the pandemic. Like the unrestricted geographical boundaries of medical innovation, previously argued by Mina et al. (2007), Rezaei (2020) also argued in a journal's editorial article that COVID has forced a more open approach, as the disease itself knows no borders. Rezaei found this to especially be the case for medical technology and biological technology development, producing "pharmaceutical and diagnostics to seek solutions to the pandemic" (para. 4). Through the urgency of the pandemic, clinicians and life science SMEs alike have been searching for drugs and therapies, leading to "a rapid and open form of COVID-19-related knowledge sharing with the global research community" (Minari et al., 2020, p. 2). Therefore, this evidences that it is influential open innovation. However, their article was funded by a scientific security agency, and so may be exposed to some corporate bias.

At the time of writing during the pandemic, the government reported that about 50% of UK businesses of any size were "temporarily closed or paused trading" (Gough, 2021, p. 2). This was due to the COVID lockdown restrictions, and so it was a worrying time for the organisational resilience of those operating in the UK. Restrictions have long since been lifted, but with unknown long-term outcomes for the national economy, or contributions to the downstream NHS backlogs. Yet, using their cash reserves as a marker of their resilience, Gough reported that 32% of UK businesses had enough capital to be resilient for three months or more, through any such further restrictions. In this post-COVID economy, it will be of

interest to UK life science SMEs to understand how these recent external forces have influenced the concepts, for future similar events. Next, concluding remarks are made about all the above reviewed influences, across the three factors (F1-3).

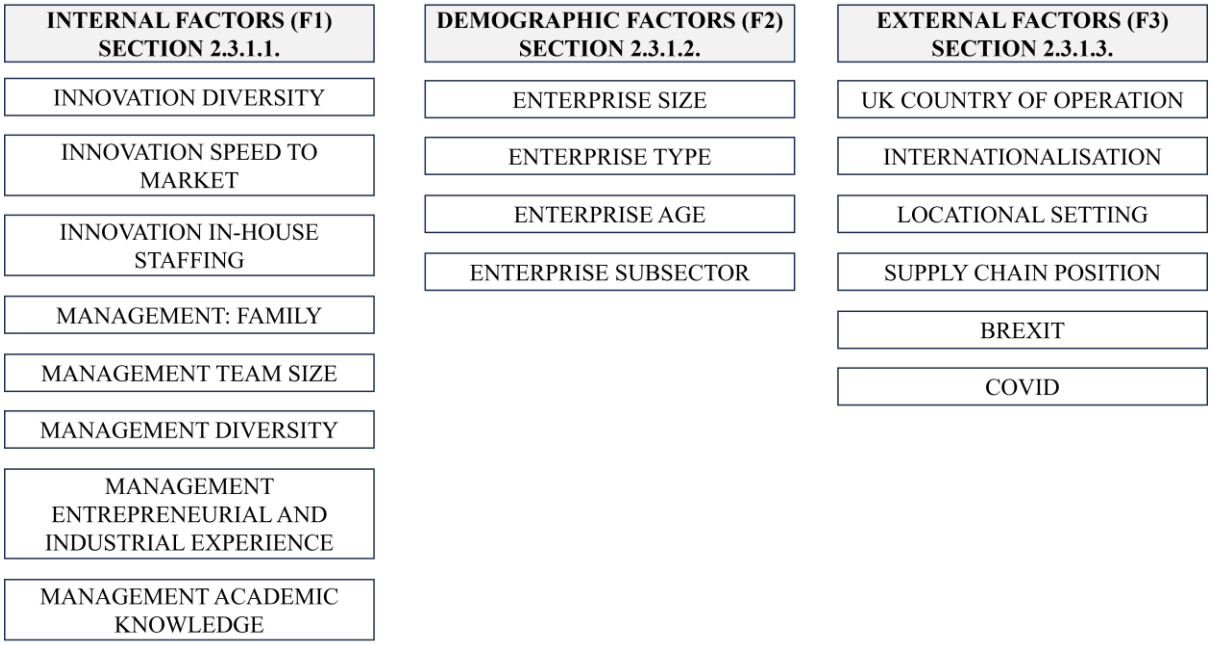
2.2.4. Conclusion of the Influences (F1-3) as Presented in the Literature

This review of literature regarding the influence of the concepts is complex and diverse. The possible scope of influence is multi-faceted and unlimited, but a strong attempt has been made to be comprehensive. With such a broad selection of influences categorised into factors (F1: internal, F2: demographic, or F3: external), it evidences many ongoing debates and unanswered questions as to what influence they have upon the individual and combined concepts of organisational resilience and open innovation. This research will, therefore, measure the influences found in the above literature, by asking:

- **Research Question Two (RQ2):** How are the concepts of organisational resilience (C1) and open innovation (C2) influenced for UK life science SMEs?

The multi-factor framework forms a formative measurement model (Figure 12). Such an analytical hierarchy process is necessary to understand the complex, multi-faceted influences of the concepts of organisational resilience and open innovation, to accurately answer RQ2.

Figure 12: RQ2: Formative Measurement Model



2.3. Concluding the Literature Review

This has been a complex chapter considering the broad scope of literature regarding both concepts (C1, C2) and both questions (RQ1, RQ2). The objective of this chapter was to critically assess the peer-reviewed literature and identify ongoing debates and unanswered questions for this research to provide a significant and original contribution to knowledge. From a systems perspective, it was evident in the preliminary literature searches that there was a gap in knowledge regarding the interrelationship and contingencies of organisational resilience and open innovation, and so it was worthy of further investigation.

Firstly, for RQ1, peer-reviewed and contextual research regarding the individual concepts were reviewed to understand how they are independently defined, strategised, evolved, and measured by UK life science SMEs. For the first concept of organisational resilience, a contextual source identified the high failure rate of UK life science SMEs (Office for Life Sciences, 2011), which is strong justification for this research. It also defends the need to identify if open innovation can make an SME more resilient. This was proposed by Marangos and Warren (2017), who found that UK life science SMEs which practice closed innovation are more at risk of failure. Evaluating relationships between business management concepts is a popular endeavour within the academic literature, although only two studies specifically measure the association between organisational resilience and open innovation (Ju, 2023; Mirghaderi et al., 2023). They found a moderate, but often[12] statistically insignificant connection. However, their research was based in different countries and sectors, so although they provide a foundation of knowledge, this research still has novelty for the context of the UK life sciences.

A critical review of the literature examining the relationship between organisational resilience and open innovation deepens the academic understanding of complex adaptive systems (Daniel et al., 2022; Ramos-Villagrasa et al., 2018) through the lens of general system theory. By analysing how organisationally resilient UK life science SMEs have an ability to “anticipate,

[12] Dependent on the direction of open innovation – inbound was found to be statistically significant, outbound was not (Ju, 2023).

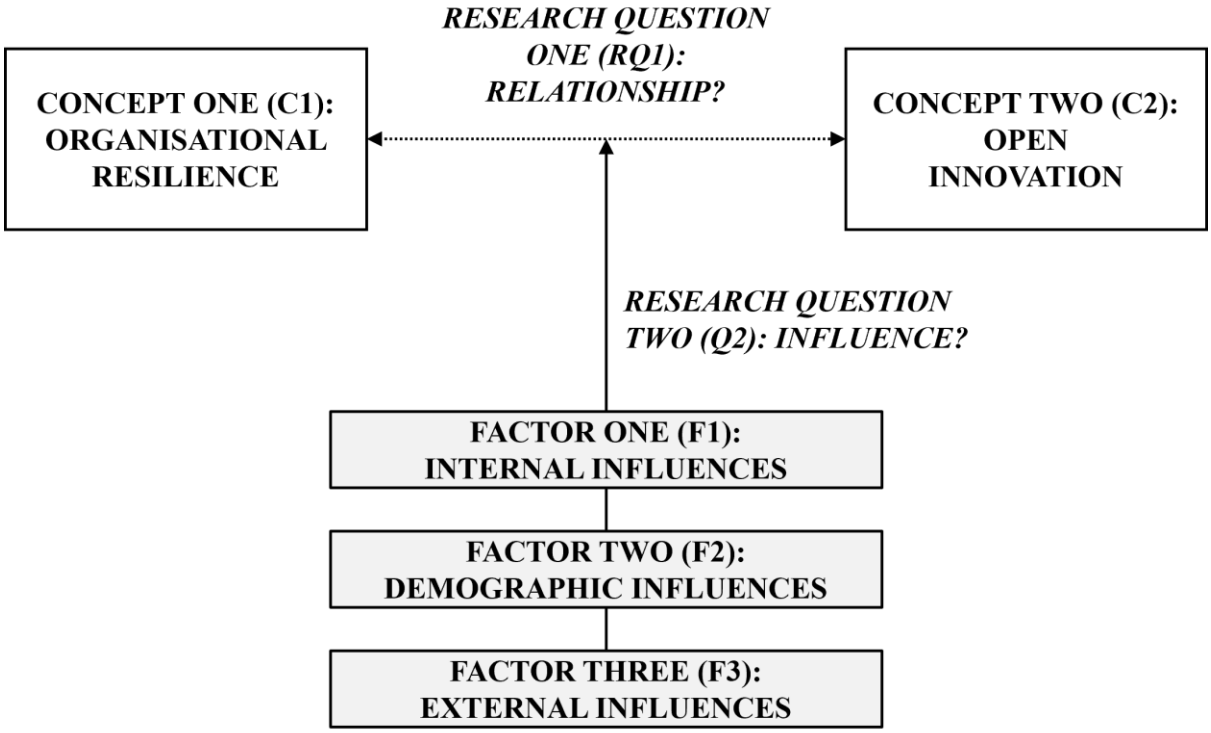
prepare for, respond and adapt to incremental change and sudden disruptions" (British Standards Institute, 2021), whilst leveraging ideas that "can come from inside or outside the company and can go to market from inside or outside the company as well" (Chesbrough, 2003), this research can highlight how open systems (Cole & Kelly, 2020; Daft, 2001; von Bertalanffy, 1928/1968) interact with their environment. This enriches general system theory by providing empirical evidence of how open systems, like the sample organisations of this research, may be able to enhance organisational resilience through open innovation. Highlighting the importance of interconnectedness and adaptability for survival and business growth.

Secondly, for RQ2, it is also of significant value to investigate what influences the combined concepts, to make a contribution to systems theory, and more specifically, contingency theory. The UK life science SMEs can then understand how to optimally allocate their limited resources, to efficiently enhance their organisational resilience and open innovation simultaneously. Much like measuring relationships in research question one (RQ1), exploring influences is also a popular investigative practice within business management literature. Attributed to a lack of UK SME research, identifying factors to measure, that may be influential of the concepts, is a challenge for business management researchers (Herbane, 2019; Lopes & de Carvalho, 2018). By applying a multi-factor framework (F1-3), an original model of influences was reviewed from thorough reading of relevant literature. It adds further significance that this original model, captured influences that are specific to the UK life sciences, as well as recent external forces as BREXIT and COVID.

Examining the multifaceted influences in the literature of either organisational resilience or open innovation strengthens the core principle of contingency theory. That there is an optimal structure and practice, depending on the internal and external context of the UK life science SMEs, which will influence the effectiveness of the combination of concepts. By exploring diverse peer-reviewed literature, this chapter has identified a comprehensive range of potential influences, across three factors (Mirghaderi et al., 2023; Tidd & Bessant, 2021), to move beyond one-size-fits-all solutions (Howson & Davies, 2018; Sullivan-Taylor & Branicki, 2011). Instead, to tailor approaches to specific contingencies (Lawrence & Lorsch, 1969; Tannenbaum & Schmidt, 1958), fostering a more nuanced view of how SMEs can optimally be organisationally resilient and practice open models of innovation in the complex and ever-changing environment of the UK life sciences sector.

To conclude, the evaluated literature (both peer-reviewed and grey) has been underpinned the systems theory of this research, by identifying ongoing debates and unanswered questions that will be answered through primary mixed method research. The design of this, will be comprehensively discussed and justified, in the next chapter. Combining the formative measurement models of each question (RQ1: Figure 7, RQ2: Figure 12) a combination model is presented (Figure 13) to provide the contribution to system theory development, across both research questions.

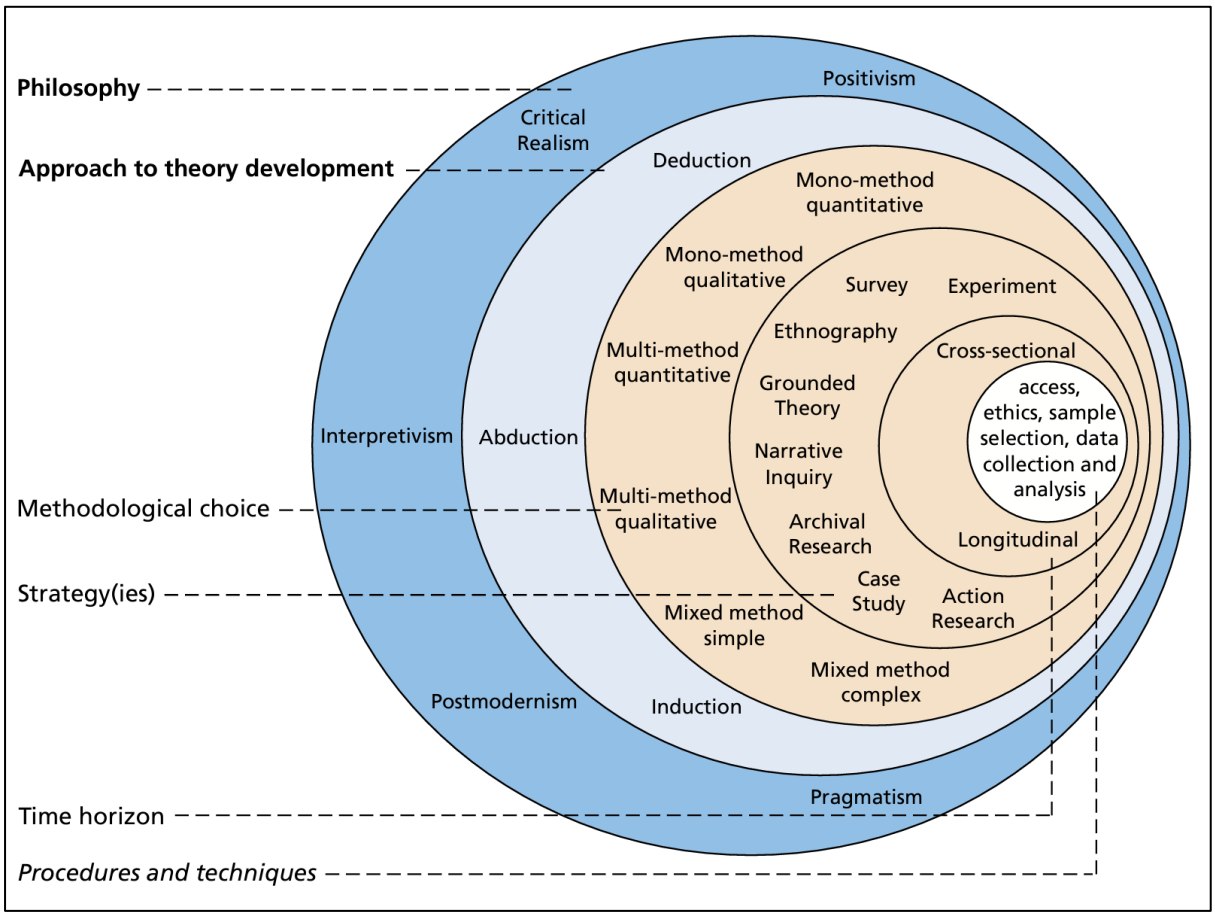
Figure 13: RQ1*RQ2: Formative Measurement Model



Chapter 3: Defence of Method

This chapter defends the methodology chosen to best capture the data needed to answer the research questions, and is structured using the 'research onion' (Saunders et al., 2023; Figure 14), with the design choices of the study being justified at every layer.

Figure 14: Research Onion for Chapter Structure (Saunders et al., 2023, p. 131)



As a brief overview, this research applies realist philosophies to best measure the business management concepts of organisational resilience and open innovation for United Kingdom (UK) life science small and medium-sized enterprises (SMEs). It is a simple mixed method choice, sequentially splitting the quantitative data collection with a survey, and the qualitative data with an interview. Mixed sampling is applied to not only increase the size of the frame for maximum exposure to the UK life sciences, but to also provide UK representativeness to reduce any bias that may come with pre-established connections to the host university. Regressions techniques are applied to analyse the quantifiable data due to their function to determine relationships between variables. Whereas thematic analysis is applied for the qualitative data,

to analyse the key a priori and emergent themes to contribute a final model as a substantial contribution to the body of knowledge.

3.1. Philosophies

The philosophical underpinning of research encompasses "the phenomena of which life consists of thoughts, feelings and actions" (Comte, 1844, p. 8), as "science is what we know, philosophy is what we don't know" (Russell, 1950, p. 35). Attempting to explain how everything is related, metaphysics is split into "being [ontology] and thinking [epistemology] … here the human being comes face to face with being" (Heidegger, 1953/2014, p. 157). The philosophy of science encompasses "conscious and unconscious assumptions and considerations, regarding the nature of reality (ontology), the creation of knowledge and understanding (epistemology), as well as the role of values and their influences on the knowledge creation process (axiology)" (Biedenbach & Jacobsson, 2016, p. 140); each of these metaphysical research philosophies are discussed, below.

3.1.1. Ontology

The philosophy of 'being', concentrates upon how the researcher sees reality and makes assumptions upon it. Whilst discussing ontological relativity, Quine (1969) proposes a need to not specify what *does* exist, as there are so many irrelevant objects in existence, but instead, the need is to specify explicitly what exists relative to the context of the theory. Therefore, the theory is only useful for one purpose, due to it being made up of a very-specific reality, objects, and relationships. This means that although the literature reviewed in the previous chapter does share a similar reality with this research, in that it can be applied to either concept of organisational resilience or open innovation, their purposes are not the same. Due to the novelty of this research of combining the concepts. Therefore, Quine states that reality can only be interpreted relative to this research, as it is reasonable to assume that the other theorists have "a different doctrine of being from mine" (p. 108). There is a very real problem of every enterprise having diverse understandings of what "different words, terms and expressions may mean, signify, or represent" (Stokes, 2011, p. 24). This point was exemplified by Muijs (2011), who warns that wording can lead to confusion by the respondent and cause them to guess definitions to complete the research. Consequently, this reduces the reliability of the data.

Ontology has its foundations in ancient Greek philosophy, with Heraclitus (as cited in Kleinman, 2013) proposing that nature, and consequently reality, is constantly changing. It was paraphrased that you cannot step into the same river twice. This means that this original research is truly unique, as the study of an everchanging reality will never be the same again. Even though there are other similar or related theories regarding the relationship of the concepts, each providing foundational knowledge, and the identification of ongoing and unanswered questions, no other research has the exact same specification to UK life science SMEs, justification, or outcomes as this research. De Vaus (2014) agreed, because "if concepts have no set meaning then anyone can define a concept any way they wish" (p. 41). Therefore, labelling of objects is a key theme of ontology, as it is a philosophy which questions the very nature of reality by putting "being into words" (Heidegger, 1953/2014, p. 45). Another ancient Greek philosopher, Aristotle (as cited in Baracchi, 2015) defined 'being' as "that which is insofar as it is" (p. 150). Thus, this description of existence forms the basis of ontology, and the specific reality can be inventoried through the act of naming the reality, objects, and relationships (Table 4).

Table 4: Ontological Inventory

Inventory	Consideration	Explanation	Definition
Reality	Regarding	UK life sciences	Blurred sector boundaries, makes it difficult to define. Attempts include the collection of its subsectors (Figure 1)
	Disregarding	Outside the UK life sciences	The global economy
Objects	Regarding	Micro, small, medium-sized enterprises	Márquez and Ortiz (2020; Figure 9)
	Disregarding	Large enterprises	Above the maximum criteria for medium-sized enterprises
Relationships	Regarding	Organisational resilience	"Ability to anticipate, prepare for, respond, and adapt … to survive and prosper" (British Standards Institute, 2021)
	Disregarding	Organisational failure	Business death (Shaw, 2023)
	Regarding	Open innovation	Using "external ideas and technologies … and allows unused ideas and technologies to go … outside" (Chesbrough, 2019)
	Disregarding	Closed innovation	"Vertical integration model where internal innovation activities lead to internally developed products" (Chesbrough, 2019)

Business management researchers, Graham et al. (2006) were dismayed and frustrated by the sheer number of labels around ideas and knowledge, which are mis-used interchangeably by health professionals. This causes high risks to end-users due to a lack of clarity. As a consequence of such issues, Forés and Camisón (2016) found that organisations which practice openness, actually create their own labels, by creating a "common language" (p. 382) to innovate. Similarly, 10 Northern Irish high-tech SMEs found that misinterpretations around terms led to inter-staff disagreements, and wider innovation not being understood. As an unfortunate consequence, they were unable to source sufficient support from their devolved government (Galbraith et al., 2017).

Despite some modern theorists claiming that the practice of open innovation is nothing new and a vague concept (Ridley, 2011; Tidd & Bessant, 2021; Trott & Hartmann, 2013), it was Marangos and Warren (2017) who found that such labels around the concept were not recognised by Chief Executive Officers. Instead, the respondents were uncertain if they practiced a binary closed or open model of innovation, so offered alternative and rich responses regarding their innovation and collaboration strategies.

It is therefore imperative for this research, that such concept labels and ideas are explicitly defined for the participants to measure against, to increase the validity of the data collected. If there were to be any confusion, it would lead to unreliable data being interpreted into false conclusions, hence the need for the above inventory. Ontologies of business management research are also discussed in the cited literature (Adams et al., 2006; Barão et al., 2017; Galbraith et al., 2017; Venkatesh et al., 2013). Through no fault of the researcher, a minor ontological limitation is that there is no English word to label a possible symbiotic relationship which synthesises the concepts of organisational resilience and open innovation as a single interaction. This research utilises multi-modal ontologies, each discussed in the following sections.

Realism

Realism originates from both Plato and Aristotle (as cited in Scruton, 2018; Stokes, 2011), whereby it can be paraphrased as concepts existing independently of how they are viewed, thought of, and experienced. Plato even presented a theory of forms, whereby the world of experience is deemed simply an illusion, and only that which is unchanging, and eternal is real and universal. A well-known thought experiment was that of a cat in a box with poison;

according to Schrödinger (1935), two realities of the cat being alive and dying of the poison are both valid. These two states of being are independent of the ideas, predictions, and expectations of the observers of the closed box, until the point in time when it is opened.

The philosophy of realism is typical within the cited literature (Pal et al., 2014; Treanor et al., 2021; Venkatesh et al., 2013). Interestingly, Marangos and Warren (2017) recommend the application of realist philosophy for future open innovation research. Therefore, the measurement of the concepts will apply a realist approach by later applying peer-reviewed frameworks (British Standards Institute, 2014, as cited in Pescaroli et al., 2020; Chesbrough, 2019, p. 30; Nilsson & Minssen, 2018) with tangible markers such as specific policies or procedures, for the participating enterprises to rate their level of organisational resilience and open innovation.

These concepts and their dichotomous (Branicki et al., 2018; Goldberg, 2020; Lopes & de Carvalho, 2018; Shaw, 2023; Trott & Hartmann, 2013) or nuanced (Bak et al., 2020; British Standards Institute, 2014, as cited in Pescaroli et al., 2020; Nilsson & Minssen, 2018; Tidd & Bessant, 2021) markers are deemed *universal* truths as they are valid across and beyond the later sample criteria of (a) countries, such as the UK, (b) sectors, such as the life sciences, and (c) sizes of enterprises, such as micro, small, and medium-sized. Next, the objectivist ontology is also defined and applied to this research.

Objectivism

In their study of enterprise internationalisation, Nummela et al. (2006) cited objectivist models of human reality and nature, which Given (2008) later asked: “are there real objects of universal terms [objectivism], or are universals simply names that humans give to mental abstractions [subjectivism]?” (p. 577). Often, but not exclusively, linked to realism, objectivist philosophy is “free and independent from particular prejudice” (Stokes, 2011, p. 89). It assumes that social phenomena exist independently of individuals, in this instance, that would be saying that organisational resilience and open innovation are independent of how UK life science SME owner-managers experience them.

In objectivist research, the standard of meaning for each concept and question are invariable (Metz, 2011), and therefore provide consistent responses to them, for ease of comparison and analysis. Furthermore, Saunders et al. (2023) suggests that an objectivist considers that the

objects and their relationships exist in a single, true reality that is external to the researcher and the participating enterprises. In the case of this research, the concepts of organisational resilience and open innovation exist, external to the sampled owner-managers of the UK life science SMEs. Adding a further layer to the explanation, the sampled SMEs exist, external to the researcher. According to Bacon (2019), it is not possible to objectively "disentangle" (pp. 86, 265-266) the researcher's experiences and beliefs from their data and analysis. After considering the ontologies of realism and objectivism, the next section considers the second metaphysical philosophy of epistemology.

3.1.2. Epistemology

Epistemology is regarding the 'theory of knowledge', and concentrates upon the way the researcher makes assumptions of the best way to conduct research within the reality of the UK life sciences sector, as explained above. It is defined as "the search for knowledge, is the search for justifications, which guarantee that truth" (Scruton, 2012, ch. 22.1.). An 'epistemic community' has developed for organisational resilience, especially following the 2007-2008 financial crisis (Annarelli & Nonino, 2016; Korber & McNaughton, 2018). A similar such community has also formed around open innovation, which has provided a wealth of knowledge to draw from (Adams et al., 2006). Due to it being a popular and contemporary area of academic interest. The upcoming participants will be probed for their knowledge to determine the relationship (RQ1) and influences (RQ2) of the two concepts (C1, C2), from the perspective of their UK life science enterprise. To answer, they will use what is commonly known as organisational memory (Kmieciak & Michna, 2018; Nummela et al., 2006; Scott et al., 2015; Xing et al., 2020).

The researcher must practice reflexive bracketing (Zeegers & Barron, 2015) to 'disentangle' (Bacon, 2019) from their own previous industry experiences of organisational resilience, or specific models of innovation, biasing the investigation. Therefore, an impartial distance is needed to not impact the reality of the participants, nor influence their responses. This increases the integrity of the research. However, the researcher will be learning from the review of literature and testing that knowledge within the upcoming primary research. The epistemologies of business management research are also discussed in the cited literature (Adams et al., 2006; Carayannis & Campbell, 2011; Duchek, 2020; Gray & Jones, 2016). Due

to the selection of mixed methods for this research, multi-modal epistemologies are applied, as discussed below.

Positivism

In the 19th century, positivism was represented as the scientific study of relations. Whereby the reality of the subject is undisturbed by the researcher, as "attempts to interfere more directly with the course of practical life, he commits the error of usurping … all practical measures" (Comte, 1844, pp. 8-9). This would lead to invalidating the data, and lead to misinterpretations within the findings. As this UK research aims to provide a significant and original contribution to knowledge, it is apt to apply a positivist approach, as according to Scruton (2012), "British empiricism [has] a profound respect for science and 'scientific method' as the one proven route to knowledge" (ch. 3.2.). Tying in with the above realism and objectivism, positivism is said to believe in everyone sharing one social reality. This reality is cited as external, observable, measurable and independent (Collis & Hussey, 2014). Assuming an honesty in the answers provided, which is reinforced by the respondents' security of anonymity and non-invasive questioning, they will only be used as an instrument to access and collect data upon the objective social reality of UK life science enterprises. According to Marangos and Warren (2017), most open innovation studies utilise a positivist approach, and so this research sits within that, by applying positivism through a quantitative survey, with the resultant significant influences used as a priori coding of the qualitative interview data, discussed later. Next discussed, is the interpretivist epistemology which is applied to the statistical analysis outputs and emergent coding of the interview transcripts.

Interpretivism

In critique of positivism, Nietzsche (1901/1968) professed that there are no facts, only interpretations. Influencing the sequencing of mixed methods applied in this research, Weber (1921/1968) insists that an interpretive method should be employed after positivism, to discern the meaning of the concepts explained by empirical, scientific methods. Social actions are essentially defined by their experience of them, and so they allow people to apply subjective meaning on the SME strategies. For this research, subjective meaning is not only from the respondents upon the actions of their enterprises, but also from the researcher upon the responses provided. This will, therefore, provide a richness and depth to the quantitative data collected.

Scruton (2012) suggests that the resultant 'primitive sentences', collected in the interviews, are evaluated by assigning value to them, in this instance, by the researcher. Scruton reasoned that "until evaluated, a sentence is simply an uninterpreted sign" (ch. 6.6.). Interpretivism has been previously applied within organisational resilience literature to collect the lived and professional experiences of owners of rural Scottish enterprises (Burnett & Danson, 2016) and the investigation of UK micro and SMEs, whereby their subjective interpretation (researcher bias) was acknowledged (Gray & Jones, 2016). It is argued by Saunders et al. (2023) that the discipline of business management, and the social actors within it, are just too intricate to be studied in the same empirical (positivist) vein as the physical sciences. However, this does mean that the researcher is entangled with the responses, and therefore non-reflexive. Interpretivism is applied through emergent coding of the qualitative interview data, discussed later. Next, the third and final metaphysical research philosophy is explored, axiology.

3.1.3. Axiology

This theory of value "does not focus directly on what we *should* do. Instead, it centres on questions of what is *worth* pursuing or promoting" (Honderich, 2005, p. 172). For this research, axiology will provide the knowledge of whether it is worthwhile, and of value, for UK life science enterprises to practice a combination of organisational resilience and open innovation. Biedenbach and Jacobsson (2016) have asked "what is actually desirable and/or good?" (p. 139). For SMEs, the *intrinsic* value of organisational resilience is fundamental due to a need for a sustainable income, yet the intrinsic value of open innovation to enterprises is harder to assess. Some theorists suggest and promote its positive value for success and productivity (Belussi et al., 2010; Carayannis & Campbell, 2011; Marangos & Warren, 2017; Bogers et al., 2018; Rees et al., 2021). Whilst other theorists demote it as having a negative value, especially from any predatory and dominating partners of collaborations with unbalanced outcomes, and the imitability risk to an SME's intellectual property (Fortuin & Omta, 2008; Zobel and Hagedoorn, 2020). The latter, negative value of the concepts is often cited as being the 'dark

side' of open innovation (Veer et al., 2013, 2016)[13]. An element of axiology is phronesis, discussed next.

Phronesis

In line with the axiological study of values, Aristotle (as cited in Flyvbjerg, 2006) proposed that phronesis is an intellectual virtue, that is "reasoned, and capable of action with regard to things that are good or bad for man" (p. 370). This can therefore be interpreted as to what is valuable for enterprises to practice. Reinforced by Weber (also, as cited in Flyvbjerg, 2006) as "activity by which instrumental rationality is balanced by value-rationality … balancing is crucial to the viability of any organization" (p. 370), which relates to the development of an *economic* organisation from entrepreneurial ideas and activity (Márquez & Ortiz, 2020). Therefore, this research will consider how the consequential business management theory can interact with practical industry application of the new knowledge.

3.2. Approach to Theory Development

Kraemer and Blasey (2016) suggest that literature reviews are exploratory by nature, "to generate the theoretical rationale and the empirical justification for proposing a certain hypothesis to be tested" (pp. 1-2). They propose that such exploration of current literature should produce enough evidence to form hypotheses, but not enough to "assure its truth" (p. 2). It is there to justify the need for the subsequent primary research, to answer its two ongoing and unanswered questions regarding the relationship (RQ1) and influences (RQ2) of the dual concepts of organisational resilience (C1) and open innovation (C2).

The application of a deductive approach to theory testing in this research, is justified by de Vaus (2014). As by using the theory sourced from the review of literature, predictions can be made of if and how the concepts (variables) will relate and be influenced within the 'real world' of the UK life sciences. This will be achieved by measuring and testing them through the

[13] Veer has recently updated this research by discussing 'conscious' (intentional) knowledge transfer by ventures (Veer et al., 2022). They find that knowledge disclosure and knowledge broadcasting have positive effects upon performance, which has the implication that there may also be a positive relationship between the concepts of this research.

primary research. De Vaus argues that “observations require explanation, but equally, explanations need to be tested against the facts. It is not enough simply to collect facts. Nor is it sufficient simply to develop explanations without testing them against the facts” (p. 9). Pal et al. (2014) and Marangos and Warren (2017) both used a similar such approach to their research of SME organisational resilience and UK life science SME open innovation, respectively. The next section explores and justifies the most appropriate methodological choices made to answer the two research questions and contribute new knowledge to the body of business management literature.

3.3. Methodological Choice

3.3.1. Mixed Method

Applying contingency theory (Daft, 2001; Donaldson, 2001; Lawrence & Lorsch, 1969; Tannenbaum & Schmidt, 1958; von Bertalanffy, 1928/1968), all enterprises have a unique, complex, and nuanced fit within a system. So, it is justified that this research uses a mixed methods approach, to comprehensively collect both quantitative and qualitative data. Referring to the early organisational resilience research of Meyer (1982), the benefits of such mixed method research were justified by juxtaposing both the qualitative and quantitative analyses, to "compound their discrete advantages, offset their inherent liabilities, and achieve a deeper understanding of adaptation than either method could have produced alone” (p. 517).

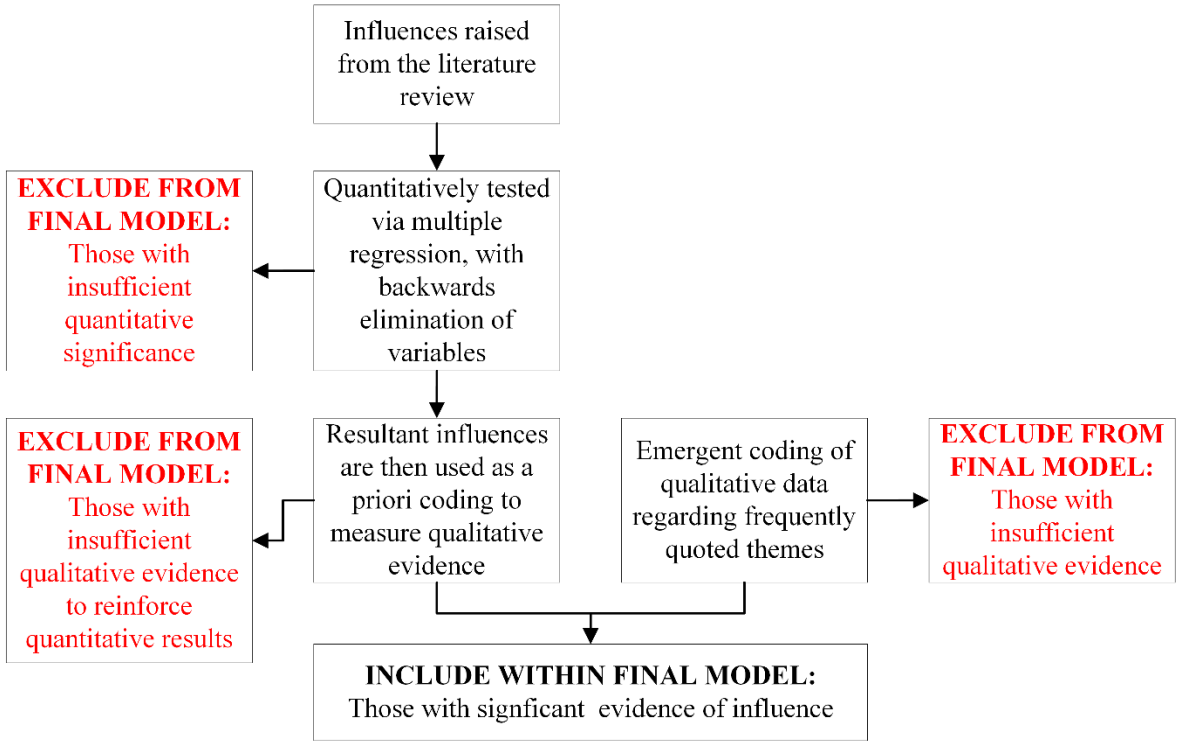
According to the innovation research of small-sized businesses by Hausman (2005), “quantitative research is often less valuable than qualitative research mainly because there is little guidance regarding what factors to measure” (p. 774). Directly related to this research, as although many influences from the literature will be quantitively tested, they will further be supplemented with in-depth qualitative research. Venkatesh et al. (2013) assert that “diversity in research methods is considered a major strength … with respect to understanding and explaining complex organizational and social phenomena” (pp. 21-22).

This diversity of data collection techniques, methodologies, and methods, represents a more complete and richer picture of the organisations being studied (Zeegers & Barron, 2015). It brings an element of dynamism and flexibility, which “can be very effective in providing higher validity and explanatory power of collected data” (Fielding et al., 2017, p. 154). There is also a distinct split within the methodology of collecting quantitative data through a survey, and

qualitative data through an interview. Each with equal priority and weighting (Bell et al., 2022). This explicit split makes these simple, rather than complex, mixed methods. By collecting quantitative then qualitative data (each discussed below), this research uses a mixed method approach. It is necessary to conduct the methods in this order, as for:

- **RQ1:** The first, quantitative method can identify trends and patterns between the bivariate relationship of the concepts, which can then provides a foundation and the information for a deeper-dive to occur in the second phase. The qualitative method can then to explore and contextualise the participants' observations and experiences of the relationship.
- **RQ2:** Due to the breadth of variables considered in the literature for RQ2, a quantitative approach can is the most efficient and effective way reduce their number to a significant model of influences. Then, these variables of interest spark further exploration, and so they inform the second, qualitative phase. A richness of qualitative data can be captured per influences, for a richness and depth that cannot be attained from the statistical method. The complex process for this question is visualised below (Figure 15).

Figure 15: Selection Criteria for RQ2 Final Model of Influences



A mixed method approach is therefore complementary of each individual method, and offers an iterative, multi-stage validation for an accurate final model.

First Phase: Quantitative Method

Quantitative data is collected to find patterns and relationships between the variables. The capturing of such data is justified by von Bertalanffy (1928/1968), who claimed that General System Theory (the underpinning theory of this research) gives exact definitions for concepts, and then measure them via quantitative analysis.

With a noted high demand to quantify organisational resilience and identify its characteristics, both Alderson et al. (2015) and Whitman et al. (2013) are alarmed by the lack of empirical and practical tools to measure it. Similarly for open innovation, Bessant and Tidd (2015) acknowledged that this datatype is said to be favoured by economists and innovation strategists alike. Due to it providing insights into the "level, type, and success of collaborative activities" (p. 413). Yet, Bessant and Tidd admit there is low empirical evidence on open innovation's industry application, with it rarely being sector specific. Therefore, this demonstrates the significance and originality of this contribution to academic knowledge and industry practice within the UK life sciences. Empirical research is commonplace in business studies, motivated by researchers not only being interested in *how* things are, but *why* things are (Bell et al., 2022) - important for both research questions regarding relationships and influences (Table 5).

Table 5: Quantitative Data Collection per Question

Research Questions (RQs)	Quantitative
RQ1: Relationship?	Ranking of each concept (C1, C2)
RQ2: Influences?	All factors (F1-3)

Although Ju (2023) claims that qualitative data is more regularly collected by business management researchers for organisational resilience, it is often difficult to find a universal conclusion from a limited number of cases. Therefore, Ju opted to collect quantitative data, as a larger sample size could be accessed, and statistical techniques can be gained for more accurate conclusions regarding the relationships between variables. Therefore, for this research, an online survey is created to efficiently collect such quantitative data from the busy owner-managers, to later be statistically analysed. A structured design is used to reduce outliers and error bias. The qualitative method is also considered, next.

Second Phase: Qualitative Method

Although preferring to apply a quantitative approach towards the development of General Systems Theory, von Bertalanffy (1928/1968) later confessed that there are "many aspects of organizations which do not easily lend themselves to quantitative interpretation" (p. 46). It is therefore argued that qualitative arguments are to be made, hence the inclusion of such methods in this research, with the aim of it resulting in "interesting consequences" (p. 47) and conclusions. Such qualitative data will be collected to provide "an opportunity to develop theory from observations" (Hausman, 2005, p. 774) that were found within the preceding quantitative data. Reflected upon by Adams et al. (2006), who recommends qualitative data for the testing of:

- **RQ1:** As quantitatively testing the relationship can only deliver a somewhat dichotomous measure of whether there is or is not an association, and so requires a "qualitative assessment of the nature of the linkages" (p. 30).
- **RQ2:** Again, quantitative testing can only test if factors are influential or not, whereas qualitive testing can "explore perceptions" (p. 31).

In agreement for this research, qualitative data will be collected as it is useful to gain an in-depth understanding of such perspectives on certain concepts (Given, 2008; Alberto et al., 2022) because they are vague. Therefore, they are tested with a quantitative phase first, which will allow for multi-stage validation for accuracy of the final model. It considers both meanings and experiences (McAvoy & Brace, 2014). Consequently, it will be of value to supplement the quantitative data to add a richness and depth to the research (Table 6).

Table 6: Qualitative Data Collection per Question

Research Questions (RQs)	Qualitative
RQ1: Relationship?	Definitions, strategies, relationship
RQ2: Influences?	*No active questioning. Instead, a priori codes will be used from RQ1 responses, and emergent codes of any new influences*

3.3.2. Explanatory

Noting that the research questions ask *how* the concepts are related (RQ1) and influenced (RQ2), Collis and Hussey (2021) suggest that this is a key signifier of explanatory research,

which aims to explain detailed characteristics of the concepts. They define explanatory research as "a study where the aim is to understand phenomena by discovering and measuring causal relationships between variables" (p. 343). This perfectly fits the description of this primary research. Such explanatory research is common within the cited business management literature (Belussi et al., 2010; Carayannis & Campbell, 2011; Lettieri et al., 2013; Marangos & Warren, 2017). To justify the overarching research questions (RQ1, RQ2) asked, a summary of the considered peer-reviewed literature per concept and research question, is provided within Appendix C: Tables of Evidence and Codebooks. The next section discusses the research strategies employed, including surveys, interviews, and the sampling.

3.4. Strategies

At the time of designing the research, COVID restrictions to socialise were active, and so this research employed an 'e-social science' approach. It is suggested by Fielding et al. (2017) that through the combination of an online surveys and online interviews, the data will provide "higher validity and explanatory power" (p. 154), which is what this research strives for. For strategy, and to coincide with the above tables of evidence, codebooks are created for each research question, as recommended and adapted from the literature (Braun & Clarke, 2022; Pallant, 2020). Again, these can be found in Appendix C: Tables of Evidence and Codebooks. However, the next sections discuss the specific strategies deployed to collect the quantitative and qualitative data to answer the two research questions, regarding the relationship and influences of organisational resilience and open innovation.

3.4.1. Surveys

Online surveys are a well-established modern method of data collection for business management research, as evidenced in the literature (Garengo & Bernardi, 2007; ten Ham et al., 2018; Ju, 2023). Surveys are appropriate for this research as they pose the following justified benefits. Such online survey links are effective for sharing invitations to participate across a large sample frame, using email and the contact forms on their websites. Previous research experienced challenges using surveys, for example low response rates (Kmieciak & Michna, 2018). Due to the limited resources of UK life science SMEs, including time, an online survey is convenient for the owner-managers to respond at their convenience. Shore et al. (2023) found online surveys efficiently collect data for their large sample, and they overcome

expected low response rates, by scheduling regular follow-up email invitations to their Qualtrics survey - both a technique and instrument applied for this primary research.

To be explicit about definitions, ‘surveys’ are the overarching research strategy applied to collect the data, whereas a ‘questionnaire’ is the instrument used to ask the questions (Qualtrics, 2023c). For further efficiency, the wording and formatting of the survey is curated to ensure efficient reading and effective data capture, to prevent any “questionnaire fatigue” (Denscombe, 2017, p. 188), which can cause a respondent to drop-out. The survey design uses a structured approach to reduce the risk of outliers. According to Saunders et al. (2023), the reliability of research refers to how free the data is of such measurement errors and skewed results. Furthermore, Muijs (2011) highlighted other mitigating factors:

> *“An item may be worded in a way that can lead to confusion, or it may be too difficult, leading to guessing. Even more random elements can intervene: the mood of the [participant] when taking the test, the temperature in the room, and so on.” (pp. 62-63)*

A conscious effort has been made to make the survey accessible for any potential owner-manager responders with disabilities or health conditions. Only question types, offered by Qualtrics, that are compatible with third-party screen readers are employed, adhering to international Web Content Accessibility Guidelines standards (Kirkpatrick et al., 2023). This allows for any potential disabled owner-managers of UK life science SMEs to fully participate in the research. For example, all email addresses and weblinks are displayed as hyperlinks. Beneficial for accessibility of the visually impaired, or learning difficulties such as dyslexia, due to them being picked-up by text-to-speech software. To ensure inclusivity in the management diversity questions, Swansea University’s Human Resources Equality Advisor recommended the sensitive wording to best capture the data, in line with the Strategic Equality Plan (Swansea University, 2020).

A pilot survey was launched to collect usability feedback. Such preparatory tests “inform key concerns including intervention delivery, contextual factors, and implementation” (Donald, 2018, p. 65). The pilot sample frame of 77 enterprises is as follows in Table 7:

Table 7: Pilot Survey Sample

Sampling Method	Network	Justification	Sample Size
Purposive	BUCANIER	Although now closed, this project was a "cross-border innovation ecosystem" (Davies et al., 2020), spanning Wales (UK) and Republic of Ireland (EU), with 72% of their partner enterprises having repeated collaboration and strong ties. Also sampled by Howson et al. (2019).	6
Stratified, non-probability	Invest Northern Ireland	Northern Irish regional development agency's company database of life and health sciences. This directory was used to provide objectivity to the pilot results. Free from any bias that the other pilot sample may have had, due to their pre-established links with the university.	71

An expert academic determined 10 pilot participants would provide sufficient feedback. Surpassing the target, 11 responses (three from BUCANIER, eight from Invest Northern Ireland) provided a 14% response rate, with enough feedback to improve the usability of the survey. Their responses emphasise that the design was commonly described as straightforward, easy, and simple. The online survey format of Qualtrics facilitates iterative design developments, based on the feedback received from the pilot participants, academics, faculty peers, and other stakeholders. The version history is audited in Appendix D: Design Audits. After eight refinements, the survey was ready for launch. See the final survey design in Appendix E: Qualtrics Survey Screenshots.

Research incentives are only discussed by Restuccia et al. (2016), who motivated participation by promising anonymity and an executive report of the results, but no financial reward. Due to the multi-method sampling applied, the sample frame was rather large, and so it was not expected that a financial incentive was needed to meet the sample survey targets (as calculated by a power analysis, discussed later in Target Respondents). Acknowledging the often-limited capacity of SME owner-managers, their participation is voluntary. This comes with the incentive of having access to the resultant new knowledge, of which they can both influence and benefit from the published results.

3.4.2. Interviews

Interviews are well cited, considered, and utilised strategies within business management research (Conz et al., 2017; Davies et al., 2020; Hausman, 2005; Iborra et al., 2020; Jones et al., 2014; van de Vrande et al., 2009). Interviews are, therefore, chosen as a second phase of research, to capture the UK life science SME's point of view upon the empirical data that came from the surveys. For the researcher to gain a genuine understanding of their reality. A semi-structured approach is considered by Collis and Hussey (2021) and Saunders et al. (2023), as useful to flexibly understand any rich or complex relationships between variables. As well as 'probe' their behaviours, attitudes, and opinions surrounding the concepts. The semi-structured design is applied in other SME open innovation research, such as Alberto et al. (2022), which validates this choice.

According to both Roberts et al. (2021) and Sy et al. (2020), synchronous interviews are deemed the gold standard in virtual (online) qualitative research. Particularly with the advancements of videoconferencing software, to not only to host the interview live, but also to schedule, record, and auto-transcribe them too. Online interviewing is also useful due to the social distance restrictions for COVID, in place at the time of writing and designing these research strategies. Furthermore, face-to-face interaction (albeit through a device screen) is useful for building rapport and trust with the respondent to garner honest, rich answers, without sacrificing methodological rigour. Much like the discussion for the accessibility of the online survey (above), Saunders et al. (2023) also suggests that online interviews are also advantageous to alleviate issues of access to participants. Notably the case when there is a disability or a substantial geographic distance between the interviewer and interviewee, which is relevant for the UK-wide sample of this research. Yet, there is a scant body of literature upon the design of such web-based interviews (Roberts et al., 2021).

An audit of the evolution of the interview design is logged in Appendix D: Design Audits. This includes the pilot interview, conducted with a business management academic, who has previous industry experience of working at a UK life science SME. There were five iterations of the interview design before launch. The participating enterprises were made aware from the emailed invitation what the research concepts are, but not made aware of the specific questions asked. It is, therefore, a synchronous approach of live questioning, to garner their real-time, unplanned responses. Unlike the structured nature of the survey to collect a breadth of

quantitative data, the interview uses a semi-structured approach (Chesbrough, 2003; Marangos & Warren, 2017) to collect a depth and richness of qualitative data. The final interview guide (Table 8) provides a structure for the researcher to consistently ask questions across the sample of UK life science enterprises, whilst unstructured prompts are applied to encourage conversation by the respondent.

Table 8: Interview Guide

	Interview Questions	Prompts
1	Introduce your enterprise.	Job role
2	Explain if and how your enterprise practices organisational resilience.	Definitions and strategies
3	Explain if and how your enterprise practices innovation, specifically regarding how closed or open your approach is.	
4	Explain if and how the concepts of organisational resilience and open innovation are related.	-

This interview guide was not a script, but simply a reference guide to ensure all points are covered and rich responses are provided. The researcher can be flexible and "depart significantly from any … guide that is being used. They can ask new questions that follow-up interviewees' replies and can vary … the wording of questions" (Bell et al. 2022, p. 427). This adaptability helps tailor the interview to the participant, making it more engaging for them. As seen below, the questions are purposefully designed as open (Garengo & Bernardi, 2007) to garner a richness, without leading the responses in any way. Testing the online interview instruments of Microsoft Teams and Zoom with business management academics was built into the evolution of the interview design development. Although both instruments offer similar features, Microsoft Teams was chosen as it (a) has superior auto-transcription which notes who was saying what and when, and (b) is fully integrated with other Microsoft applications used for the purposes of this research.

Due to the deficit of the survey response rate, the researcher to introduced an incentive for the second phase of research: the interviews. However, to mitigate any incentive bias, a randomly selected participant would win an Amazon gift card, rather than offer a payment per participant. Also, the gift card amount was set at £50, as it was big enough to incentive participation, but not enough to sway the results.

3.4.3. Mixed Method Sampling

The Sample Frame

In related research regarding SME open innovation, Brunswicker and Vanhaverbeke (2015) utilises a mixed method sampling to capture data upon a large sample of 30,000 enterprises. At the time of writing of this research, 82% of the 6300 UK life science enterprises are small and medium-sized (Office for Life Sciences, 2020), which calculates as a population estimate of 5166 for this research. Yet, it is unfeasible to survey the whole population of UK life science SMEs, so like Brunswicker and Vanhaverbeke's research (above), mixed method sampling has been applied. Including purposive, random cluster, and stratified non-probability. Appendix F: Sampling displays and discusses each sample method, source, and frame.

Reduction of Sample Biases

Raymond and St-Pierre (2010) expressed concern that their own sampling biases may cause their collected data to be different than the general population. To identify and mitigate such biases in this research, a multi-method sampling technique has been applied. The purposive sample from pre-established partnerships with the host university may be at risk of sampling bias due to responses being provided with the perception of maintaining a good working relationship with the institution. To counter this, the stratified sample is taken from Companies House, which will provide a truly diverse sample frame, free from any association with the university, and with a geographical range across the UK. Also, although the survey invite will be shared from the researcher's Swansea University email address, it is self-administered, and so it will be free from any researcher influence.

Attempts have been made to access failed ventures, with Fortuin and Omta (2008) sampling the hard-to-reach subsection of failed inter-company (open) collaborations. However, organisations that have experienced failure will be near impossible to sample. Therefore, all enterprises invited to participate in the research will be active. Arguably due to the greater accessibility of sampling live enterprises, Nikolić et al. (2019) proposed that "there is a greater body of research focused on successful SMEs than on the failed ones" (p. 15). However, it is important to acknowledge that the sample will have a survivor bias (Green et al., 2021), and makes entrepreneurial failure difficult to research (Shore et al., 2023). To mitigate this bias for

this research, the data will capture some insights into enterprises that are not organisationally resilient, by asking respondents about any previously failed ventures they may have had.

Target Respondents

According to Varis and Littunen (2010), collecting enterprise data is "highly dependent upon who the respondent is, and what function he or she performs in the organization" (p. 148). The operational significance of the role of owner-manager, at the top of any enterprise hierarchy, means that they are the most appropriate single informant to provide insight into their enterprises for this research:

> *"A significant role in making all the necessary investment and operating decisions; as the managerial competence of the owner manager or the entrepreneur is a crucial factor in the long-term survival and success possibilities of SMEs ... they are best to inform us as to what strategic choices are made." (Marangos & Warren, 2017, pp. 213-214)*

Owner-managers (and sometime the entrepreneurs) are often cited as the key informants of other related business management research (Beynon et al., 2020a; Brunswicker & Vanhaverbeke, 2015; Chesbrough, 2003; Santoro et al., 2020). A useful distinction in terminology and ontology for this research is that the UK life science SME is the participant (subject), whereas the owner-manager is the respondent. Herbane (2020) recommend owner-manager respondents as being the most insightful option, as their seniority are the system designers. They can allow for an all-encompassing understanding and interpretation of the concepts, at enterprise-level of the UK SME. Likewise, in the similar research of Mirghaderi et al. (2023), respondents were targeted who has relevant (a) work experience, (b) organisational position, and (c) fields of study. Therefore, it is relevant for this research to also sample the UK life science SME owner-managers, for their awareness of the organisation.

A power analysis is calculated to find a representative survey sample size to ensure the dataset is powerful enough to find statistically significant relationships in the population. The statistical method of power analysis is calculated using the correlation of the expected strength of relationships and the level of confidence we desire in the results (de Vaus, 2014). The expected strengths are sourced from the current literature. The 'a priori' statistical analysis (prior to the research) is recommended to determine the sample size needed to achieve the target level of statistical power, which will consequently lead to the rejection of the null hypothesis (Robson & McCartan, 2016). The power analysis was calculated using pre-established formulae (Hulley

et al., 2013). The better the estimates, the better the power, and so pre-established data is extracted from similar research found within the literature review (Iborra et al., 2020; Marangos & Warren, 2017; Santoro et al., 2016; ten Ham et al., 2018). Acknowledging that it is a subjective amount, 0.2 was decided by an expert academic for this circumstance, as the lowest correlation that exceeds 'no correlation'. It was then calculated that a sample size of 194 UK life science SMEs needs to participate to accept or reject the null hypotheses.

Considering the scope of variables, and to ensure a representative sample, Bell et al. (2022) argue that a sample size must be appropriate to "support convincing conclusions" (p. 397). Referring to the time boundaries of this research in the introduction chapter, the interview sample size is also restricted by time to schedule, conduct, and analyse them. Therefore, an expert academic proposed an achievable target of 15 to 20 participatory enterprises, which is suggested to be enough to ensure that their responses are generalisable to the wider population. A similar sample size to the research of Alberto et al. (2022), who has garnered 14 interview responses from SMEs regarding their open innovation.

3.4.4. Variables and Hypotheses

Hypotheses are defined as propositions or statements, which are developed from theory, that can be tested for association or causality between variables, against empirical evidence, based on observation or experience (Collis & Hussey, 2021). Both the null and alternative hypotheses must be possible, and so they are tested against the primary research, to indicate if there is a statistically significant association between the variables, to reject the null hypothesis (H_0). Likening it to a court case, hypotheses should be assumed false (or 'null') until proven beyond a reasonable doubt through statistical analysis (Kraemer & Blasey, 2016). The variables are defined as a characteristic of the population (Albright & Winston, 2020), and are set out in relation to this research.

For RQ1, the concepts were assigned to replicate the similar research of Mirghaderi et al. (2023), with organisational resilience as the dependent variable, and open innovation as the independent variable. In terms of the hypotheses of this question, the null (H_0) posits that the concepts are independent of each other, whilst the alternative (H_1) proposes a dependent relationship between them. As displayed in Table 9:

Table 9: RQ1 Variables and Hypotheses

Variables		Hypotheses	
Dependent	**Independent**	**Null (H_0)**	**Alternative (H_1)**
Organisational resilience (C1)	Open innovation (C2)	Variables are independent	Variables are dependent

If a relationship is identified between the two concepts, RQ2 will uniquely combine them into an interaction to become the dependent variable. Then each of the influences will be measured against them as independent variables to determine which are significantly contingent upon the combined concepts. Like the above, this question assumes that the influences are not significantly impactful of the concepts (null hypothesis, H_0). Whereas the alternative hypothesis (H_1) estimates an interplay between them. As displayed in Table 10:

Table 10: RQ2 Variables and Hypotheses

Variables		Hypotheses	
Dependent	**Independent**	**Null (H_0)**	**Alternative (H_1)**
Interaction of concepts (C1*C2)	Influences (F1-3)	Variables are independent	Variables are dependent

Following the discussion of these strategies, the element of time in the research design is probed next.

3.5. Time Horizon

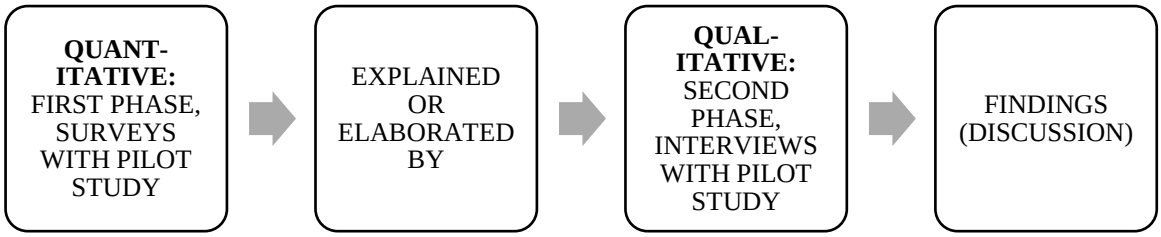
3.5.1. Cross-Sectional

An attempt was made to invite and sample as much of the UK life science enterprise population, as possible. To gain the widest insight into their perceptions. However, it is acknowledged that it is simply not possible to capture them all, due to sheer number and blurred sector boundaries. A cross-sectional approach to the data collection is used to gain a snapshot of a UK life science SME sample in 2022-2023, especially within the context of a post-BREXIT, post-COVID economy. Scott and Davis (2007) suggest that organisations vary over time, so it is important to capture this period of transition and uncertainty, and Porter (1998) also disregarded a longitudinal approach due to time restrictions. Cross-sectional data is also collected within the cited literature (Dahlander & Piezunka, 2014; Pickernell et al., 2019; Raymond & St-Pierre, 2010; Shore et al., 2023; Varis & Littunen, 2010).

3.5.2. Sequential

This research also applies a sequential, multi-phased model of data collection, which Saunders et al. (2023) promote as being more dynamic than single-phase models, as they allow for both interaction and iteration. Taking inspiration from the research design flowchart models (Bell et al., 2022; Bowen, 2017), the following figure demonstrates the proposed sequential process for phase one and two of this research. It is intentionally designed sequentially, for the explanatory results of the first phase (the quantitative survey) to influence the design of the second phase (the qualitative interviews), as displayed in Figure 16. Sequential mixed methods are also applied within the literature (Gray & Jones, 2016; Lettieri et al., 2013; Sullivan-Taylor & Branicki, 2011).

Figure 16: Explanatory Sequential Model (Bell et al., 2022, p. 571)



With timings in mind, the online survey could be completed at any time. At the convenience of the busy schedules of UK life science SME owner-managers. Through the pilot study of the survey, Qualtrics collects the duration and so a mean average time was calculated of nine minutes to complete. Following feedback, some final adjustments to the survey which streamlined it, and so it was promoted as taking an efficient five to 10 minutes to complete; intentionally not a major time investment for busy owner-managers. Likewise, the pilot study of the interview lasted 37 minutes, which meant they could be advertised as taking 30 to 45 minutes to participate. Conciseness and flexibility were also offered by the researcher in the registration form, by arranging timeslots in daytime, evenings, and weekends (Appendix G: Interview Scheduling). Also, a complete schedule of the research from 2020 to 2024 can be found in Appendix H: Gantt Chart. The following section considers the techniques and procedures applied, specifically regarding the data analyses and ethics of the research.

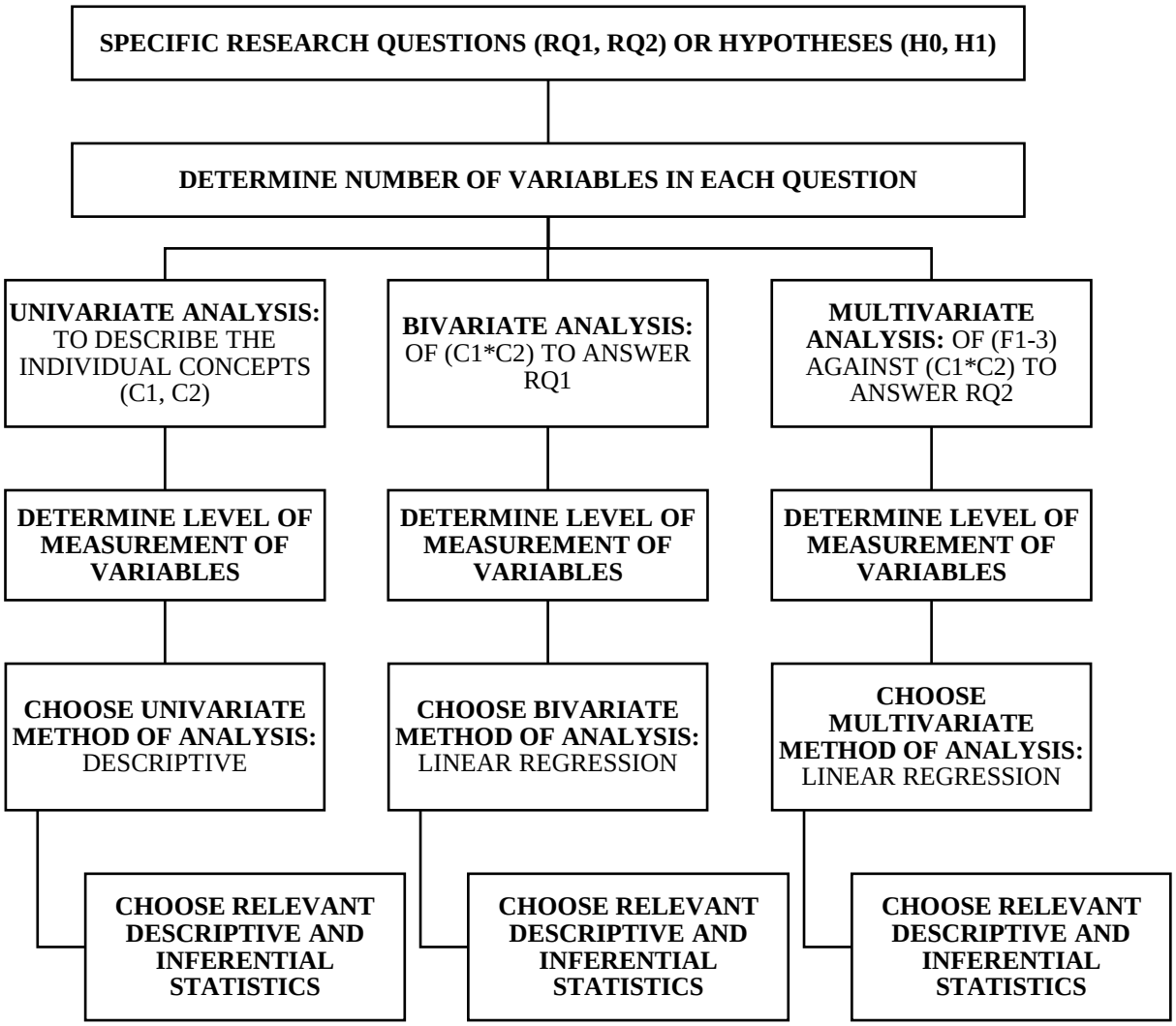
3.6. Technique and Procedures

3.6.1. Data Analysis

Quantitative

The statistical analysis of the collected data is calculated through a combination of the following instruments: IBM SPSS (International Business Machines' Statistical Package for the Social Sciences) and Microsoft Excel. As stated by de Vaus (2014), the methods of quantitative data analyses depend on the complexity of the research aims, and so they are selected as follows, and visualised in Figure 17: (a) describing the individual concepts (C1, C2) requires a univariate analysis, (b) testing the relationship of the concepts (RQ1) requires a bivariate analysis, and (c) testing the influences of the concepts (RQ2) requires a multivariate analysis.

Figure 17: Methods of Statistical Analysis (Adapted from De Vaus, 2014, p. 206)



Univariate Analyses

As seen in other theses (Bagheri, 2021; Bowen, 2017; Hayman, 2021), univariate analyses will be conducted for each concept (C1, C2) to garner their individual frequencies and distributions (Bell et al., 2022). According to Evans (2016), this is to (a) categorise, (b) characterise, (c) consolidate, and (d) classify them into a useful package of information.

Bivariate Analyses

A bivariate crosstabulation and simple regression is applied for research question one (RQ1) to determine if and how the concepts are related. Depending on if there is a bivariate relationship between the concepts, this research will uniquely combine the concepts into an

interaction variable (C1*C2). Due to the utility of regressions, Albright and Winston (2020) propose that they are very popular calculations within business management research, as very-well evidenced in over 30 of the cited literatures (See for example: Herbane, 2020; Marangos & Warren, 2017; Rothaermel & Deeds, 2006; Santoro et al., 2020).

Multivariate Analyses

The multi-factor framework (F1-3), used to structure the literature review, is not considered within the quantitative analysis. Instead, each of their influences and indicators are added as independent variables into the multiple regression equations, to answer research question two (RQ2). Determining what influences the combined concepts. The statisticians, Gray and Kinnear (2017), promote regressions as they predict relationships by utilising the association between variables, which can be applied to answer both research questions.

Relative to this research, a multiple linear regression can "help to resolve complex issues of causation" (Gray & Kinnear, 2017, p. 471) or 'influence', and allows for an "exploration of the interrelationship within a set of variables." (Pallant, 2020, p. 153). Paraphrasing Albright and Winston (2020), multiple regressions are advantageous over simple regressions, as any number of explanatory variables can be entered into the equation. However, such a large number of such potential influences can make it difficult to know what to include. Consequently, IBM SPSS offers a series of automated options of variable selection (enter, stepwise, remove, backward, and forward). Each method will systematically recalculate and reconsider each remaining option to determine the most accurate, until only a set of variables remain which all have a P-value under the default threshold of 0.1 (IBM, 2022) – providing a list of significantly influential variables.

The outputs of the regression identifies the most significant influences. Suggested by de Vaus (2014), such analyses must "eliminate as many alternative explanations of the pattern as possible" (p. 29) to increase the validity of the regression coefficients. With so many possible influences being tested, there is also a risk of multicollinearity, which will also be tested for rigour. It is therefore important that the variables can be examined in isolation, to evaluate their influence upon the concepts (Stokes, 2011).

Qualitative

Only a simple download of the interview auto-transcription is required to export the qualitative data from Microsoft Teams, into the analysis instrument of Microsoft Word, all within the same suite of apps. Once there, a thematic analysis is conducted. As leading academics upon this type of qualitative analysis, Braun and Clarke (2022) define thematic analysis as a method of "exploring, interpreting, and reporting relevant patterns of meaning across a dataset" (p. 224), whilst also systematically using codes to create a priori and emergent themes within the data. By using both types of coding, this research is comprehensive, as "themes sit somewhere on a spectrum from analytic inputs [a priori] to analytic outputs [emergent]" (Braun and Clarke (2022, p. 243). Using the previously-cited interview guide (Table 8), a priori codes will be taken from the interview questions asked, but their responses will also be coded with emerging themes to count (as per the positivist philosophy) and interpret (as per the interpretivist philosophy) common definitions and strategies by the UK life science SMEs for each question (RQ1, RQ2).

A Priori Coding

According to Braun and Clarke (2022), and Jackson and Bazeley (2019), a priori codes are theoretically derived from earlier reading and understanding of the literature. Therefore, they form anticipated themes, as cited in the literature (Acquaah et al., 2011; Adams et al., 2006; Green et al., 2021; Malerba & Orsenigo, 2015; West et al., 2014). It is warned that reliance on a priori codes alone can confine thinking, by reducing open and organic interpretations of the qualitative data, resulting in foreclosure.

Emergent Coding

The inclusion of emergent codes offers a supplementary method. Through actively identifying data-derived themes, indigenous to the transcripts; as considered or applied in the literature (Blair et al., 2007; Branicki et al., 2018; Marangos & Warren, 2017; Verreynne et al., 2018; Xing et al., 2020).

Semantic Coding

Referring back to realism, Crossley (2002, as cited in Burr, 2015) asserted that the narratives of respondents are explicitly expressed in language, at face-value. Therefore, this research

adopts this semantic focus of meaning, by looking explicitly at what is being said. Rather than look for any *latent*, hidden meanings through the respondents' vocal intonation, speaking pace, or body language, for example. Also integrating positivism, Scruton (2012) explained this as "laying bare the logical relations between our sentences" (ch. 3.2.), with empiricists relating spoken words to ideas (or, the aforementioned codes). Braun and Clarke (2022) find that such semantic coding is participant driven, and descriptive at a surface-level, allowing the researcher to interrogate the dataset and make meaning from the qualitative data.

3.6.2. Ethics

For rigour, ethical approval has been sought and approved twice from the host university committees at the Medical School and the School of Management (evidenced in Appendix I: Ethical Approvals).

On account of the cross-disciplinary nature of this academic research. This research abides by the following four ethical principles for online business research, as proposed by Bell et al (2022):

1. **Avoidance of Harm:** A risk assessment, following Swansea University's (2023; Appendix J: Risk Assessment) template, identifies and minimises potential hazards for participants and researchers. Ensuring compliance with health and safety policies. While the research itself doesn't mention risk assessments, theorists have highlighted the importance of them for organisational resilience (Annarelli & Nonino, 2016; Bak et al., 2020; Green et al., 2021; Lengnick-Hall et al., 2011; Pescaroli et al., 2020).
2. **Obtaining Informed Consent:** Like Treanor et al.'s (2021) research, detailed briefings ensure that informed consent is provided. Active questioning will confirm willingness before each data collection method. Participants retain the right to withdraw anytime (Davies, 2018; Minari et al., 2020). Surveys use logic to automatically exit non-consenting participants, while interviews allow withdrawal upon request (Appendix K: Briefings and Informed Consent).
3. **Preventing Deception:** Respondent and participant deception is mitigated through anonymity (Bell et al., 2022), and so this is implemented in the research to encourage a higher participation rate and honesty in their answers. This results in higher research validity, as their personal dignity and enterprise integrity will be protected (Marangos & Warren, 2017). Furthermore, the researcher has no reason to deceive the respondents,

and is fully open in the research descriptions within the briefings. Respondents are made aware that they have the right to withdraw without judgement, should they ever feel deceived.

4. **Protection of Privacy through Confidentiality:** Schabacker et al. (2019) highlight the importance of data confidentiality, integrity, and availability in the digital age. To ensure participant anonymity and honest responses, this research will anonymise all respondent data. Anonymity protects participants from potential risks to personal, professional, and organisational integrity; common concerns in business management research (Forés & Camisón, 2016; Herbane, 2020; Lettieri et al., 2013; Restuccia et al., 2016; Santoro et al., 2016). In contrast, Minari et al. (2020) warns that complete anonymity in life science research can raise doubts about data quality and informed consent.

Furthermore, the instruments chosen for data collection (Microsoft, 2023; Qualtrics, 2023a) both explicitly comply to the UK industry policy and legislation of General Data Protection Regulation (GDPR) and International Standardization for Organization (ISO:27001) for information security management. The importance of which is highlighted in the literature (Asthana et al., 2019; Minari et al., 2020). Localised to the host university, this research also complies with their data protection policy (Buckley, 2022) and research privacy notice (Swansea University, 2022).

3.7. Dissemination of Research Outputs

It is also important to consider how the research results will be disseminated to peers in academia, practitioners in industry, and policy-makers in government. This will be achieved through journal publications, conferences, non-traditional research outputs, and presentations. Evidence of each are listed in Appendix L: Research Outputs.

3.8. Concluding the Defence of Method

The objective of this chapter is to defend the method of primary research used to answer the two research questions most effectively. Achieved by discussing and justifying the choices, strategies, and methods selected at every layer of the research onion (Table 11). Also, it indicates the validity of the investigation to provide a significant and original contribution to knowledge. There is confidence in the appropriateness of the mixed method approach chosen,

as it provides a truly comprehensive contribution to knowledge. There is significance in the size and representativeness of the sample frame, and there is originality too. It is reported that there is a dearth of quantitative research upon the concepts, and so this research contributes to fill that deficit. Furthermore, it is novel to conduct *online* interviews, spurred on by COVID's social distancing and advances in videoconferencing software. The next chapter explores the results from the above-defended methods, presented sequentially: quantitatively then qualitatively.

Table 11: Methodological Choices as per Research Onion (Saunders et al., 2023, p. 131)

Onion Layer	Choices
Philosophy	• Ontology (Objectivism and Realism) • Epistemology (Positivism and Interpretivism) • Axiology (Phronesis)
Approach to Theory Development	• Deductive
Methodological Choice	• Mixed Method • Explanatory
Strategies	• Survey then Interview • Mixed Sampling (Purposive, Random Cluster, Stratified Non-Probability)
Time Horizon	• Cross-Sectional • Sequential
Procedures and Techniques	• Analysis (Regression and Thematic) • Ethics (Avoidance of Harm, Obtaining Informed Consent, Preventing Deception, Protection of Privacy through Confidentiality)

Chapter 4: Analysis of Findings

The objective of this chapter is to present and interpret the analysis of the data collected via the two-phase sequential process of mixed methods. Reflected in the structure of this chapter, by first analysing the quantitative data from the surveys, then qualitative data from the interviews, to answer both research questions:

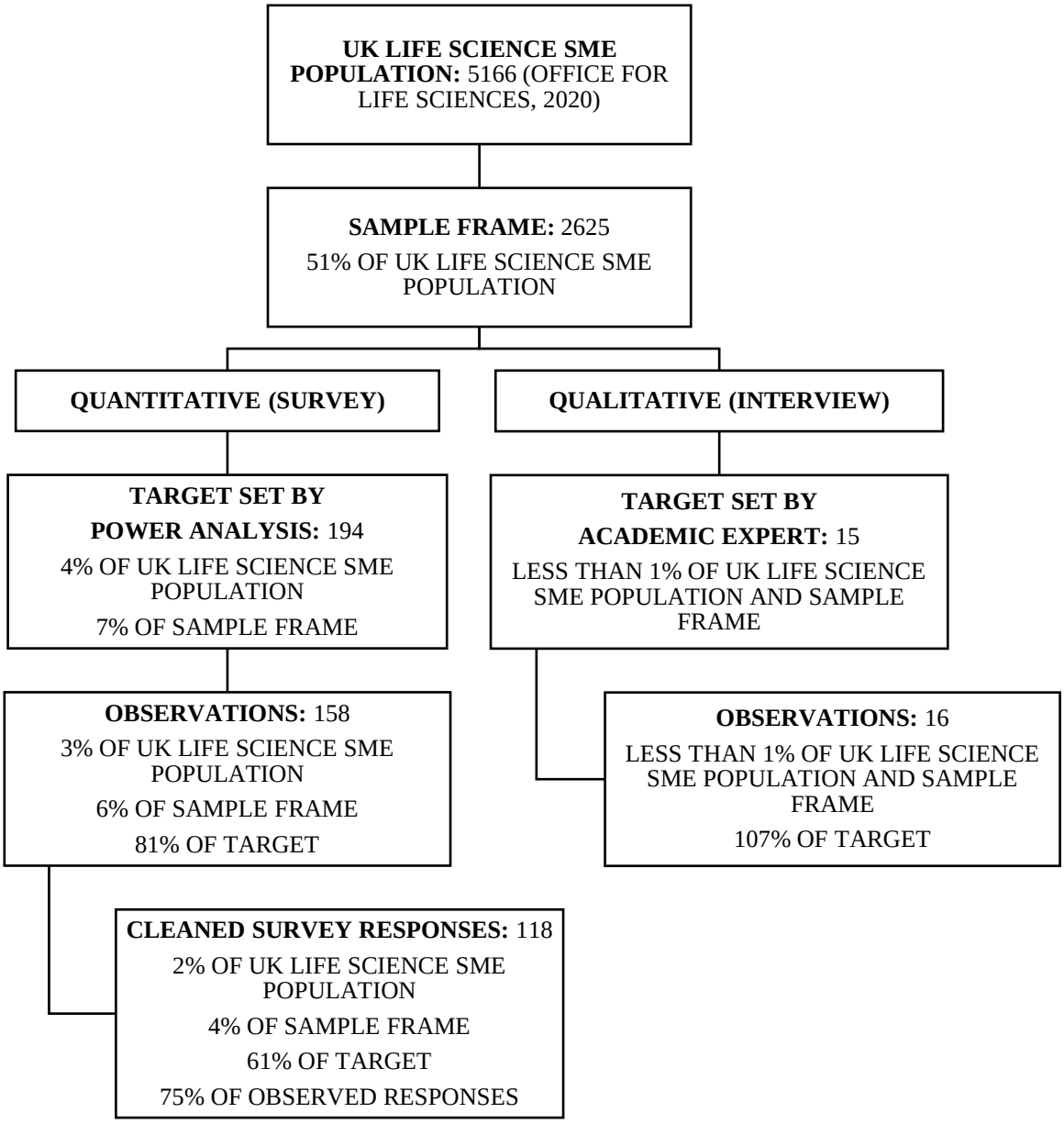
- **Research Question One (RQ1):** How are the concepts of organisational resilience (C1) and open innovation (C2) related for United Kingdom (UK) life science small and medium-sized enterprises (SMEs)?
- **Research Question Two (RQ2):** How are the concepts of organisational resilience (C1) and open innovation (C2) influenced for UK life science SMEs?

Then the findings of the two datasets are integrated to provide comprehensive answers to both of the above questions, to offer a thorough understanding of the concepts, as a contribution to knowledge. Having received 158 survey responses, this chapter begins with the iterative process of cleaning the quantitative data, ready for statistical analysis. As a reminder, survey respondents are cited as ‘e1s’, for example, whereas later, interview respondents are cited as ‘e1i’. Before analysis could begin, the quantitative data had to be cleaned to ensure validity of responses. The audit of this process can be seen in Appendix M: Quantitative Data Cleaning and Substitution Audit.

4.1. Sample Representativeness

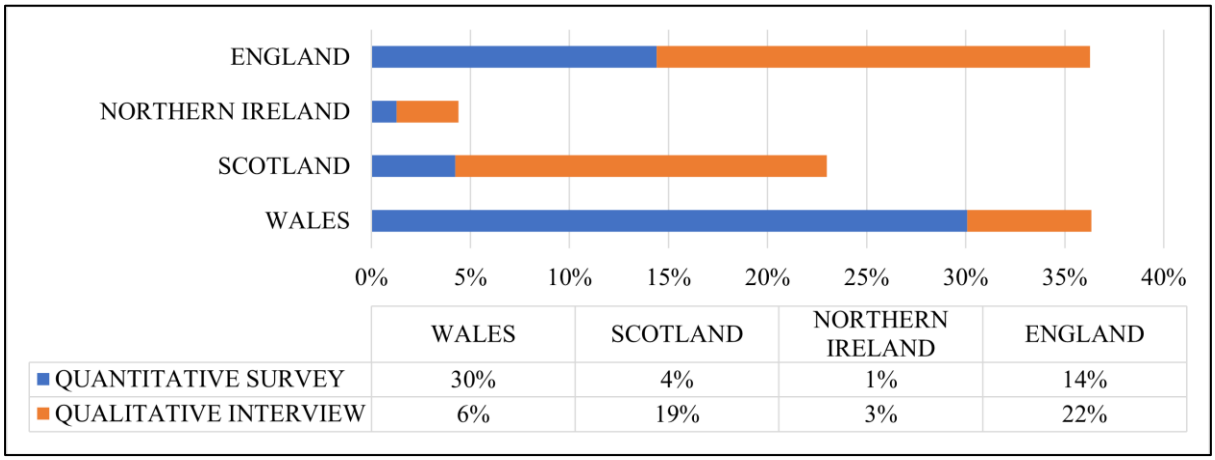
Following the cleaning of the 158 quantitative survey responses, 118 were deemed appropriate for statistical analysis. The strong efforts made to create a large sample frame of 2625 UK life science SMEs, and repeated invitations to participate in the quantitative survey, achieved 60% of the power analysis target. This was to ensure that the quantitative dataset has enough ability to precisely predict the outcome for the wider population. Due to the research boundaries of time and budget, no further survey promotion could take place, and so the subsequent qualitative data collection is therefore justified to contribute to the deficit and provide accurate findings. The qualitative interviews received 16 responses, surpassing the target minimum of 15, for a representative dataset. This flow of responses is visualised in Figure 18, next.

Figure 18: Response Rates per Method



The following stacked bar charts visualise the cumulative percentages of sample representativeness, across both methods and different characteristics. Due to the different ways this baseline sample data was collected, percentages are used to capture their covariance, rather than their actual frequencies. To start, there is a healthy sample representation from England, Wales, and even Scotland in Figure 19, but Northern Ireland had a very low (4%) representation across both methods.

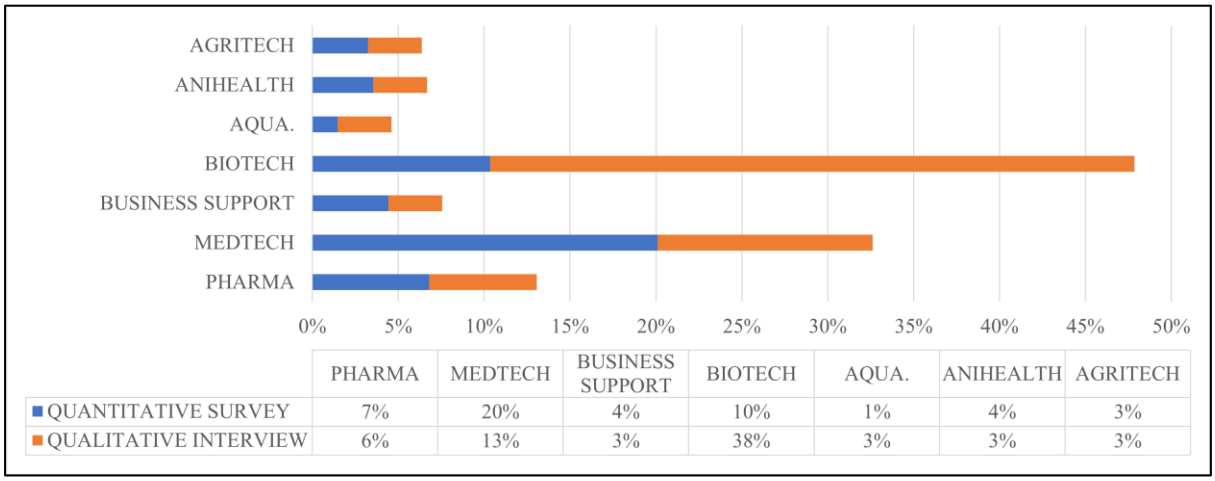
Figure 19: Representativeness of UK Countries of Operation within the Samples



	WALES	SCOTLAND	NORTHERN IRELAND	ENGLAND
QUANTITATIVE SURVEY	30%	4%	1%	14%
QUALITATIVE INTERVIEW	6%	19%	3%	22%

In Figure 20, the subsectors of display biological and medical technology leading the representation within the overall sample, which coincides with the contextual sector definition of the "application of biology and technology to health improvement" (Bell, cited in Office for Life Sciences, 2017). There is fairly equal representation from all other subsectors.

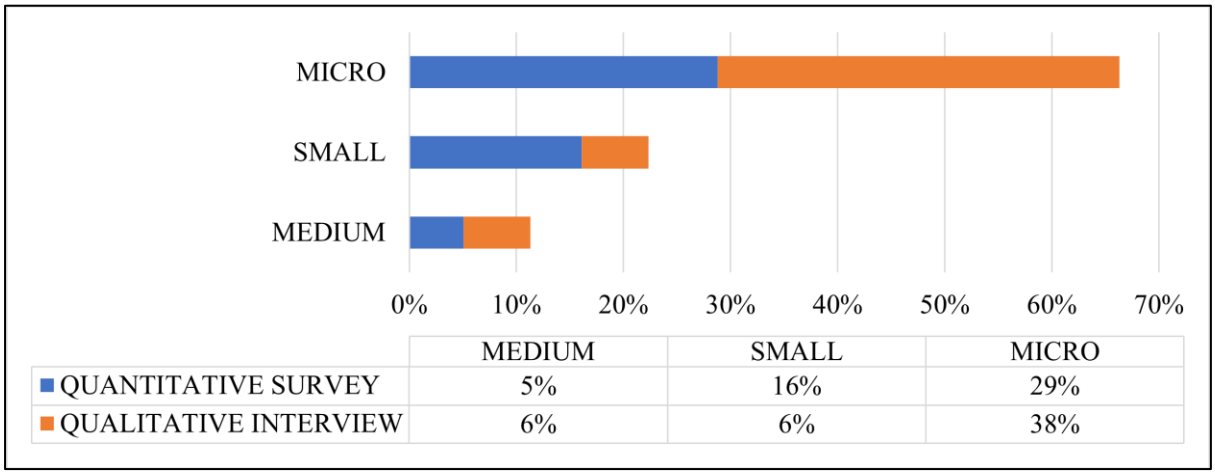
Figure 20: Representativeness of Life Science Subsectors within the Samples



	PHARMA	MEDTECH	BUSINESS SUPPORT	BIOTECH	AQUA.	ANIHEALTH	AGRITECH
QUANTITATIVE SURVEY	7%	20%	4%	10%	1%	4%	3%
QUALITATIVE INTERVIEW	6%	13%	3%	38%	3%	3%	3%

Two-thirds (67%) of the sample is represented by micro-sized enterprises, and so Figure 21 shows that representativeness decreases with as the size of enterprise increases.

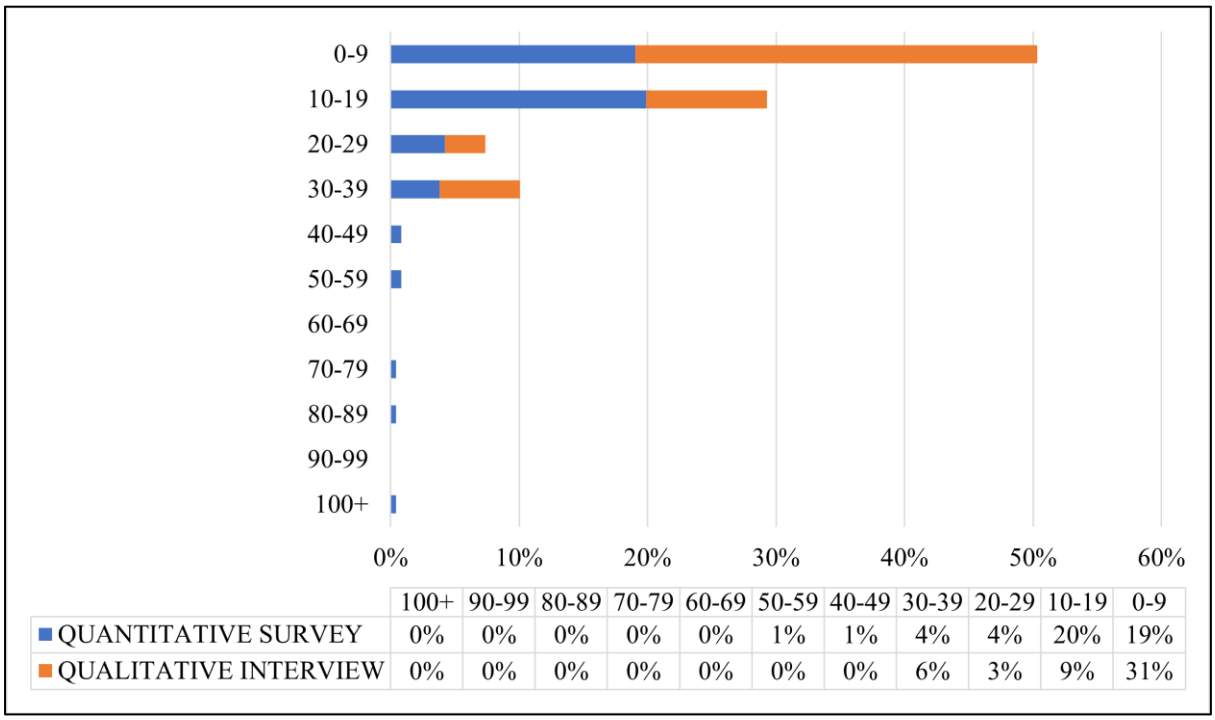
Figure 21: Representativeness of Enterprise Sizes within the Samples



	MEDIUM	SMALL	MICRO
QUANTITATIVE SURVEY	5%	16%	29%
QUALITATIVE INTERVIEW	6%	6%	38%

Those enterprises aged under 10 years old, make up 50% of the sample, which Figure 22 exhibits. The younger the enterprise, the more sample representation it has, which makes sense, due to enterprises being early-stage businesses (Márquez & Ortiz, 2020). However, this raises questions as to why the much older businesses, still consider themselves as enterprises.

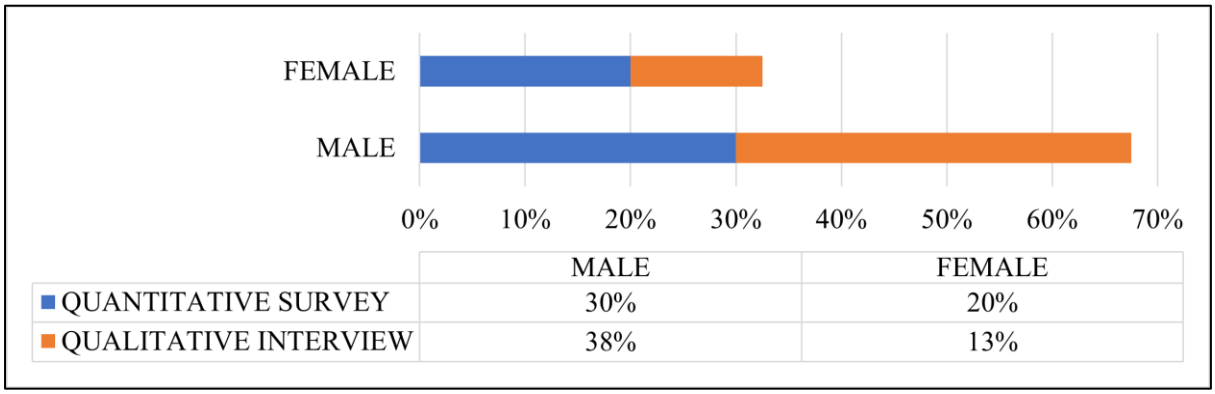
Figure 22: Representativeness of Enterprise Ages within the Samples



	100+	90-99	80-89	70-79	60-69	50-59	40-49	30-39	20-29	10-19	0-9
QUANTITATIVE SURVEY	0%	0%	0%	0%	0%	1%	1%	4%	4%	20%	19%
QUALITATIVE INTERVIEW	0%	0%	0%	0%	0%	0%	0%	6%	3%	9%	31%

A little over two-thirds (68%) of the sample were male-led enterprises, which is shown in Figure 23.

Figure 23: Representativeness of Enterprise Respondents within the Samples



	MALE	FEMALE
QUANTITATIVE SURVEY	30%	20%
QUALITATIVE INTERVIEW	38%	13%

Using the sequential methods, the analyses of the findings are presented in the quantitative then qualitative analysis. The participating enterprises are cited as e1s, e2s, e3s, etc. for the survey responses, and e1i, e2i, e3i, etc. for the interview responses.

4.2. Quantitative Findings

The raw quantitative data can be found in Appendix N: Raw Quantitative Data.

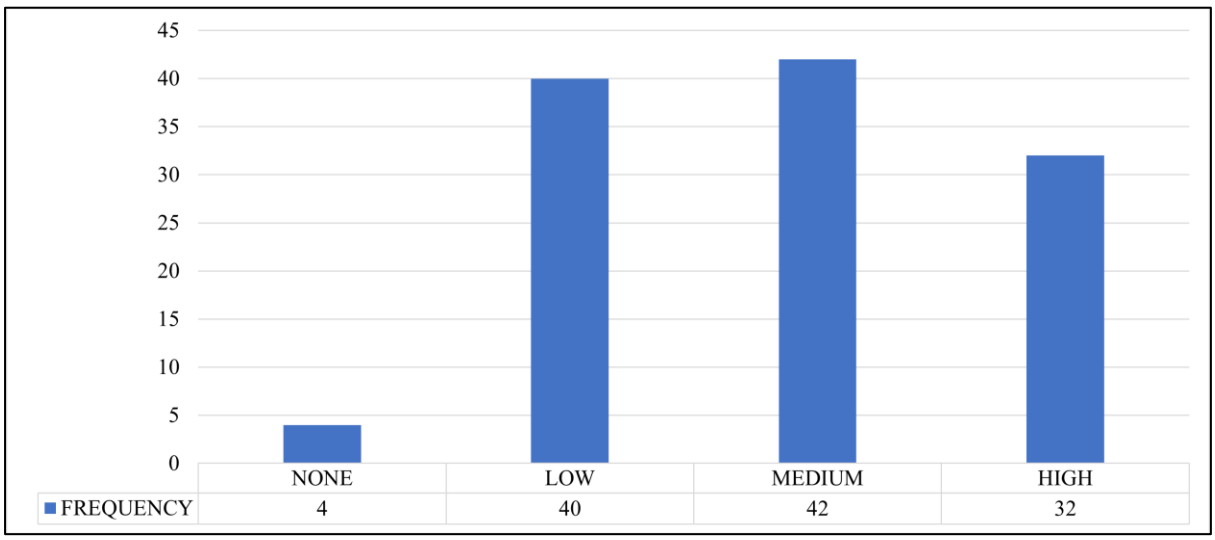
4.2.1. How are the Concepts Related? (RQ1)

Firstly, each concept will be individually examined through univariate analysis, to understand how the enterprises practice organisational resilience, and then open innovation, separately. Then, taking the same dataset, a bivariate analysis is applied to answer this research question by understanding their relationship.

Organisational Resilience (C1)

To begin, the quantitative univariate descriptive analysis of the first concept of organisational resilience is displayed below (Figure 24). Respondents cited their organisations as having medium levels of organisational resilience, and that the fewest enterprises consider themselves as having no resilience.

Figure 24: C1 Quantitative Frequencies

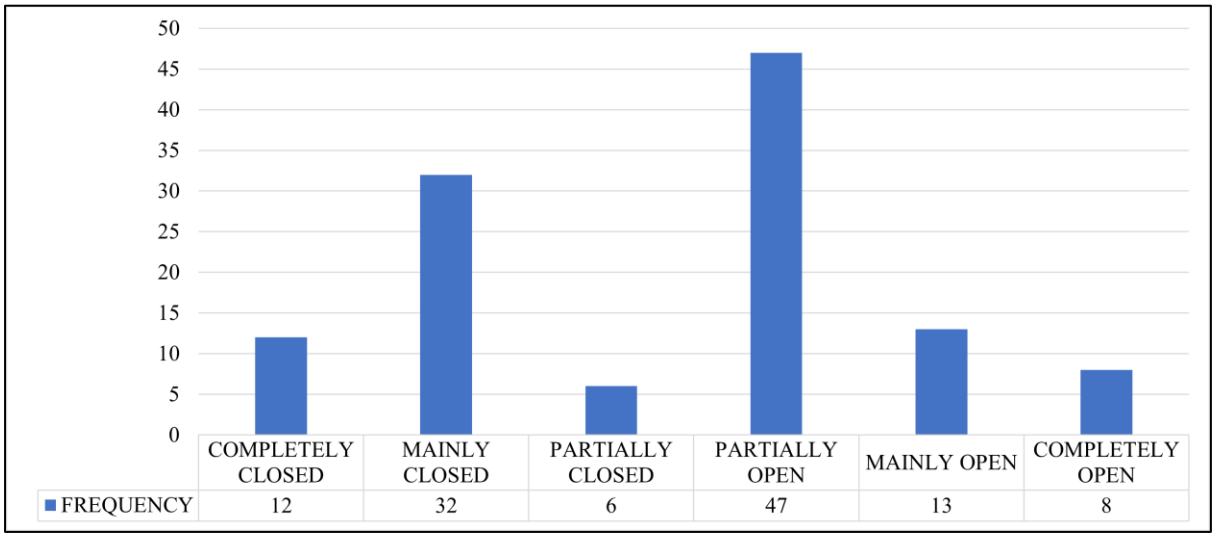


Encouragingly, most (42, 35.6%) of the sample of 118 UK life science enterprises have a medium level of organisational resilience. Using the dichotomous approach of either vulnerable or resilient, it is an encouraging that a vast majority (114, 96.6%) have at least *some* organisational resilience. Compared to four participating enterprises (3.4%) declaring no organisational resilience at all. Due to it only quantitatively capturing a snapshot of their current rating of organisational resilience, it is unknown if those four enterprises were either start-ups (yet to become resilient), or sadly, due to fail and become a 'business death' statistic.

Open Innovation (C2)

The quantitative univariate descriptive analysis of the second concept of open innovation (Figure 25) demonstrates that most enterprises consider themselves to practice partially open models of innovation; with the fewest enterprises practicing partially closed models.

Figure 25: C2 Quantitative Frequencies



The quantitative analysis of survey responses from 118 UK life science enterprises, resulted in 47 (40%) of them considering themselves as practicing 'partially open' models of innovation, which was the most frequently rated level. The least frequently rated was 'partially closed' with six of them (5%) practising such a model of innovation. In an only six-tier framework, it is notably odd that there would be such a stark contrast between the most and least popular ratings, which are situated together in the middle of the range. If a dichotomous approach is applied, then 50 (42%) enterprises utilise a closed model of innovation, compared to 68 (57%) enterprises utilising an open model of innovation.

Their Relationship (C1*C2)

To calculate their relationship, both concepts are entered into the equations as equally weighted, and so it did not matter which one was attributed to the dependent, explanatory variable or independent, predictor variable. The results would be the same regardless. However, the following allocation was chosen:

- **Organisational resilience (C1)** is considered the dependent, explanatory variable.
- **Open innovation (C2)** is considered the independent, predictor variable.

The hypotheses being tested are:

- **The null hypothesis (H_0)** predicts that the dual concepts (variables) are independent of each other, and so have no relationship.
- **The alternative hypothesis (H_1)** predicts that the dual concepts (variables) are dependent, and so have a relationship.

To establish "the probability that there is a relationship between two variables in the population from which a … sample was derived" (Bryman & Cramer, 2011, p. 203), a crosstabulation (Figure 26) of the bivariate datasets was analysed. This test calculates the "the possibility of a statistical association, or correlation, between the variables that have been measured" (Gray & Kinnear, 2017, p. 3).

Figure 26: Crosstabulation and Chi-Square Tests

Crosstabulation

			ORGANISATIONAL RESILIENCE				
			NONE	LOW	MEDIUM	HIGH	Total
OPEN INNOVATION	COMPLETELY CLOSED	Count	1	7	2	2	12
		Expected Count	.4	4.1	4.3	3.3	12.0
	MAINLY CLOSED	Count	2	17	5	8	32
		Expected Count	1.1	10.8	11.4	8.7	32.0
	PARTIALLY CLOSED	Count	0	2	2	2	6
		Expected Count	.2	2.0	2.1	1.6	6.0
	PARTIALLY OPEN	Count	1	11	23	12	47
		Expected Count	1.6	15.9	16.7	12.7	47.0
	MAINLY OPEN	Count	0	2	7	4	13
		Expected Count	.4	4.4	4.6	3.5	13.0
	COMPLETELY OPEN	Count	0	1	3	4	8
		Expected Count	.3	2.7	2.8	2.2	8.0
Total		Count	4	40	42	32	118
		Expected Count	4.0	40.0	42.0	32.0	118.0

Chi-Square Tests

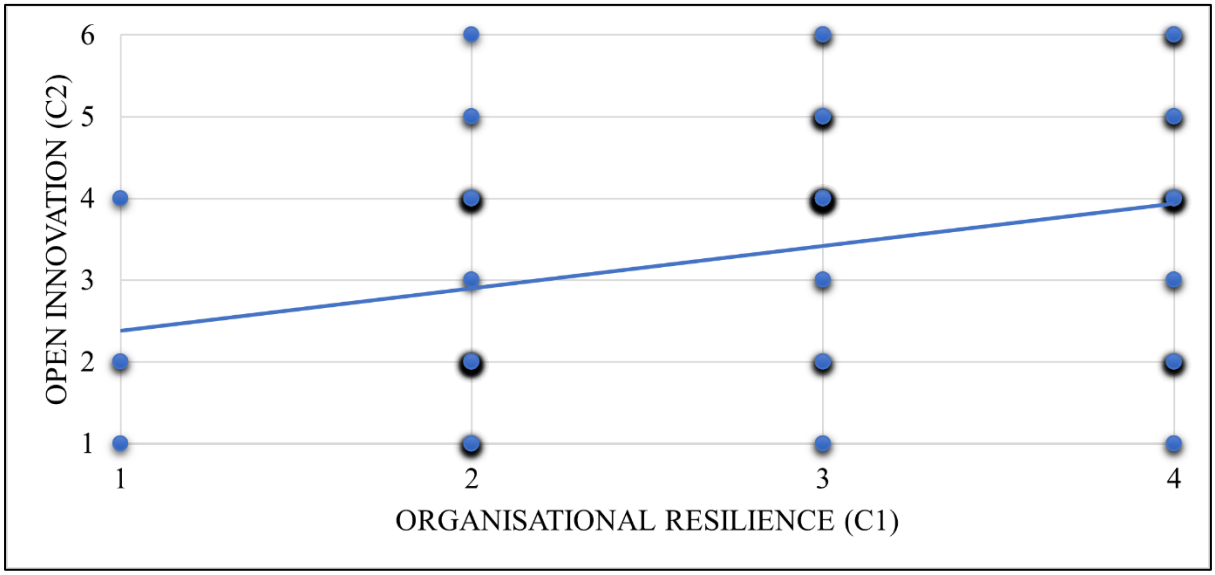
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	22.950[a]	15	.085
Likelihood Ratio	24.075	15	.064
Linear-by-Linear Association	11.432	1	<.001
N of Valid Cases	118		

a. 18 cells (75.0%) have expected count less than 5. The minimum expected count is .20.

The results of the crosstabulation will provide the first stage of statistical inference needed to accept the above null hypothesis, that the bivariate are independent by chance and have no relationship (H_0). Or, to accept the alternative hypothesis that the bivariate are dependent and

have a relationship (H_1). Alongside the frequencies, which match the univariate analysis column charts (Figure 24 and Figure 25), this contingency table includes the expected values of each level of the concept, calculated if there was no association between the variables. With the highest count on the crosstabulation, 23 of the sampled 118 UK life science SMEs (19%) have remarked that they practice medium organisational resilience, and partially open models of innovation – the most popularly cited levels of each concept. In contrast, the lowest counts fell upon 'no' organisational resilience, and 'partially closed', 'mainly open', and 'completely open' models of innovation, which can be interpreted as vulnerable UK life science SMEs practising more closed models of innovation. The "joint distributions" (Gray & Kinnear, 2017, p. 131) of the bivariate crosstabulation is then visualised in a scatterplot (Figure 27).

Figure 27: Scatterplot



Using density plot points (sized by frequency) and a trendline, a linear relationship is displayed between the dual concepts (C1, C2) for the sample of UK life science enterprises. It is a positive linear relationship, as both concepts increase together. Although there is variance across all levels of organisational resilience, there is only limited variance between mainly closed and partially open models of innovation being practiced. As reflected in the scatterplot, enterprises with no organisational resilience practice mainly closed models of innovation, whereas enterprises with high levels of organisational resilience practice partially open models of innovation.

Returning to Figure 26 (above), a chi-square test for independence is recommended for datasets with 50+ datapoints (Evans, 2016). This has been achieved with the 118 valid enterprise responses. However, there is somewhat of a sampling error due to not meeting the power analysis target of 194 enterprise responses, and so the dataset is deemed underpowered. This scenario leads to implications upon sample representation. To compensate, the data is further enriched by the later collection of qualitative data via the interviews. Regardless, the calculated 'asymptotic significance' (P=0.085) has a higher value than the conventional alpha-value (A=0.05). This "relates to the probability that we might be making such a false inference" (Bryman & Cramer, 2011). It can therefore be interpreted that the bivariate is calculated as independent, and their relationship is deemed statistically insignificant, accepting the null hypothesis (H_0). There is only an 8.5% chance of dependency between the two variables in the wider population.

However, they warn that the chi-square test is only a probability approximation, as it is calculated against the expected, rather than observed, frequencies of each concept. The greater the expected frequencies, the more accurate the result, and so SPSS reported that 18 cells (75%) have expected count less than five, which makes this particular test even less reliable. Furthermore, the chi-square test only calculates *if* there is a significant association. It does not indicate the *form* of dependence (Bryman & Cramer, 2011) between the bivariate. Further quantitative and qualitative investigation is still needed to confidently answer the question of the concepts' relationship. As experts in business analytics, Albright and Winston (2020) state that the subsequent correlation and covariance calculations require pairings of the same frequency of responses for each concept rating, which was validated through the cleaning and substituting of the dataset. However, both concepts were captured on different Likert rating scales (organisational resilience: levels one to four; open innovation: levels one to six). Correlations will standardise them for comparison, to measure their linear relationship (Gray & Kinnear, 2017).

Albright and Winston (2020) also describe the analysis of covariance (commonly known as 'ANCOVA'). This is an average of the products of deviations of each concept, from their respective means, to determine if the concepts (C1, C2) vary in the same direction (to 'co-vary'). Covariance, as a calculation, has no upper or lower limit, and is dependent on the scales of measurement. The limitation of covariance is that it is very sensitive to (a) the units of measurement, which differ and can create noisiness by reducing the statistical power for

rejection of the null hypothesis; and (b) any outliers, which can dramatically skew the results – although this is mitigated by the highly structured nature of the survey. The calculated covariance coefficient (S=0.381, Figure 28) is a positive number above zero, it can be concluded that the bivariate relationship is positive too.

Figure 28: Bivariate Correlation

Descriptive Statistics

	Mean	Std. Deviation	N
ORGANISATIONAL RESILIENCE	2.86	.857	118
OPEN INNOVATION	3.35	1.423	118

Correlations

		ORGANISATIONAL RESILIENCE	OPEN INNOVATION
ORGANISATIONAL RESILIENCE	Pearson Correlation	1	.313**
	Sig. (2-tailed)		<.001
	Sum of Squares and Cross-products	85.831	44.559
	Covariance	.734	.381
	N	118	118
OPEN INNOVATION	Pearson Correlation	.313**	1
	Sig. (2-tailed)	<.001	
	Sum of Squares and Cross-products	44.559	236.754
	Covariance	.381	2.024
	N	118	118

**. Correlation is significant at the 0.01 level (2-tailed).

The concepts both increase as they change, which affirms the crosstabulation and scatterplot. However, although covariance demonstrates the *direction* of the relationship, it cannot provide its *strength* to accept or reject the null hypotheses of bivariate independence. As it is nearer zero, it suggests a present but moderate bivariate relationship. The Pearson correlation coefficient (R=0.313) holds more validity in this instance, as the two concepts were measured on different scales (C1: 1-4, C2: 1-6), and so should therefore be calculated 'unit free' (Gray

& Kinnear, 2017). By using the -1 to 1 scale, a similar finding has been produced of a moderate relationship, as it is above the alpha-value of A=0.05. However, due to it being a positive integer, it is a positive relationship between the dual concepts. A regression equation is then calculated for a further statistical analysis of the concepts' relationship (Figure 29).

Figure 29: Model Summary, ANOVA, and Coefficients

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.313[a]	.098	.090	.817

a. Predictors: (Constant), OPEN INNOVATION

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	8.386	1	8.386	12.562	<.001[b]
	Residual	77.444	116	.668		
	Total	85.831	117			

a. Dependent Variable: ORGANISATIONAL RESILIENCE

b. Predictors: (Constant), OPEN INNOVATION

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.234	.193		11.576	<.001
	OPEN INNOVATION	.188	.053	.313	3.544	<.001

a. Dependent Variable: ORGANISATIONAL RESILIENCE

The coefficient of determination is how much of the variance in the dependent variable is explained by the model (Pallant, 2020), and so the coefficient (R^2=0.098) can therefore be interpreted as a small and trivial association (Cohen, 1988). Furthermore, as a percentage, R^2 has 9.8% strength of the bivariate relationship. Yet, due to the sample being underpowered, it is necessary to consider the adjusted R^2 too, as using R^2 can be too much of an optimistic overestimation anyway (Pallant, 2020). The adjustment corrects this by providing a more accurate model. To do this, the calculated analysis of variance (ANOVA, adjusted R^2=0.090) is only slightly less than R^2 predicts, meaning that the positive but moderate relationship is still correct. Using adjusted R^2 means that there is an unexplained variance of 91%, and so the

subsequent qualitative data regarding the relationship of the concepts will somewhat contribute to reducing that deficit.

A regression calculation comparing the difference in means of the two concepts (F=12.562) demonstrates that there is *some* explanatory power, but as it is not large, and the power is not strong. However, with the significance being less than 0.001, this means that the previously calculated adjusted R^2 is higher than the level of significance, so, the null hypothesis (H_0) of bivariate independence can be accepted. The unstandardised coefficient (B=2.234) is corroborated by the scatterplot, as it is where the trendline intercepts the y-axis. Therefore, the predicted observation of the UK life science SMEs that score the minimum unit of 1 on the dependent, explanatory variable of organisational resilience (C1) only practice mainly closed models of innovation. The 'regression slope' of the trendline, then "measures the estimated average change in the dependent variable [organisational resilience, C1], that results from increasing the value" (Gray & Kinnear, 2017, p. 450) of the independent variable (open innovation, C2) by one unit.

Conclusion of Quantitative Findings for RQ1

With an underpowered sample, it is unclear if the lack of statistical relationship between the concepts is accurate, specifically due to there being evidence of there being at least a moderate relationship of a positive direction (they both increase together). Therefore, the following quantitative analysis to answer how they are influenced will comprehensively test the concepts combined, and then individually too.

4.2.2. How are the Concepts Influenced? (RQ2)

As concluded above, the relationship between organisational resilience and open innovation is moderate but statistically insignificant. However, they do increase together, so it is, therefore, of use to perform a conceptual synthesis. To uniquely test their combined influences, to contribute significant, practical knowledge for UK life science enterprises to implement.

Influences of C1*C2 (Combined)

For the purposes of firstly *quantitively* testing and answering this research question (RQ2), the following concepts are allocated to variables:

- **The interaction of the dual concepts (C1*C2)** is the dependent, explanatory variable.
- **The prospective influences (F1-F3)** are the independent, predictor variables.

The hypotheses being tested are:

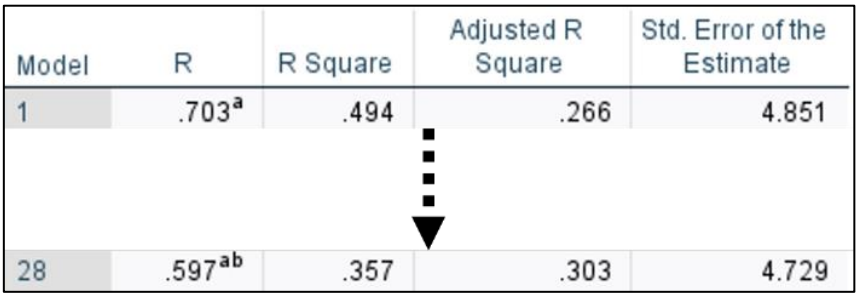
- **The null hypothesis (H_0)** predicts that all the influences together are independent of the combined concepts, and so they are not influential.
- **The alternative hypothesis (H_1)** predicts that all the influences together are dependent of the combined concepts, and so they are influential.

According to Albright and Winston (2020), the most difficult part "is deciding which explanatory variables to include in the regression equation … Data sets frequently offer an overabundance of potential explanatory variables" (p. 477). For rigour, and to decide upon the best method of variable selection to apply to the multivariate regression, each method has been calculated with all independent variables (F1-F3) against the combined dependent variable (C1*C2). Rather than considering the R^2 output for this decision, the adjusted R^2 is instead applied to the equation. It is more accurate as it provides "a better estimate of the true population value" (Pallant, 2020, p. 166). As noted in Table 12, the highest value was calculated from the *backwards* elimination of variables (with an adjusted R^2=0.303, rounded to 30.3%; Figure 30).

Table 12: Adjusted R^2 Value Contingency Table (for C1*C2 when F=0.1)

Variable Selection	Adjusted R^2
Enter	0.266
Stepwise	0.22
Remove	0
Backward	0.303
Forward	0.22

Figure 30: Model Summary (Abridged)



Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.703[a]	.494	.266	4.851
28	.597[ab]	.357	.303	4.729

This selection method will be applied to determine which set of predictor variables (F1-F3) have the most significant influence upon the explanatory variable (C1*C2). Backwards elimination of variables in a multiple linear regression promotes the principle of parsimony, as it provides an efficient interpretation of the dependent variables, with a model of as fewer variables as possible (Evans, 2016). Or, as very simply put by Albright and Winston (2020), "explaining the most with the least" (pp. 477-478). This makes it easier to interpret and answer what influences the combined concepts. The backwards elimination of variables will continually recalculate models of regression until only a list of fewer significant influences best explains the combined dual concepts. This method of elimination of variables is promoted as best suited for novel research, where there is not yet a "coherent body of theory to guide the researcher" (Gray & Kinnear, 2017, p. 474). This means that it supports the aim of this research to provide a significant and original contribution to knowledge.

After calculating 28 models of the regression, the full coefficient table can be found in Appendix O: Regression Coefficients. However, the following table influential (Table 13) is more concise, as it only presents the p-values of each independent variable. P-values demonstrate the "statistically significant unique contribution to the equation … [and] the prediction of the dependent [interaction] variable" (Pallant, 2020, pp. 166-167). Assessing the strength of evidence against the null hypothesis (H_0) of independence. Lower p-values indicate a stronger significance of influence towards the concepts. The calculated nine influences are listed in descending order, which allows for a clear understanding of which independent variables have the strongest influence on the model's prediction of the dependent (interaction) variable.

Table 13: Significance of 28th and Final Model of Regression

Influence (Most to least Significant)	**Significance (Ascending P-values)**
Internationalisation	0.000
Management Qualifications: Science	0.001
Supply Chain: Manufacturer	0.006
Management Team Size	0.012
UK Country of Operation: Scotland	0.014
Enterprise Size: Medium	0.035
Supply Chain: Distributor	0.064
Enterprise Size: Small	0.072
Subsector: Business Support	0.076

This 28th model of regression has calculated the final list of nine influences. As a collective, they are significant to the combined concepts, as they all have P-values under the default threshold of 0.1, as set by the SPSS software used (IBM, 2022). However, when considering the list in finder detail, the latter three variables (Supply Chain: Distributor, Enterprise Size: Small, Subsector: Business Support) are above the alpha-level (A=0.05), which means as individual variables, they are less predictive of the combined concepts. This reinforces the need for the qualitative research to determine if they are indeed significant enough to include in the final model.

Interestingly, the T-values (as seen in Appendix O: Regression Coefficients) predicts the direction of the linear relationship (Albright and Winston, 2020). Most of the significant influences have positive T-values, meaning that they *increase* as the dual concepts increase. However, two of the significant influences have negative T-values. This means they *decrease* as the dual concepts increase:

- Management Team Size (T=-2.556)
- Subsector: Business Support (T=-1.820)

This can be interpreted that the smaller the management team size, or the less concentrated/isolated life science business support services are (encouraging crossover with other scientific subsectors), the more influential they are of the concepts. Although the above calculates probability, the confidence of the coefficients are also calculated.

Due to the different measurement scales used to collect the quantitative data of each factor and influence, the standardised coefficients (β) are used to compare the results of the regression, as they are unit-free measurements (Gray & Kinnear, 2017). The β-values are the slope angle of the regression line of each individual significant influence, calculating the ratio by which the influence changes as the dual concepts increase by one standardised unit. For example, internationalisation (the most significant influence, β=0.309) *increases* the quickest, at a rate of 30.9%. Whereas management team size (β=-0.219) *decreases* the quickest, at a rate of -21.9%, which further reinforces its T-value (above) by implying that the smaller the team, the more they practice organisational resilience and open innovation. According to Field (2018), an underpowered sample can lead to 'underfitting' the regression model, by overlooking otherwise significant independent variables. It can affect the ability to calculate the true mean average in the population, so it is necessary to use the standard error to compare how each influence is estimated to differ.

Rather than a focus on the mean calculations, the lower and upper bounds of confidence intervals were used to calculate boundaries within which we believe the population will fall. With the differing measurement scales of the influences, the variability of the sample is what is calculated, rather than variability of the observations. All B-values of the nine influences fall within the confidence intervals, which indicates validity, but the size of the interval determines how close the sample mean is to the true mean. The influence with the smallest range is that of 'Management Team Size' (confidence interval=0.937), which means it is close to the true mean and so more of a valid prediction that it will be influential within the wider population. The widest range is that of 'Supply Chain: Distributor' (confidence interval=7.536) which Field (2018) says is "a bad representation of the population" (p. 67). The lower and upper confidence intervals of the following influences each cross the value of zero, and so have confidence that they do *not* have a correlation with the dual concepts:

- Supply Chain: Distributor
- Enterprise Size: Small
- Subsector: Business Support

The highest part correlation value of the significant influences is that of 'Internationalisation' (0.284), which provides a 28.4% unique contribution towards the explanation of the combined concepts. However, 'Enterprise Size: Small' (0.139) had the part correlation value that was

nearest to zero. This signifies that it only has a 13.9% unique contribution. Further to these unique contributions, issues arise when there is significant multicollinearity between variables. Making it difficult to isolate and analyse one independent variable upon the dependent variable (Evans, 2016). Upon inspection of all the considered influences (F1-F3) within the equation, there could arguably be similarity within each of the factors, which could lead to intolerance to multicollinearity. According to Pallant (2020), by checking the regression outputs against each variable, the full correlation table (Appendix P: Correlation Matrix for C1*C2) shows no variables with a higher correlation than 0.7. This means that this analysis is free from multicollinearity of intercorrelated values of similar influences, and therefore valid. The separate and unique contributions of the variables can be calculated without fear of combining influence upon each other, rather than a focus solely upon the influence of the dual concepts.

Also, as seen in the collinearity statistics, Pallant (2020) also suggests that the tolerance of each influence is calculated, to indicate:

> *"How much of the variability of the specified independent is not explained by the other independent variables in the model … If the variable is very small (less than 0.1) it indicates that the multiple correlation with the other variables is high, suggesting the possibility of multicollinearity." (pp. 163-164)*

Fortunately, all variables are above the recommended collinearity level of 0.1, signifying that they all have tolerance, and therefore, multiple correlation is low. The nine significant influences each have very similar tolerance intervals. For example, the 'Subsector: Business Support' has the highest tolerance interval (TI=0.948), whilst the 'Supply Chain: Manufacturer' has the lowest tolerance interval (TI=0.801). Yet none are anywhere close to the 0.1 value that indicates collinearity, so no multiple correlations are present in the 28th model of regression. To add further validity to this, the Variance Inflation Factor (VIF) is the inverse of tolerance, with only those with value above 10 being a concern (Pallant, 2020). Neither of which apply to this analysis, therefore no variables need to be removed from the final model of regression, which may have otherwise skewed the results.

Next, the analysis of variance (ANOVA; Figure 31) calculates a 'Sig.' value (P=<0.001) for the collection of these variables. The findings are under the standardised significance alpha-level (A=0.05), and so the null hypothesis can be rejected in favour of the variables being

deemed dependent (Pallant, 2020). This, therefore, adds validity, as they collectively influence the predictor variable (the combined concepts, C1*C2).

Figure 31: ANOVA for C1*C2 (Abridged)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1837.076	36	51.030	2.168	.002[b]
	Residual	1882.721	80	23.534		
	Total	3719.797	116			
28	Regression	1326.636	9	147.404	6.591	<.001[ac]
	Residual	2393.161	107	22.366		
	Total	3719.797	116			

To understand if there are any outliers within the dataset, first the critical chi-square value is pre-calculated by Tabachnick and Fidell (2013; Figure 32).

Figure 32: Critical Values of Chi-Square (Tabachnick & Fidell, 2013, p. 10)

df	0.250	0.100	0.050	0.025	0.010	0.005	0.001
1	1.32330	2.70554	3.84146	5.02389	6.63490	7.87944	10.828
2	2.77259	4.60517	5.99147	7.37776	9.21034	10.5966	13.816
3	4.10835	6.25139	7.81473	9.34840	11.3449	12.8381	16.266
4	5.38527	7.77944	9.48773	11.1433	13.2767	14.8602	18.467
5	6.62568	9.23635	11.0705	12.8325	15.0863	16.7496	20.515
6	7.84080	10.6446	12.5916	14.4494	16.8119	18.5476	22.458
7	9.03715	12.0170	14.0671	16.0128	18.4753	20.2777	24.322
8	10.2188	13.3616	15.5073	17.5346	20.0902	21.9550	26.125
9	11.3887	14.6837	16.9190	19.0228	21.6660	23.5893	27.877
10	12.5489	15.9871	18.3070	20.4831	23.2093	25.1882	29.588

By crosstabulation of the nine independent variables calculated by the multiple regression, as the degrees of freedom (df), and an alpha level (A=0.001), the proposed chi-square value for this research is 27.877. This can then be applied to interpret the residual data (Figure 33).

Figure 33: Residual Statistics

	Minimum	Maximum	Mean	Std. Deviation
Predicted Value	1.77	17.52	9.95	3.401
Std. Predicted Value	-2.424	2.235	-.004	1.006
Standard Error of Predicted Value	.837	2.263	1.329	.355
Adjusted Predicted Value	1.74	18.27	9.95	3.470
Residual	-9.400	13.809	.013	4.566
Std. Residual	-1.988	2.920	.003	.966
Stud. Residual	-2.045	2.979	.003	1.007
Deleted Residual	-9.954	14.375	.012	4.970
Stud. Deleted Residual	-2.077	3.096	.005	1.017
Mahal. Distance	2.639	25.578	8.823	5.366
Cook's Distance	.000	.077	.009	.014
Centered Leverage Value	.023	.220	.076	.046

For example, the maximum Mahalanobis (Mahal) distance value is 25.578, which is under the pre-calculated critical value of 27.877, and so the data does fit the model, and so there are no significant outliers. Also, in the same residuals table, the maximum Cook's Distance value is 0.077. As this value is not greater than one, Pallant (2020) states that this signifies that no outlier has undue influence, furthering the validity of the end model of regression. As a final check, Field (2018) suggests the interpretation of the Centered[14] Leverage Value (which has a maximum possible value of one), to check if any of the survey responses (e1s, e2s, e3s, etc.) has any undue influence over the model. With the calculated minimum (0.023), maximum (0.220), mean (0.76), and standard deviation (0.46) values of the final model of regression, all sitting well under that leverage, and so no cases have undue significant influence. Each of these tests indicate high validity, as no cases or variables need to be removed to recalculate the model for a better fit.

[14] American English, as featured within the SPSS output.

Figure 34 is a probability-probability (P-P) plot which maps the expected against observed cumulative probabilities of each influence. According to Evans (2016), there is normality within the dataset as all points sit close to the diagonal line and so has a normal distribution, which validates the use of this model for the dataset. There are no peaks or sags and so there is very little kurtosis. The plot is somewhat symmetric, so there is no skewness displayed within the results.

Figure 34: Normal P-P Plot of Regression Standardised Residual

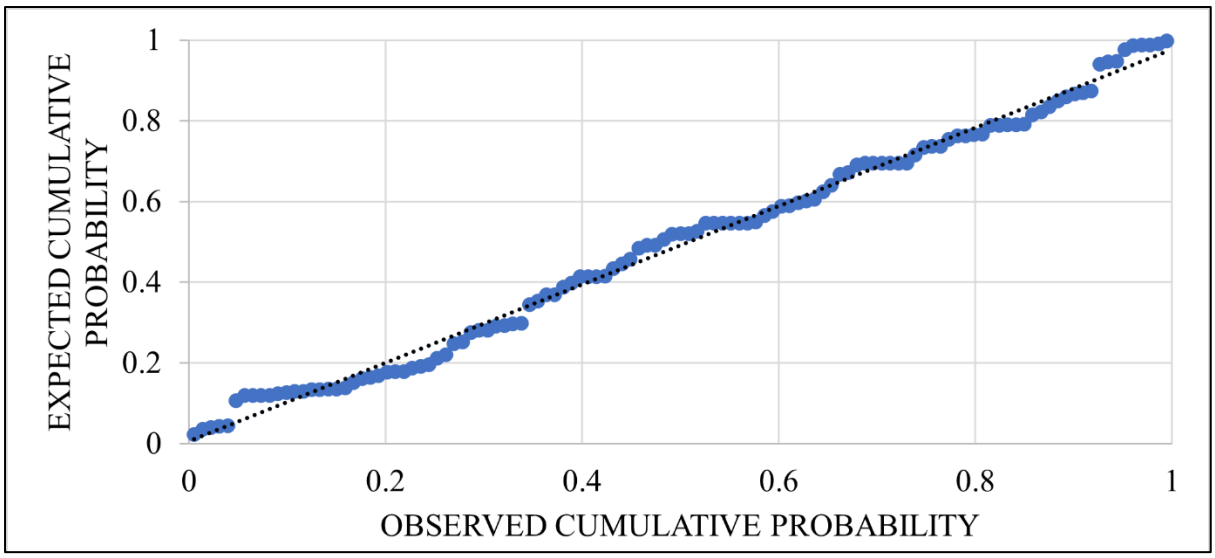
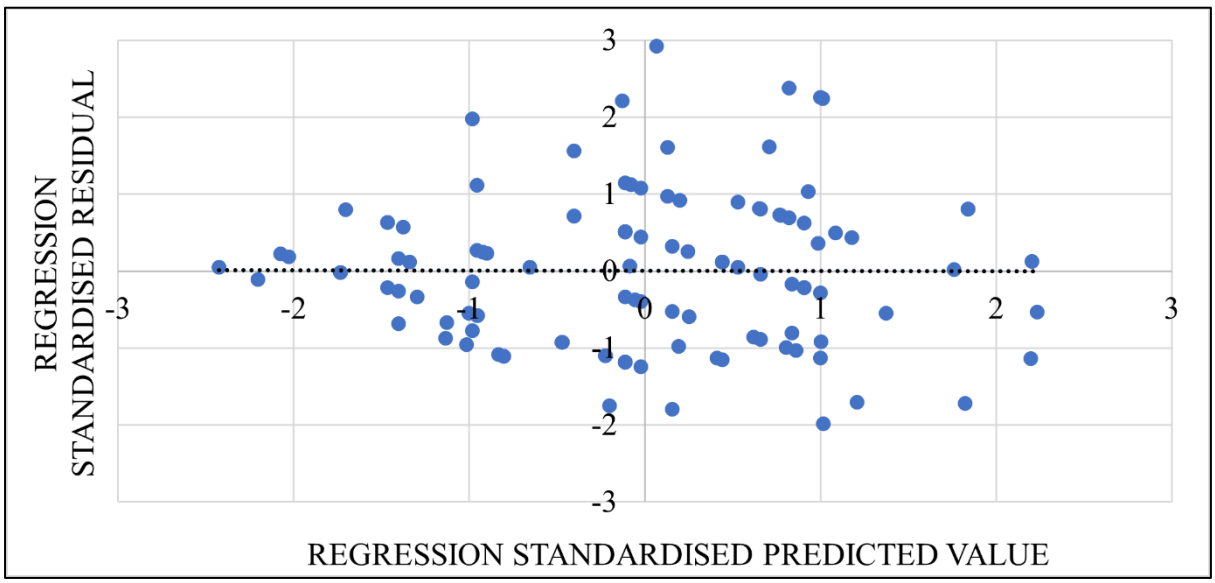


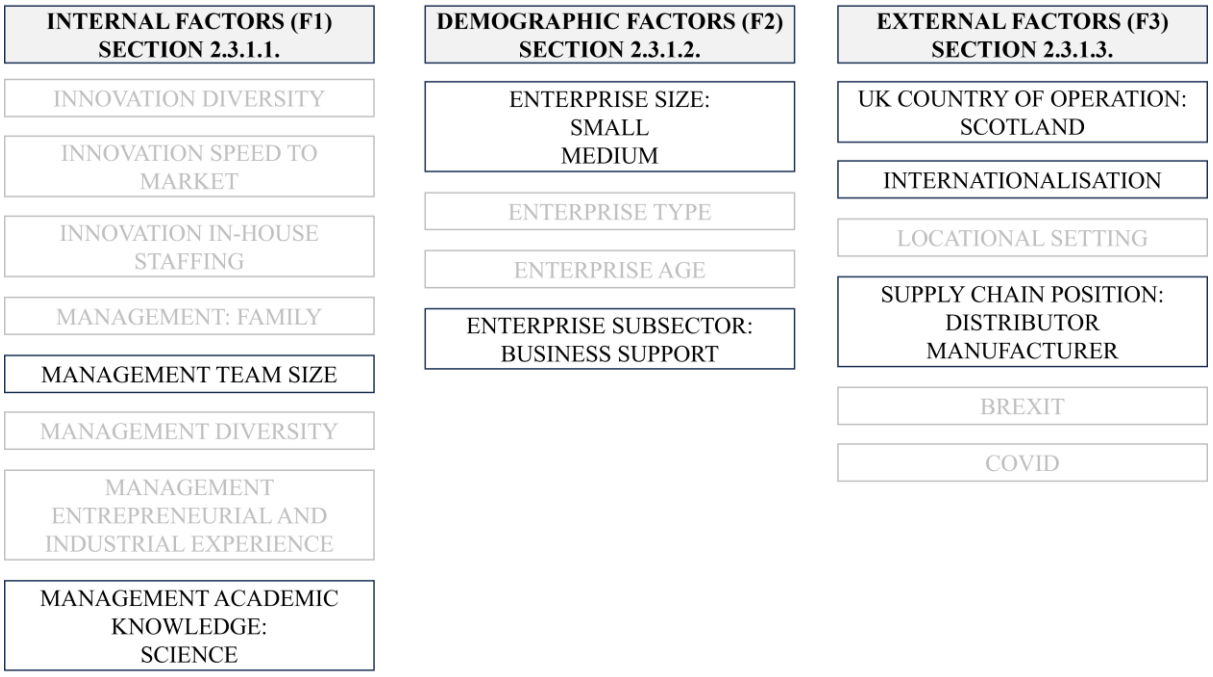
Figure 35 displays the residual against predicted values in a scatterplot, and the circular mass of plots evidence that the variables are dissociated, and that the regression line is horizontal at 0 on the y-axis (Gray & Kinnear, 2017). This means that there are no outliers, as such deviations would otherwise "suggest some violations of assumptions" (Pallant, 2020, p. 164). The scatter of plots is suggested to be 'ideal' by the survey platform, Qualtrics (2023b), when they are (a) fairly symmetrical, (b) clustered within low values of the Regression Standardised Residual y-axis (either positive or negative), and (c) there are no clear patterns, meaning that it is an accurate, valid model.

Figure 35: Standardised Scatterplot



To conclude the quantitative analysis, the evidence calculates nine significant influences. The analysis of variance calculates that the resultant collective *does* have influence over the combined concepts. However, with a 69.7% deficit of explanatory power, it is worthy of further qualitative investigation. As a continuation of the original model of influences sourced from the existing literature (Figure 12), the resultant significant influences from the regression are displayed in Figure 36, against their allocated factors. Through this first stage of validation, the insignificant influences are disregarded by being greyed-out, ready for the next stage of qualitative analysis.

Figure 36: RQ2: Model (Concluding Validation Stage 1: Regression)



Influences of C1 and C2 (Individually)

It is also recommended to "cross-validate your model by splitting the data" (Field, 2018, p. 400), and so the multiple regression of backwards elimination has been repeated for the individual concepts (C1, C2; Appendix O: Regression Coefficients) for supplementary information regarding the significant influences. For the influences of organisational resilience, the multiple regression calculated 27 models of backwards elimination of variables. This resulted in 10 significant influences, with internationalisation also the most influential of this individual concept too (P=0.000). With such high significance, it perfectly rejects the null hypothesis of independence, as it is unlikely to be calculated due to chance. For the influences of open innovation, the multiple regression calculated 24 models of backwards elimination of variables. This resulted in 13 significant influences, with the Scottish location of operation for UK life science enterprises being the biggest influence (P=0.000). Similar to internationalisation for C1*C2 and C1, this influence also perfectly rejects the null hypothesis of independence. It is strongly linked to influence on the individual concept, as it is unlikely due to chance.

Conclusion of Quantitative Findings for RQ2

To empirically conclude, the following research questions are answered using the results of the statistical testing.

Research Question One (RQ1): How are the concepts of organisational resilience (C1) and open innovation (C2) related for UK life science SMEs?

All statistical test results of the bivariate equations (P=0.085, S=0.381, R=0.313, R^2=0.098, and the adjusted R^2=0.090) are calculated above the alpha-level (A=0.05). Therefore, these accept the null hypothesis (H_0) of independence between the concepts of organisational resilience and open innovation for UK life science SMEs. However, the sample is noted to be underpowered, and so although there is a moderate (albeit statistically insignificant) relationship, it warrants further investigation in the next phase of qualitative research to verify if the empirical results are valid. The direction of the relationship, which was also calculated, is positive, which means that the two concepts increase together. Furthermore, by practicing mostly closed innovation, UK life science enterprises experience no organisational resilience (complete vulnerability to failure), whereas they only have to practice partially open innovation in order to achieve high organisational resilience (growth and success).

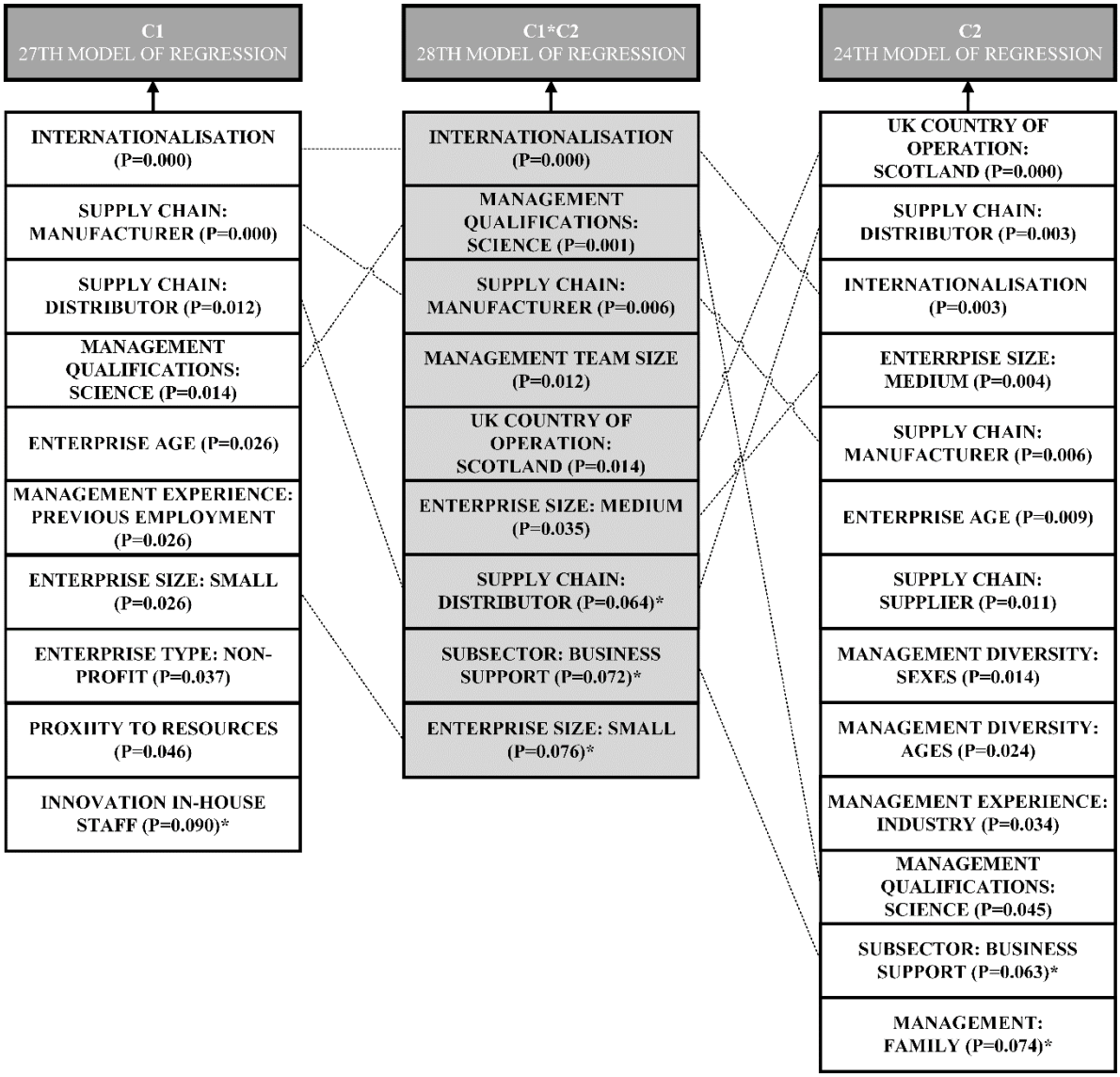
Research Question Two (RQ2): How are the concepts of organisational resilience (C1) and open innovation (C2) influenced for UK life science SMEs?

The statistical testing began by uniquely combining the Likert scales scores of both individual concepts into one interaction variable (C1*C2), and then measuring each variable's influence upon them. By conducting comprehensive testing of all methods of variable selection, the backwards elimination is calculated as the most accurate, with the highest adjusted R^2 value of 0.303. The final, 28th model of this method of multiple regression, resulted in nine calculated influences of the combined concepts, with internationalisation being the most significant (P=0.000). However, the calculation does leave a 69.7% deficit of explanatory variables, but the qualitative data will collect any emergent influences to explain the shortfall.

Beyond other insightful statistical tests, the same multiple regressions, with backwards elimination, are also conducted upon the individual concepts (C1, C2). Using the same framework of influences, these separate regressions determine their influences too. The results

of which are compared and visualised in Figure 37. Internationalisation (P=0.000) was also the most influential of organisational resilience, whereas UK Country of Operation: Scotland (P=0.000) was the most influential of open innovation. The crossover between models is frequent, however each have their own unique influences too. The subsequent qualitative analysis of the interviews will further validate and increase the explanatory power of these quantitative findings.

Figure 37: Comparing Quantitatively Significant Influences of C1, C1*C2, and C2



4.3. Qualitative Findings

Following the quantitative analysis of the survey responses, the raw qualitative data was examined from the interview transcripts, found in Appendix Q: Raw Qualitative Data. During

initial qualitative data analysis, I explored the use of data displays in NVivo. While these methods can be useful for identifying initial patterns, they did not provide the level of detail, scrutiny, and interpretation needed for such doctoral research. The word clouds primarily revealed frequently used words which were evidently connected to the themes, and so offered limited further insight into the underlying meanings. Similarly, branching diagrams became cluttered and difficult to follow as the data became more complex. To address these limitations, I opted for a manual, text-based approach to the thematic analysis using Microsoft Word, allowing to identify recurring themes within the data. Providing a more nuanced and insightful understanding of participant experiences of the two concepts. The following interpretations of the discussions with each participating enterprise includes quotations to demonstrate the voice of the UK life science SME owner-manager respondents, across both research questions.

4.3.1. RQ1: How are the Concepts Related?

To qualitatively answer this research question, an interview question asked if and how the two concepts of organisational resilience and open innovation are related. Firstly, the responses which confirmed a relationship is analysed.

Confirmed Relationship between Organisational Resilience and Open Innovation

Corroborating the quantitative results, half of all the interviewed enterprises cite that there *is* a relationship between the concepts of organisational resilience and open innovation, evidenced below. To begin, an aquaculture enterprise (e1i) suggests that it is common sense that they are profoundly linked. They comment that if SMEs only used their internal resources (citing knowledge and finances) for innovation, they would not be able to scale to successfully achieve their aspirational impact, as the costs would be enormous. Instead, they recommend collaboration to not only meet their organisational vision and mission, but also holistically across the life science 'sphere':

> *"They're fundamentally linked … If you did everything from within, the intellectual and capital expenditures that you need to be able to do would be just astronomical. And making best use of what somebody else has done, and maybe improving it … It's common sense … You can't do everything yourself, right? That has to drive collaboration to create the improvements that you want to see in our sphere." (e1i)*

Taking a similar stance, one enterprise that provides specialist business services to the sector, states that organisational resilience is a vital pre-requisite to practice open innovation, and this is universal across the life sciences. This life science business support enterprise (e2i) observed that over the past decade, very few enterprises can manage to survive on their own, and so they develop a business model of collaboration. Especially with large companies, who desire the SMEs' specialist outputs (specifically cited as compounds) and expertise:

> *"Resilience is important for open innovation, but in the sense of collaboration, it is critical to all companies in the field, if we're looking at open innovation as sharing … It's become less and less important for the life sciences." (e2i)*

Arguably, such collaboration and sharing could currently be on trend for businesses, because predictable and cyclical patterns could be easily followed to identify where the life science industry and patient care is going. However, now that idea is outdated, as the sector is described as continually refining, improving, and progressing upon their dynamism and adaptability. For example, a medical technology enterprise states that innovativeness is derived from a desire to succeed, and it is therefore the stronger and resilient enterprises that survive:

> *"They [are] definitely directly linked … [We] have been able to be adaptive as a business, you need to constantly be looking to see where the business needs to move. You know, where the industry's going, where patient care is going. It's a very cyclical process … There are trends … It's the stronger, the resilient, that survives." (e3i)*

Equally confirming the positive relationship, but with a no-nonsense statement, a biological technology enterprise suggests that dynamism and flexibility is required within business plans for long-term success. Otherwise, they will simply fail, as evidenced during COVID:

> *"Companies that don't innovate die … Resilience comes from innovation. And innovation comes from being resilient as a business … So for me they are so closely interlinked." (e5i)* [15]

[15] Although made clear by the researcher during the interview, the responder from this enterprise makes the link between organisational resilience and innovation, rather than *open* innovation.

Likewise, although both concepts are ‘interlinked’, organisational resilience should be prioritised. A biological technology enterprise argued that that open innovation is inevitable for any SMEs that practise closed innovation, who need to bolster their limited resources to successfully innovate. It is said that they do:

> *“Associate, very well … it is always resilience which comes in first, and then only we can be able to do these kind of [open] innovations.” (e6i)*

The UK life sciences are already deemed to practice open models of innovation by one of the sampled SMEs (e12i). They state that life science enterprises are forced to practice open innovation internationally, otherwise they fail. Contemplating their own recent history (circa five years old), their response provides a damning, but unverified, sector statistic:

> *“I think it has to be very [related] … You need to be open so that you can spread your wings. If you don't collaborate with people worldwide, then it's very difficult for [Contract Research Organisations] to survive … 60% of private [Contract Research Organisations] like mine have gone bust.” (e12i)*

Likewise, one of the younger sampled enterprises, operating in the agricultural technology subsector, admits to being just as vulnerable. Attributed to being in such early-stages of their organisational journey, with only two years of operational experience so far. They observe a positive correlation between the concepts, as they are hopeful that when:

> *“We're a bit more resilient, we might be a bit bolder about being more open.” (e13i)*

So far, a positive relationship between the concepts is confirmed within the qualitative data, with both organisational resilience and open innovation increasing together. Interestingly though, whilst the next-quoted medical technology enterprise agrees that there is an association, they uniquely report a negative relationship:

> *“If an organisation has got very high resilience, there is lesser open innovation. I think if they [have] got lesser resilience, it's one of the channels, in terms of innovation, that they need to explore in order to secure their future. If they are doing what they're doing without the need for external organisations, external collaborations, the question, in many instances, is ‘Well, why are we doing that? Why are we bringing someone else in, when we don't need to? We've got a lot of resilience. Everything's going well. Why [are] we bringing somebody in?’” (e4i)*

Next, quotations are analysed from those enterprises which do *not* observe a relationship between the two concepts.

No Confirmed Relationship between Organisational Resilience and Open Innovation

A quarter of the sampled enterprises observed no relationship between the concepts in the UK life sciences. Whilst speaking positively about open innovation, and recommending it's practice, one medical technology enterprise assumes organisational resilience is an independent concept. Any competitive advantage through innovation is transparent for all in open environments:

> *"Openness is one of the things that everybody should be, providing you're not coming across any intellectual property … I don't think it enhances it [organisational resilience]." (e8i)*

Similarly, the following biological technology enterprise is also sceptical of any relationship between the two concepts. Stating that UK life science SMEs are forced to be open, due to a lack of resources. There are likely risks to organisational resilience that comes with that:

> *"I'm not convinced there's a strong correlation between innovation, uh, openness of innovation and resilience … I wouldn't see a natural correlation on in either direction. That may be wrong. Yeah, there is a risk … It depends, a lot, on resources. If you're a multinational company with 20,000 employees, you have the opportunity to do things internally, whereas if you're a, you know, a couple of guys in the garage, you don't have that opportunity and you're forced to be more open." (e9i)*

An animal health enterprise sees no relationship. They confess to practising a closed model of self-reliance. Observing a link between open innovation and marketing with industry and would like for the UK to practice more open innovation. Considering a partnership with a specific company within the life science ecosystem, to fill a deficit in their skillset and expanded representation in the marketplace. This would, arguably, enhance their organisational resilience. Although this was not specifically addressed as an outcome of the collaboration:

> *"It's been driven by things outside our control … We've used it [open innovation] … We're, sort of, getting there, we have a bit closer relationship this year. We're going to run a competition using their product, along with ours. So in an area [that] they're not stronger in." (e14i)*

Finally, a biological technology enterprise did not think SMEs need organisational resilience to practice open innovation. Instead, they argued that there is a strong link of needing strength with closed models of innovation. Supposedly, if you are self-reliant, and something goes wrong, then vulnerability and failure looms large:

> *"Open innovation [is] more important than resilience. No, I think you don't need resilience. I think you need resilience for closed innovation, because if you are doing something where you're not collaborating with others, and you're just doing it yourself, you have to be able to be resilient and weather the storm. Whereas, if you are openly innovating with other people, then it doesn't matter because if you're not, you know, resilient." (e15i)*

Finally, the qualitative analysis now considers the enterprises that are uncertain if there is a relationship between the concepts.

Unsure of a Relationship between Organisational Resilience and Open Innovation

The remaining quarter of the sample were unsure if a relationship exists between the concepts. For example, a medical technology enterprise (e7i) proposes that there may well be a relationship between the concepts in other industries, especially for new high-tech enterprises. They believe that such enterprises stand to benefit from specialist knowledge exchange and tax avoidance, by not having to formally employ someone to access their knowledge. Particularly beneficial to SMEs with low financial resources. However, it does also leave them vulnerable to larger, predatory life science actors, which complicates the relationship between the concepts:

> *"With [medical technology] … the crossover is a little bit more difficult between open innovation and resilience, it shouldn't be, but there's more paranoia." (e7i)*

Another biological technology SME was repeatedly hesitant to assert if the two concepts are related or not. However, they did affirm that openness is, instead related to confidence. Not only in the specialist competencies of enterprises, but also in their management of resources and technologies. Noting the vulnerabilities of early-stage enterprise strategy, they claim that:

> *"They're running about everywhere there, going from here-to-there, working with different companies and different people. And some of that is scattergun. They're just trying to survive. They're just trying to find where the value is. They're trying to find that kind of product-market fit." (e10i)*

Acknowledging their lack of financial resources to pay the expensive UK patenting costs, the following medical technology enterprise is feeling forced to take on new risk. Due to entering more open models of partnership working, even though they identify as being in a vulnerable state. Yet, they have mixed feelings about it all. They have not confirmed either way:

> *"Talk about organisational resilience all you want, and open innovation, but you don't want open innovation, you want to have some proprietary innovation. So you want to build your own industry. Open innovation means you're sharing everything. And you're going in from a from a position of weakness in a partnership, it's really a pity … You're giving away your trade secrets … We have paid for patents in the [United States of America] and UK. But it's extremely expensive to put in place, and most startups can't afford that." (e11i)*

Finally, a pharmaceutical enterprise has repeatedly found difficulty in ascertaining if the concepts are related. They first proposed that an openness mindset of people within an enterprise, may allow for more organisational resilience. But then they quickly countered that with the promotion of closed mindsets, due to the need to be commercially sensitive over any secrets, again for more organisational resilience:

> *"Resilience is more within the company. And it's more, like, operational procedures, a lot of it. As the openness tends to, as I said, transcend companies, and it's more to do with individual people, and people wanting to know things … You can't be too open. You know, obviously, you've got your commercial secrets … It's our clients that we have to protect … because it's our client's data … We've been here, ticking along for 15 years now. I don't know how much longer, just because we rely too much on a small number of clients, and that's where that goes in with your resilience." (e16i)*

Conclusion of Qualitative Findings for RQ1

With a majority of the responses qualitatively promoting a relationship between the concepts, it bolsters the quantitative evidence that there is actually a significant association. Therefore, it is relevant to answer the second research question, by using the results of the regression for the *combined* concepts as a-priori codes, followed by any emergent themes in the transcribed dataset.

4.3.2. RQ2: How are the Concepts Influenced?

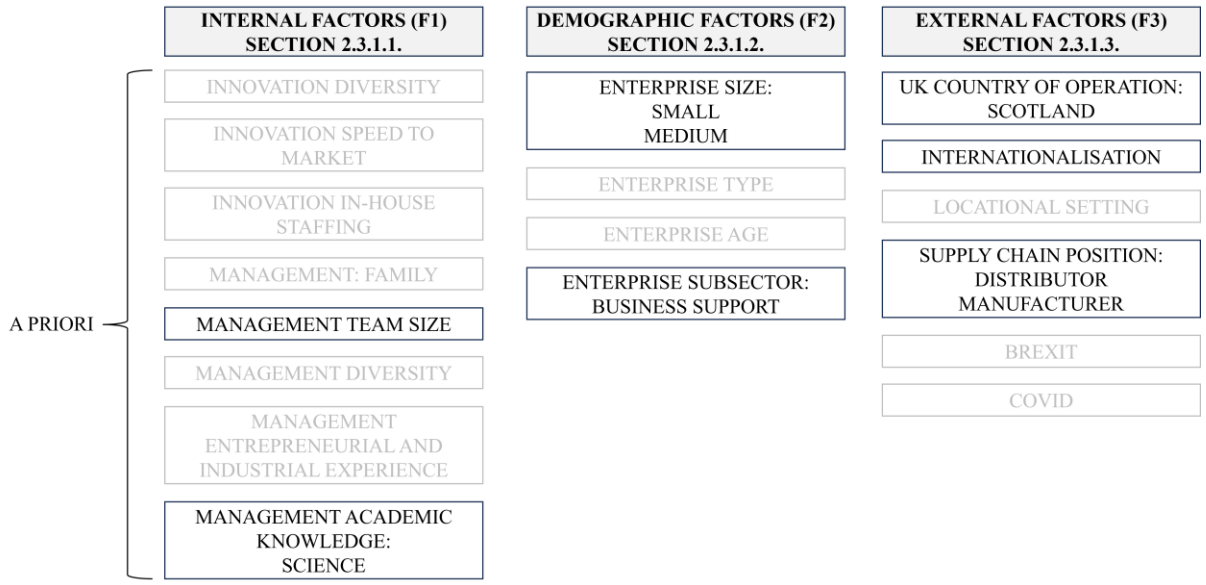
Through an iterative process, this section analyses the interview transcripts to validate the influences identified as quantitively significant of the combined concepts.

A Priori Influences

The a priori codes are sourced from the results of the quantitative analysis, whereby nine significant influences were identified in the final model of regression (see section 4.2.2. How are the Concepts Influenced?; Figure 38). They will each be discussed in descending order of

their quantitative significance (p values), to determine their qualitative significance and therefore validate their inclusion in the final model.

Figure 38: RQ2: Model (Entering Validation Stage 2: A Priori)



Internationalisation

From the statistical analysis, internationalisation has a perfect significance value (P=0.000) and is the most quantitively influential of the combined concepts. It is therefore no surprise that it is also heavily featured within the qualitative findings, even though it was unprompted. Enterprises identify that opportunities to export are a positive influence upon the concepts, but this comes with increased administration, currency differences, and language barriers (e28s). With some quick statements by other enterprises claiming there is now too much red tape and costs surrounding UK medical regulations (e50s, e84s, e10i, e11i). Instead, they seek international certification, which is later discussed by e3i, below.

The following aquaculture enterprise argued that internationalisation was an early priority for their growth. Evidenced by them already developing their operations in other countries, for early entry into their scientific certification global marketplace. It was motivated by the slow-evolution and failures of government's industrial bureaucracy to meet global challenges, and so they exploited this niche for commercial gain, and organisational resilience. Likewise, they also found that open innovation with modern western democratic governments was modest in comparison to those in developing countries. The latter were deemed more pervasive,

engaging, and flexible in their collaborations, and facilitated partnerships to encourage the prosperity of their SMEs too. Yet morality was another barrier to their internationalisation, due to developing nations being at risk of using slave and child labour:

> *"I'd say this [internationalisation] is absolutely a priority for us in the sense that when the world of certification was evolving early on, it was a reaction of many about the failure to move policy (national or international) forward at a significant pace to meet the challenges in front of it." (e1i)*

Looking to collaborate globally, a life science business support enterprise mentioned that there are also vulnerabilities to organisational resilience, as some regions outside of Europe do not respect or recognise confidentiality agreements. Therefore, the UK enterprises risk losing their specialist competitive advantage. Yet, despite wanting to practice open innovation with the continent, one enterprise highlights a problem because of BREXIT. They claim that the UK life science market is currently frozen out, whilst the UK and European Union (EU) governments negotiate the Northern Ireland protocol:

> *"Post-BREXIT, the government said it would sign up to the EU science thing, but that's not going through because the EU won't sign it until the Northern Ireland border is sorted. This is a huge, huge problem and the UK's been frozen out of, not just the money, but also the potential to collaborate on a lot of big projects." (e2i)*

Two participating enterprises (both micro-sized and enterprises aged 15 years) raise concerns about collaborating with Asia. Owing to an opinion that they are less stringent about legal protections, which is a barrier to both concepts of organisational resilience and open innovation for UK life science SMEs:

> *"Japanese companies have a reputation for not respecting confidentiality. Maybe it's an attitude, but it is something that people talk about in the industry ... There are suspicions about certain companies ... Individual companies that have a reputation for being less careful than others." (e2i)*

> *"We're sending stuff over to China, and they just nick the compounds and they don't care about any copyrights. So that's why I think a lot of stuff has come back from China. Rather than my very in-house [Contract Research Organisation] ... You have to be commercially sensitive." (e16i)*

Discussing a previously US-based enterprise which had raised millions of dollars in investment, the medical technology enterprise admitted that they failed to seize the market. Consequently, they scaled right back and identified the UK as somewhere they could continue

to operate, to bring in revenue. However, they were then faced with a change in dynamic of UK regulatory expectations for medical devices. Consequently, this is identified as their biggest barrier to their organisational resilience, but improving quality of life science outputs overall:

> *"Our biggest barrier, at the moment, is the changing dynamic of regulatory platforms, in that BREXIT hasn't helped, because that's now meant that CE [Conformity with European Standards] markings, no longer cover the UK, so we don't have a product recognised in the UK … For a long time, [USA] were seen as the easy route to market, that you could get product through FDA [Food and Drug Administration] quite, quite easily. Then you would use that to help you get into other parts of the world, and that's just not the case anymore ... It's catching companies that are maybe not as compliant, and as structured, and rigorous, with how they go about things. But it's made it hard for the people that are still trying to do things properly." (e3i)*

Yet, two enterprises (e5i, e6i; who are strikingly similar, as they are both Welsh, micro-sized, aged under 10 years, and male-led enterprises) are in exciting stages of growth. The first is organising collaboration with USA and Swedish companies, whereas the other is expanding their territory beyond UK borders.

The UK government is said by another medical technology enterprise to be of a huge support to their internationalisation. Not only through funding but brokering partnerships too. Specifically, the Department of International Trade is motivating them to conduct *intra*national open innovation within UK industry by brokering partnership working within the country. But, to also practice *inter*nationalisation by importing and exporting with other countries, for the benefit of the organisation and wider economy:

> *"I've built relationships with across many [in] Europe … collaboration agreements with them, innovation hubs, funding … So government, mainly for grants. I tell you who's been fantastic, I would say, the Department of International Trade. They're really big on trying to link with the right people, but their effort is there … That was a surprise to me. I didn't realise how heavily involved they were." (e7i)*

Another enterprise is currently planning to licence out to industry, from the UK, but to around the world (e8i). The changing UK regulations mentioned above by e3i, are perhaps not a universal barrier for all UK life science SMEs, which is a prompt for further investigation.

The following two micro-sized enterprises are considering leaving the UK (e9i, e10i). The first, a medical technology enterprise wishes to operate from the EU or USA, and enter the Asian

and Middle-Eastern markets for their organisational resilience. Rather damningly, they quote their reasons as the UK having a lack of big ideas, no national strategies for the bigger picture or longer-term, and that the National Health Service (NHS) is a nightmare stakeholder. They see open innovation as just a route to acquisition, rather than for their organisational resilience:

> *"I don't believe UK gains much. The UK is probably losing out, because we do all the hard work and they're quite happy to give it away for a good price. And so alternatively, to make a quick buck, you sell-up rather than going into production." (e9i)*

Whereas equally, the second enterprise is regularly evaluating the geopolitical threat of BREXIT, specifically the Northern Ireland Protocol, which is identified by the respondent as holding prominence on their risk register. However, the biological technology enterprise mitigates this by being a virtual company. Flexible enough that they could operate out of the Republic of Ireland, should the need ever arise to work from the EU (e10i).

Yet, establishing in another country is deemed extremely difficult by one enterprise. Rather than investing in 'bricks and mortar' in other countries, and the expense of frequent travel to them, they too have become a virtual company. This, by its very nature, is "shrinking the world" (e11i) and motivating internationalisation, especially with the EU. Instead, this biological technology enterprise can reallocate those funds into their own resources, for the purposes of innovation:

> *"Europe is a gangbuster in innovation, right now. So, either you're [the UK] going to get their hand-me-down innovation or you get in the game of developing your own … The more that Western countries cooperate is becoming extremely critical." (e11i)*

Equally, a pharmaceutical enterprise argues a strong link between internationalisation and survival, particularly after the 2007-2008 financial crisis. Due to the high prices of the UK's NHS, they saw it was a "no-brainer" (e12i) to open worldwide sites to drastically cut costs and reallocate their limited financial resources elsewhere. They are now operating in Europe and beyond too.

Finally, the only animal health enterprise sampled, has been unsuccessful in exporting, making them become more self-reliant. They actually wish for more closed innovation at a national level. Therefore, internationalisation has not had a positive influence upon their organisational resilience or open innovation:

> *"We've never really been successful in exporting … Ideally we would have liked it to be a global product. I [am] still looking for someone to partner it really, to take it to, perhaps America or Europe, and so on … The whole country needs to be more self-reliant." (e14i)*

There is enough qualitative evidence for internationalisation, so this will be included within the final model of significant influences. The following a priori code is that of scientific qualifications being present within the management team, statistically calculated as the second-most significant influence.

Management Qualifications: Science

In the quantitative analysis, the presence of scientific qualifications within the management team had a near-perfect level of significance (P=0.001) influencing the combined concepts. To introduce the topic, it is said by a biological technology enterprise that "the academic reputation that we have is what draws clients in" (e15i). Science was the only academic domain that was calculated as significantly influential of the two concepts, which is qualitatively evidenced by one owner-manager of the following pharmaceutical enterprise. finding confidence in their ability to lead their enterprise. Connected to them being very well medically qualified, and long-standing industry experience:

> *"I've had over 35 years of clinical research experience, as well as working in different therapeutic areas of medicine. So, I'm well qualified to lead a team of clinical research people." (e12i)*

Another pharmaceutical enterprise advocates for scientist managers, as they bounce technical ideas between each other within their enterprise. They can therefore influence localised intradepartmental open innovation. They confess that their scientists within management:

> *"Tend to fire ideas off each other. So that's why these meetings are important to go to. Because you go, and then you have a discussion with somebody, and find out what they're doing, something that is useful for you. So yeah, I think it's basically science family, as it were." (e16i)*

Yet, to counter this, a medical technology enterprise would prefer more board-level diversity. Scientific directors are labelled as very defensive, and would therefore restrict open models of innovation:

> *"The Board of Directors who are from all sorts of different backgrounds. You generally want them from [medical technology], although you would be flabbergasted, intellectual property wise, especially in [medical technology], very, very guarded." (e7i)*

The medical technology enterprise (below) expressed that scientist managers are not famed for their (a) organisation skills to follow internal policy, (b) formal communication, (c) ability to change business processes, or (d) ability to record and reflect upon any business lessons learnt. All of these are said to impact their organisational resilience. They even likened their continually difficult business management as an ongoing battle in a scientific environment, as they are trying to get up to date with best industry practices. Yet, they do interact with academic institutions, so there is potential there for cross-domain open innovation:

> *"Trying to organise a group of scientists [to] produce anything is a bit like herding cats and trying to get them to follow a process is sometimes ordinarily impossible … It's often the problem to get processes in place formally. Very, very difficult, [a] lot of resistance and that obviously impacts resilience. We are making the same mistakes all the time … My background and my colleagues' backgrounds are in big science … Naturally we have interaction with experts in these institutions." (e9i)*

With scientists present within a management team, their academic knowledge can be both very specialised and technical. One biological technology enterprise suggests such niche scientific expertise positively influences open innovation, as they still need to seek external valuable ideas, outside of their own capabilities:

> *"My business partner was a postdoc … on the computation biology side. But he's an experienced guy … One of the other things that we can work with on, not just academics, but other [biological technology actors], is not just compounds into our cascade, but also biology expertise … We have a number of different programs … We're not experts in, we're not doctors or clinicians and therefore, we're not experts in disease." (e10i)*

A combination of scientific and business qualifications within the management team is encouraged by a number of the sampled enterprises. Although the current management team, of a sampled agricultural technology enterprise (below), have scientific backgrounds, there is an identified deficit of business knowledge to grow and become resilient:

> *"Prior to that [I] was a research scientist … So, if we grow, I think, I suppose, none of us are business people, [to] have the skills necessary to put that together. It really needs someone who can take it to a new level." (e13i).*

Equally, a biological technology enterprise expressed difficulty and frustration in applying for Innovate UK funding. They just did not have the business acumen to describe the enterprise from a professional, rather than scientific perspective, to get shortlisted:

> *"They [Innovate UK] seem to write it in the wording that they want to receive it in. And I think it's sometimes very limited, where you only have 400 words to express, or put something as an answer down. Especially in this kind of technical field." (e8i)*

There is a satisfactory amount of qualitative evidence for this influence to feature in the final model. The next a priori code is that of being a manufacturer within the life science supply chain, which was quantitatively calculated as the third-most significant influence of organisational resilience and open innovation.

Supply Chain: Manufacturer

The manufacturer position of the life science supply chain was statistically calculated as the next significant influence (P=0.006) of the two concepts. Although calculated as a significant influence upon both concepts, the following life science business support enterprise deems it a *negative* influence upon open innovation. They spoke of how big companies are now looking at owning more of the supply chain to control the means of drug discovery, dominating the supply of the sector. Encouraging UK life science SMEs to remove themselves from their collaborations, and work independently under a closed model of innovation, for their own survival:

> *"People could remove things from the collaboration to work on themselves, because big companies are now looking at technologies earlier in the system … They want to control the means of discovery, so it's earlier up the stream. And that makes it harder to do pre-competitive science, unless you're looking at areas that nobody's interested in." (e2i)*[16]

Going from a completely virtual manufacturer, to now one that offers a subcontract model of manufacturing, a medical technology enterprise has made positive progress over the last three

[16] Pre-competitive science by SMEs conducting open innovation, is defined as "the exploration phase of R&D" (Alberto et al., 2022).

years to own as much of their supply chain as possible. However, they are currently lacking funding to make further advances, which is a reaction to their past supply chain issues affecting their organisational resilience:

> *"What is probably holding that back is funding … Everything's got more expensive. And supply chain issues are definitely, definitely real … Forcing us to have to buy large inventory of materials, to make sure that we don't run out." (e3i)*

Continuing on, a medical technology enterprise also suggests that the UK sector's supply chains need an overhaul, for both up and down stream, and both social and economic benefit:

> *"That's where the industry is partly refining and improving on. Before it was just 'Let's put something in that we know works, in that set' and there was no real understanding of what that necessarily meant upstream or downstream of the device, or what the what the actual human factor impacts were on the patient with this device." (e3i)*

As a manufacturer, another medical technology enterprise spoke of the initial caginess of a distributor, due to the perception of a threat upon their business. However, this later turned into appreciation, as the was due to the innovation solved a problem that their customers had been demanding a solution for anyway:

> *"We win because they're the customer, then they buy the technology, to then place with the customer who uses their drug, and then the technology monitors the patient and it's great. It's great for everybody." (e7i)*

Although considered within the quantitative data as a potential influence, an innovation's speed to market was not calculated as a significant influence. Yet, a biological technology enterprise experiences an increase in pace, through their *very* open innovation with major manufacturers:

> *"There are probably major manufacturers out there that could bring it to market very quickly, because I see the need for it, and whether we could do that by getting the [intellectual property] and then licensing, it could be a very open way of doing it." (e8i)*

Considering another aspect of time, the only agricultural technology enterprise is currently considering better integrating their manufacturer as a partner. To increase the longevity of their innovation outputs, and better oversee their supply chain. However, the manufacturer is hesitant due to their micro-size, so they are having to prove themselves by making the product successful first:

> *"We are working with our manufacturer to affect the product, and between us, we, sort of, know various contacts to get other stuff done … One idea we did discuss it fully with our in our partnership, is whether we should include our manufacturers as a partner … but we're very small in their [eyes], but if we make this product successful, I could see that they would be interested to get further." (e13i)*

Lastly, an animal health enterprise notes that, oblivious to the public, supply chain management is very risky for the organisational resilience of UK life science SMEs:

> *"The selling point-of-view is being driven by consumer pressure, for the producer to retailers to be carbon neutral … I think the public don't realise these things, so [it] is a risky business. You know, you you're at the beck and call of the retailers." (e14i)*

Again, this influence has enough qualitative evidence to reinforce its quantitative significance. It will be included within the final model. The a priori code of management team size is explored next, to determine if it has enough qualitative responses to also feature in the final model.

Management Team Size

Management team size is quantitively calculated as the fourth significant (P=0.012) influence of the combined concepts, and yet is scarcely acknowledged within the qualitative data. With a negative linear relationship (indicated by T=-2.556), the smaller the management team, the more they practice organisational resilience and open innovation. One enterprise, who had a sole owner-manager, found that having the ability to bounce ideas around a management team may have influenced the concepts, but it was not a possibility for them until they experienced success and growth (e89s).

Enacting this, a pharmaceutical enterprise promotes excellent internal communication and networking skills. Sharing ideas across their personable small team, which increases their organisational resilience. However, they did not refer to it affecting either closed or open models of innovation:

> *"We're very friendly bunch because we're a small team. Everyone knows each other really well. So everyone knows what's happening within the company" (e12i)*

However, the following animal health enterprise *did* refer to open innovation - although their three-person management team are effective in communication too. Their deficit in up-to-date

scientific knowledge forces them to seek external expertise through partnerships. Furthermore, fewer people can lead to honest and open discussion which leads to trust and alignment, enhancing both organisational resilience and open innovation:

> *"We haven't really got any direct links to any sort of scientists at the moment, other than our own knowledge, which one of our partners is really good at. So actually, the three of us [have] got aspects about what we do, and know, which work together quite well. So as a group we're … effective, and we're very open, and communicating with each other about what we're doing." (e14i)*

This ease of communication across a small management team is a common theme. With fewer owner-managers, communication can be more direct, reducing any misunderstandings. It can also help facilitate quicker decision-making with fewer layers of hierarchy to bypass, making the enterprise more agile to practice organisational resilience and open innovation. Thus, this will feature in the final model of significant influences. Next, the qualitative evidence is explored regarding Scotland as an influential location to practice the two concepts.

UK Country of Operation: Scotland

Out of the four UK countries of operation, it was only Scotland that was a quantitatively influential location for organisational resilience and open innovation (P=0.014) - the first *demographic* influence (F2) calculated as significant. The founder of a life science business support enterprise detailed how she is also making an impact in Scottish academia, through the postgraduate teaching of biological technology entrepreneurship (e2i). This provides an interesting dynamic of industry-academia knowledge transfer, through their cross-sector employment and lived-experiences. Another Scottish enterprise, operating in the medical technology subsector, spoke of how well connected they are within their local life science community:

> *"Locally, we're an active member of the our local Chamber of Commerce. There's a bio-cluster … which we are part of. We have a three-way agreement in place with the University of [redacted] and NHS [redacted], so we definitely expand our capability by using the network that we have." (e3i)*

Equally, a Scottish biological technology enterprise favours local, face-to-face collaborations to save time and money travelling down south:

> *"Being a Scottish company, we try to keep it [Scottish]. Not that I'm for Scottish independence, but we try to keep it within Scotland … I'd rather it be within a locality. You can go and see [them], right, rather than having unfortunately travelled down to London, or the South of England, which involves costs and everything else." (e8i)*

It was also cited that Scottish government kindly offered a beneficial start-up grant for their medical technology enterprise, which anchored them in the region, as well as the Scottish NHS boards were accessible to deliver their life science enterprise outputs:

> *"We had a government grant when we moved the business to the UK, came to Scotland it was very easy to get an initial grant … Not saying we wouldn't consider the NHS, but we originally tried to raise enough funding to build the first one and keep it, and then we were going to let the NHS use it for free in Scotland, with the idea, of course, that it's worth its weight in gold." (e9i)*

A pharmaceutical enterprise is celebrating two decades of life science and healthcare experience in Scotland, indicating strong organisational resilience. Like the above, this was due to practicing openness with government as a funder and distributor of their innovation. They operate across Scottish regions including other cities and the remote, peripheral islands. All motivated to reduce the identified high national mortality rate by patients with their specialism (e12i).

Although there were qualitative responses coded to the benefits of life science SMEs operating from Scotland, there is not enough evidence that it specifically influences the concepts of organisational resilience and open innovation. For this reason, it is the first a priori code to be *disregarded* from the final model of significant influences. Next, the qualitative coding of another demographic influence of enterprise size is analysed.

Enterprise Size: Medium

From the empirical calculations, another demographic factor was deemed significantly influential of the combined concepts: medium-sized enterprises (P=0.035). Only two of the 16 sampled enterprises identified as this size-type, but it was only cited by one, and only in relation to organisational resilience. Describing their origins, an aquaculture enterprise started out with barely any makings for an operational organisation. Including insufficient finances, but they have since successfully grown to now be operating for over 10 years:

> *"When we started, we essentially had next to nothing that would count as an operational organisation, including not enough money. So, it was a classic startup scenario." (e1i)*

Yet, business growth is not linear, as evidenced by one of the sample medical technology enterprises. Their "company has been small, medium, tiny, nearly non-existent at several times" (e3i). Therefore, examining enterprises by size is difficult as it is not a static status. Furthermore, there is a challenge with the terminology that may skew the qualitative results. Many (within the literature, sample, and wider everyday) misuse the term 'small businesses' to describe *all* sizes within the SME bracket. However, small-sized enterprises are also calculated as a significant influence of the combined concepts, as discussed later. There is a notably large imbalance of quotes coded between the small-size and medium-size of enterprises. Due to the lack of citations to reinforce the statistical significance of medium-sized enterprises as influential, this will also be disregarded from the final model of influences. Continuing the discussion about the life science supply chain, the qualitative evidence for the distributer position is analysed, next.

Supply Chain: Distributor

In the quantitative findings, the distributor position of the life science supply chain was calculated as the next significant influence (P=0.064) of the two concepts. However, due to it being above the alpha-level, this influence requires extra scrutiny if it is to be of influence. Yet, there were no qualitative citations within the transcripts, coded to the distributor position's influence on the dual concepts. As a result, this influence will not feature within the final model. The next a priori code is that of the life science-specific business support services subsector, and if it is deemed qualitatively significant of organisational resilience and open innovation.

Subsector: Business Support

Although the business support subsector of the UK life sciences was statistically calculated as the only subsector of influence (P=0.072), its significance is questioned due to it being individually calculated above the alpha-level. Interestingly, it's negative T-value (T=-1.820) is interpreted as it being more influential of the concepts, as the subsector's concentration decreases, and it becomes more diluted with other subsectors. This affirms that the life sciences have blurred sector boundaries.

Operating for over a decade, an aquaculture enterprise offers business support to the aquaculture subsector in the form of quality standards. They find organisational resilience and open innovation opportunities through "improving the environmental and social footprint" of the UK life sciences (e1i). Equally, a life science business support enterprise finds survival and success by supporting the life science innovation of others by providing them with intellectual property protections (e2i).

Operating for a quarter of a century, a medical technology enterprise has integrated a small-sized business consultancy into their deliverables. They advise and collaborate with mainly pre-revenue SMEs in the sector, which is a niche that big consultancies allegedly avoid. Yet, they find it interesting and beneficial to their organisational resilience:

> *"We have targeted the area in the market, which is probably the lumpiest. It's when companies are probably pre-revenue, but they need products built to the standard which it will be, ultimately, in full scale manufacturers … That's not particularly attractive business to big companies … You can get very small volumes, high demand, low expectation on price, you know all the negatives, but it's an interesting space to be in … We've had to trial multiple different businesses, so to summarise here, we are resilient." (e3i)*

Another medical technology enterprise has found success in offering business support in the sector. Whether it be in life science leadership and management development, or project evaluations of industry and/or academia (e4i). Although, no comment was made upon their influence upon the two concepts. Similarly, a biological technology enterprise (below) has re-labelled themselves as a 'TechBio' as they are leading with their technologies, rather than their science. They practice and promote open innovation by being highly integrated within their subsector:

> *"[Biological technology actors] operate as, sort of, a hub-and-spoke type of approach where, sort of, that idea of open innovation is inherent, where you pull in expertise from Contract Research Organisations and so on … Some of those companies will be just purely in silico – so, just on the software side and then they will outsource all of the biology." (e10i)*

A pharmaceutical enterprise offers business support within their remit, for the benefit of open innovation. They claim to be very well connected, so they collaborate with their client enterprises, to support their funding applications, such as for Innovate UK:

> *"In [the] pharmaceutical industry … the [Drug Metabolism Discussion Group]. So, you're going to [their] meetings, and other people are sorts of*

> *discussing work that they've done, that they can discuss … They've been like a university department of people, we [are] popping in and out of each other's lab discussing stuff and get ideas about. So, I think it has to be called collaborative, to a certain [extent].” (e16i)*

The above findings provide evidence that UK life science SMEs are relying on their secondary business support services, rather than their primary life science expertise and objectives. There is enough qualitative evidence to include this influence within the final model. The topic of enterprise size is next re-entering the qualitative analysis, to determine the strength of its evidence of influence upon organisational resilience and open innovation.

Enterprise Size: Small

The last of the statistically calculated significant influences, is that of small-sized enterprises (P=0.076). Another variable that is individually in need of scrutiny, due to it being above the alpha-level. Promoting the advantages of being small, the following two sampled enterprises confess that their size does make it easier to make changes along the way. Also, that it is motivational that their modestly sized team can experience the same journey, and have the same organisational vision:

> *“Contacts and network; Shared values.” (e28s)*

> *“Being small does mean that it's quite easy to make changes. You don't have an awful lot of bureaucracy to go through to change a procedure, or a policy, or a way you do things ... As a small company, everybody having the same feeling, that we're pulling in the same direction, for the future of the company, and then the future of the team, because they're all acutely aware of the journey that business goes on.” (e3i)*

A small-sized medical technology enterprise would really like to be more open, as this can lead to such-sized enterprises getting acquired by larger life science actors. They claim that this is often for the public relations strategies of the larger actors:

> *“Huge companies, who will look at the smaller ones to solve problems, or they'll look at them for PR [Public Relations] … I think their motives are brownie points ... We'd love to be able to offer more, and we're [a] very small company. But I would love that.” (e7i)*

Although one of the above enterprises (e7i) also declared that they were obsessed with competition, two enterprises begrudged such rivalry. They are both small-sized Contract Research Organisations, who find it difficult to compete with the larger NHS hospitals, who

often win the tenders for so many big studies (e12i, e15i). Likewise, it is claimed that the life science "market is saturated by multinational, very large companies, that don't want to see a change within that market" (e8i) as they are making millions of pounds, and so this cited enterprise really feels as if they must prove themselves, by bringing innovative products and methods to the life science ecosystem. Although not explicitly cited, such innovative methods could arguably be inclusive of open innovation, for example.

A biological technology enterprise has declared that many fellow life science enterprises fail because they were neither organisationally resilient, nor able to adapt to turbulent market conditions:

> *"A lot of businesses, small businesses went out of business. And it was just because of they weren't resilient, they couldn't manage, they couldn't adapt." (e5i)*

A medical technology enterprise (e9i) admits that due to them being a small startup, their biggest barrier is funding. There is just a lot of threats to assess and mitigate:

> *"Resilience, if you like, just by its nature, when you're a small enterprise, there is a lot of commercial risk and there's a lot of danger involved." (e9i)*

An agricultural technology enterprise considers such small-sized enterprises as having very limited resources to research and grow. Discovering that social media marketing is productive solution and bringing them a lot of optimism:

> *"We're a very small company, we have limited resources ... We're at that stage of carrying on the research trying to grow, grow sales and get customers. So we're finding the social media is actually really helping." (e13i)*

Learning as they grow, an animal health enterprise (below) promotes themselves as a market leader. They boast that they are well-recognised by government and industry alike. Recently rebranded which has increased their success. Due to their size, they have the flexibility to continually try new things for their betterment. This could arguably include trials at practicing open innovation:

> *"We're just so small, and we haven't really got [the resources]. I suppose that we've been sort of learning as we've been going along, and every time we do, we find something else out to think: 'Oh OK, so we need to know about that.'" (e14i)*

Like previously quoted, a pharmaceutical enterprise was also sceptical of partnerships with big companies, as it can be forced due to the vulnerable position of the SME, and may not be profitable for them:

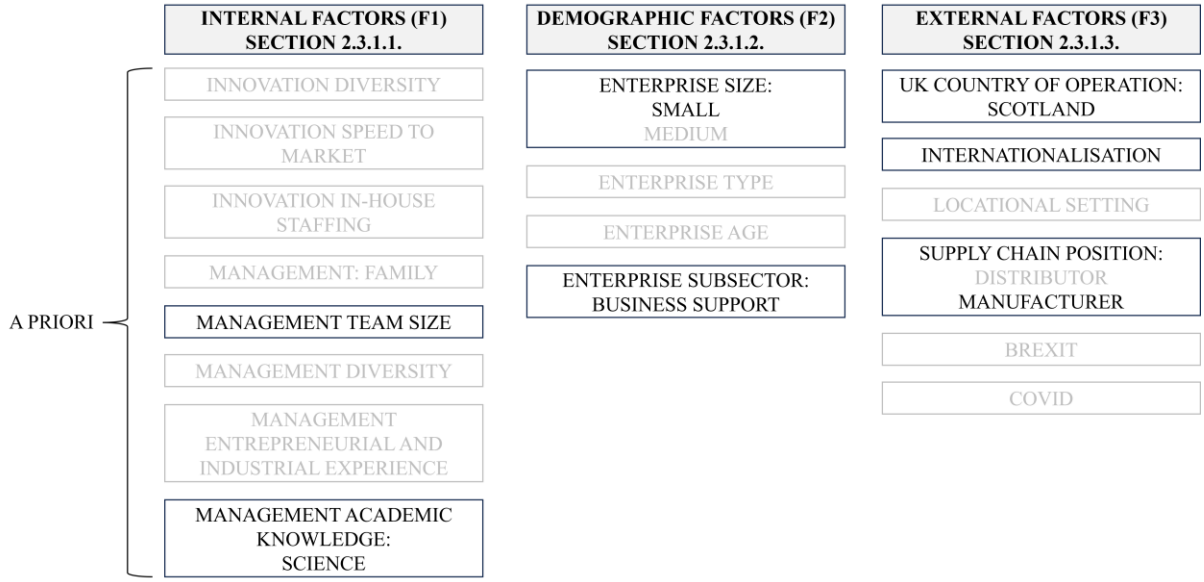
> *"Resilience is difficult for a small company like ours … Now you're getting all these small companies getting the money from the big companies. So it's [all] sort of outsourced to the small companies … There's things like being big, doesn't mean it's good." (e16i)*

Small-sized enterprises are influential of organisational resilience and open innovation due to being small enough to lack bureaucracy and have a strong vision. They are aligned by all those working for the enterprise, which encourages organisational resilience. However, they are also large enough to be considered as a competitor, collaborator, or even as a considered acquisition by larger actors within the life science sector, which encourages open innovation. Therefore, there is enough qualitative evidence to include this as an influence of the combined themes within the final model. Interestingly, micro-sized enterprises were not calculated as being a significant influence of the combined concepts, but that may be due to the language used. The blanket use of 'small' to describe all SMEs, means that micro-sized enterprises do not get explicitly mentioned, despite being majority represented within the sample. This qualitative analysis now moves onto the emergent coding of influences.

Conclusion of A Priori Coding

In this first phase of thematic analysis, a priori codes were sourced from the results of the quantitative, regression analysis, to determine if the significant influences can be qualitatively validated. Seven of the nine influences were validated, with only 'Enterprise Size: Medium' and 'Supply Chain: Distributor' being disregarded, as insignificantly influential of the two concepts. These results are displayed in the following version of the RQ2 model of influences (Figure 39). Next, continuing with thematic analysis, emergent coding is applied to the qualitative data.

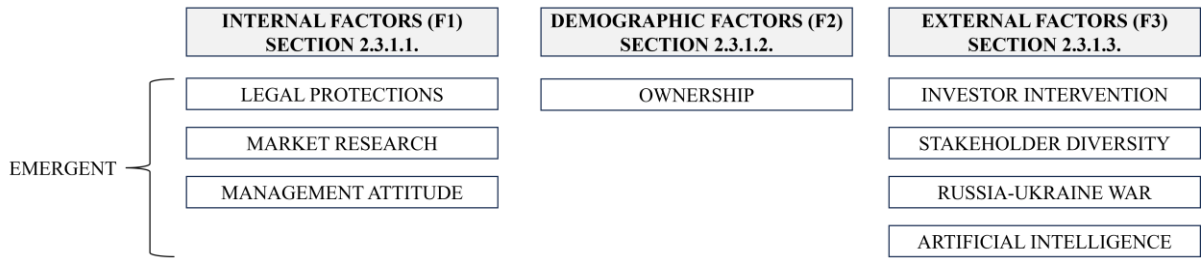
Figure 39: RQ2: Model (Concluding Validation Stage 2: A Priori)



Emergent Influences

Beyond the a priori influences (explored above), the subsequent emergent influences are commonly identified themes that emerged from thorough analysis of the qualitative data. This data was sourced from the final, qualitative question of the survey and the interview. These follow an interpretivist philosophy, with the researcher interpreting the emergent codes from commonly cited themes in the transcripts, to identify if they have significant qualitative influence of the combined concepts (Figure 40).

Figure 40: RQ2: Model (Entering Validation Stage 3: Emergent)



The following emergent codes are discussed in order of frequency of responses, starting with the most common. Although these potential influences may be commonly discussed, through the semantic analysis of the transcripts, it will be identified if they are significant and worthy of including in the final model. Firstly, the legal protections of data and intellectual property will be explored as the first emergent theme.

Legal Protections

The most commonly cited emergent theme (included within seven survey responses, and nine interview responses) is that of legal protections, as being potentially influential of the dual concepts of organisational resilience and open innovation. It is regarding the UK life science SMEs safeguarding their limited internal resources and innovation. Therefore, it is allocated as an internal influence (F1). Intellectual property (IP) protects innovation from imitability, which can positively influence organisational resilience. Yet, in the UK it is expensive and difficult to apply and enforce, which could negatively influence any open innovation by the SMEs, which is evidenced in the responses below.

Without such protections though, one enterprise claims that innovation would be pointless (e3s). It is also promoted by another enterprise that "openness is based on trust" (e16s), but really requires a Data Protection Officer to oversee such open collaborations for organisational resilience purposes (e20s). Such a job-role can help with the legal protections of the enterprises. Likewise, another enterprise prefers to practice open innovation, but does so very carefully, under Confidential Disclosure Agreements (e47s). Similarly, two enterprises operating within the medical and biological technology subsectors (respectively), protect themselves under 'tight' Non-Disclosure Agreements. They both ponder if they are legally binding though, as they have experience of still being dropped as an innovation partner:

> *"That's how I approach everything with regards to external innovation, collaboration and that we're very tight. It's [Non-Disclosure Agreements]." (e5i)*

> *"You have to be very, very careful with the way contracts are set up; watching your back ... We have [Non-Disclosure Agreements] ... But [they] are not legally binding. And nor are [Master Service Agreements], so like, even though you've signed a [Non-Disclosure Agreement], you've talked to [them] and they said "Yes, you know, we're going to do this study, we'll sign the Master Services Agreement to say yes, we're all in collaboration". And those have got [Confidential Disclosure Agreements] in them as well ... They're not legally binding, so they could just turn around and say 'Oh, well, after all this, we've got no funding. So see you later'." (e12i)*

Linking the two research concepts, one enterprise finds it difficult to gain investment and ensure resilience against dominant actors within the life sciences, without intellectual property (IP) protection prepared:

> *"Intellectual property and experience … Very hard to gain significant backing until IP protection is in place, and the product is proven to be profitable. Also at the mercy of others who may take the idea. Openness in business is really questionable until the idea is already fully developed and protected from predators." (e55s)*

Another enterprise uses patents to protect their innovation (e100s). Equally, the following other enterprises operate closed models of innovation, and is unwilling to share. Even if they are not going to commercialise it themselves:

> *"Institutions not willing to share foreground IP even though they say they do not want to commercialise." (e144s)*

> *"If organisations have things that they consider to be unique, that has intellectual property, they're very protective of it. They don't see that it's anything they would share, until such a time it was well protected. In the academic environment, we have seen the desire to protect intellectual property, but not the desire to commercialise it." (e4i)*

The following two enterprises operating within the business support and biological technology subsectors (correspondingly) claim that aquaculture, pharmaceutical, and medical technology subsectors have vast numbers of patents. It is said to be impossible to raise investment without patents, therefore affecting their organisational resilience, and their ability to practice open innovation. Practicing internationalisation (as discussed above in the a priori coding), they warn that regions in Asia do not respect such legal protections. However, this is derived from anecdotal evidence, as they themselves claim there is no data on where the leaks are. Therefore, there is an ongoing debate about its influence upon the concepts:

> *"Data protection is not much of an issue really … I'm not sure it really goes to open innovation … People worrying about [General Data Protection Regulations] probably don't understand it very well … Quite [a] curious system where people are seeing it as an issue. It's interesting … Collaboration, protected by patents, is absolutely crucial." (e2i)*

> *"[Data protection] does affect it because unless someone gives, let's say now myself, if I don't give my consent, you can't use it. The products or the information out there, so open innovation is always affected by the [General Data Protection Regulations] which has come into place." (e6i)*

The following medical technology enterprise argued that data is vital for the UK life sciences, and so protecting the intellectual property is necessary when opening up models of innovation:

> *"Data, now, is becoming it's worth in gold. It's gold, you know, it's pure gold … I think protecting the IP when it comes to opening, but allowing a massive cross-collaboration when it comes to everything else, that isn't absolutely precious, and could result in the company just losing its edge." (e7i)*

A biological technology enterprise considers the legalities of protecting their resources:

> *"Technologies, ideas/knowledge, intellectual property: they're all just different sides of the essentially what is the same coin in my mind. Intellectual property is how you're sort of protecting [them] … and wrapping them up in a kind of a legal wrapper." (e10i)*

Yet, it is extremely expensive for SMEs to enact, oftentimes beyond what their budgets allow. It is often risky to leave their innovation and organisation to be so vulnerable, and so this is an identified area of support needed for two of the sampled enterprises (within the biological and agricultural technology subsectors, respectively). Their new innovations are claimed to be safe to emerge in the life science marketplace:

> *"It's extremely expensive to put in place, and most startups can't afford that … It does not protect the inventor. And you're talking about enterprise resilience. Resilience is coming from the inventor … It's the inventor who's trying something new and risky. And it needs support for there to be something new to emerge." (e11i)*

> *"The difficulty with intellectual property is you really need the funds to protect it." (e13i)*

Impeded by the changing UK regulations following BREXIT, legal protections are a complex issue for life science SMEs, especially if they already practice open innovation. With it being so widely discussed, unprompted, the influence is included within the final model. The following emerging theme regarding the investor intervention of UK life science SMEs is now considered.

Investor Intervention

With it being included within four survey responses and 11 of the interview transcripts, investor intervention frequently emerged in the qualitative data as motivating UK life science SMEs to practice organisational resilience and open innovation. Due to most (but not all) of the following quotations regarding investment from outside the enterprise, this emergent theme is allocated as an external influence (F3). Life science financiers can not only offer vital capital,

but also expertise and contacts. This section explores if their interventions are influential of the concepts.

One enterprise found that research and development is hard without money (and intellectual property) and so abiding by investor instruction is arguably obligatory for their growth:

> *"Money and IP are key influences - without these to start with innovation is either hard (without money) and pointless (if no IP)." (e3s)*

Another enterprise does not seek external investment, and instead is self-reliant on funding (and other resources) from internal stakeholders. Their innovation models are not influenced by this though, which implies that they practice closed innovation, independent from the influence of investors:

> *"If we need any resources, we will find and fund them. Funding internally is not usually an issue … If we want to approach an external resource, we will, but I would not count these as stakeholders at the current time. Our innovation will not be swayed by these factors, though we may collect ideas from any of these sources." (e4s)*

Pessimistically, investors are said by one enterprise, to "dominate any significant decisions" (e9s), and therefore want overarching control of their funded enterprises. Another enterprise only listed their funding sources, such as angel investors and government, without divulging the influence of their invention within the enterprise (e20s). In the early stages of an aquaculture enterprise (below), they were very vulnerable due to a lack of financial resources. Yet, their organisational resilience was enhanced by their new investors, who gratefully invested to grow their business to achieve a sustainable commercial income:

> *"We had some sticky moments in the early parts of the development where our cash position was fairly fragile, so finding financial supporters that were willing to invest in us and move us into a position where our commercial income could sustain us, was really important." (e1i)*

Beyond funding, some investors may take an active role by intervening in operations, as evidenced by the following life science business support enterprise. Their funders motivated them to conduct better risk management, which again, enhanced their organisational resilience. Also suggesting that there is an expectation that investors also provide market advice and industry contacts, which is cited to be influential of open innovation:

> *"Investor intervention may want you to have better risk management, but most investors idea of risk management is what sort of backup have you got for the computers? It's unlikely that they've jumped much further than that. … You may get people saying 'That's a small market, so can we use this technology in bigger markets, that may lead to more open innovation?' That may be a concern." (e2i)*

Agreeing with e2i, a medical technology enterprise has been instructed by Welsh government to support other industry actors to receive funding:

> *"If you have an investor coming into your organisation, they should be able to contribute more than money … Investor intervention potentially would also increase open innovation because they might open peoples' eyes to say 'Listen, through my network, I think it would be valuable to engage with this organisation as well'." (e4i)*

A medical technology enterprise claimed below that there is a risk, whereby investors can have a negative influence upon organisational resilience. Investors hold the power to withdraw their multiple million pound funding streams, causing the SME to have to scale right back. This led them to relocate to the UK, as they were determined not to fail. Now, they have an understanding investor, but have also learned to be very frugal with their spending, whilst they still have small revenue. They are currently in an awkward position regarding their organisational resilience.

> *"We have an investor who sees that his return on investment isn't necessarily improved by the strategy, but not enough for him to be willing to dilute his shareholding in the business. From that perspective, it's quite hard to manage, because we are holding back from trying to develop the business." (e3i)*

Financiers can also be a source of motivation for the owner-managers, as the investors are not only investing in the success of the life science enterprise, but also in the development of the individuals running it, which is cited to influence organisational resilience. A biological technology enterprise quotes feedback from their funder:

> *"'I always invest in your companies because you don't stop, you'll keep going and all it takes is one thing to go right and we're all very rich, and it's like that's the plan.' That's why I do this. So, yeah, so I mean, yeah, resilience." (e5i)*

Equally, a biological technology enterprise is considering relocation, but this time, out of the UK. They were denied 'Horizon 2020: Phase One' grant based on their location. They are eager

to practice open innovation with EU companies, to access both their investment and ideas (e11i). An example of the EU government investors intervening in the business operations, to encourage open models of innovation on the continent. Investor attitude towards openness is said, by another biological technology enterprise (quoted below), to have had a huge influence on how their business operates. Funders that have an amenable and unguarded approach influences open innovation. On the flip side, there are financiers that want complete control over things, which leads to closed innovation:

> *"We do have investors, so they are more open, and that is why we are also open. So, they don't have any particular issues, let's say, on being more innovative, and because of that we are able to do [it]. But there are closed investors who comes in, and they want complete control over all things, [so] then we have to become a closed innovator." (e6i)*

Equally, a medical technology enterprise found that their investors' influence how open they were. This motivates them to have a mixed approach, of keeping some things private, but also publish their results too:

> *"[I] can imagine some investors saying we want to keep it private and we've talked potential investors that weren't impressed that we haven't published. That's why we did do it. So you know either way." (e9i)*

Claiming previous organisational naivety and vulnerability, the following medical technology enterprise now acknowledges they make smarter use of investment by being completely transparent (which they repeatedly relate to being open). They are now taking moral and strategic steps toward their organisational resilience. A top-down approach by their management team, as the owner-managers currently fund the enterprise:

> *"There's full transparency, at least for me, of what the expectations were from our bosses [who] are the investors essentially, that's how you think any company, such as ours, should look at that money, and look at what we do, until we start selling and making revenue … In a perfect world, you want them to know exactly what you're dealing with, because then they can help you with finance and understand, but also, they can probably offer some good advice, or at least, some good networking." (e7i)*

Lastly, two enterprises operating in the biological technology and pharmaceutical subsectors respectively (both enterprises aged under 10 years), made a strong association between survival and life science investment:

> *"As a founder, I'm not worried about resilience. You're really worried about trying to survive, and that survival is really from investment, particularly within their sector." (e10i)*

> *"We had a private investor come in as well and that sort of really helped us along the way at that period." (e12i)*

As every enterprise is complex and unique, so is the influence of their investors' interventions on the dual concepts. Some of the sample found that investors offered finance and sectoral knowledge, which benefits the organisational resilience of those they capitalise. They can also provide networking opportunities to share ideas, therefore influencing open innovation. But they can also be too controlling to ensure their return-on-investment and can clash with the organisation vision of the owner-managers and employees. Due to the vast number of responses of this emergent theme, it will be included in the final model of influences of the dual concepts. Next, marketing is considered as an influence of the combined concepts.

Market Research

Marketing is a business function that is emergent from the qualitative data, with it being included within four survey responses and 10 interview transcripts. It is allocated as an internal influence (F1). Through conducting market research, UK life science SMEs can identify opportunities and threats for organisational resilience, and potential collaborations for open innovation. To begin, one of the sampled enterprises uses their market research to influence their organisational resilience:

> *"We continually watch the behaviour of partners/competitors to maintain our resilience." (e4s)*

Another finds many different methods to gain market feedback to influence both concepts, but they are limited by low financial resources. They "find as many ways as possible to get support and feedback that does not involve borrowing money" (e55s). Also, the complexity and speed of consumer change and social benefit is also monitored by the following enterprises:

> *"The culture of continual improvement as the complexity of the customer requirements from us increases." (e73s)*

> *"Speed of consumer change." (e120s)*

> *"For us to work in the marketplace, then we have to engage consumers through marketing, so I think that will be a societal benefit." (e1i)*

Although market research is deemed influential of organisational research, a life science business support enterprise (quoted next) was unsure of its influence upon open innovation. When researching potential life science partners, it is claimed to be important for them to consider if they could then access their customers. Patients with lived experience have unique expertise of their conditions, and can therefore be used to guide and enhance their innovation:

> *"Market research [is] influential ... I'm not sure it links really to open innovation, but certainly links into resilience." (e2i)*

As an interesting competition tactic, two medical technology enterprises (both male-led) conduct market research to identify competitors. Then, they keep them in near proximity for healthy rivalries, open collaborations, and validation of their innovation:

> *"We're trying keep our enemies as close as possible. So we probably have one or two, sort of, direct competitors, and we definitely keep fairly close contact with them, so it's friendly fire, and that's healthy to have more than just one company, more than one product, because it generally improves the awareness and uptake of that device. If you're the only one, then it can be a hard battle to convince people that that's the right one, whereas if there are other products in the market, doing the same thing, it validates your technology." (e3i)*

> *"There's so many competitors ... The only thing that [management] record when it comes to threats to a company survival is competition ... If [the competition] are opening the doors or marketing, that's fine because as long as we're aware of the opportunity that's the main thing ... You know there's going to be competition. If there wasn't, it means we're not in the right market. You know there has to be competition because it means that there's something to go for and there's a big enough that they're getting invested in." (e7i)*

A medical technology enterprise has advised that their market research provides valuable marketplace information that can increase both (a) organisational resilience as it can change their strategies, and (b) open innovation as it brings forth new concepts and opportunities that they may have been unaware of:

> *"[It] provides additional knowledge, if the market research provides, you know, valuable information that can increase resilience because it can change its strategy ... In terms of open innovation, market research can bring forward concepts or opportunities that the organisation might not have been aware of." (e4i)*

Yet, a biological technology enterprise has found that market research was only influential of organisational resilience. They conduct their due diligence to identify threats or market issues that they can be proactive in tackling. However, they do not believe it influences open innovation (e6i). Fortunately, biological and medical technology enterprises (cited below, both operating from Scotland and male-led) have self-identified themselves as having advantageous positions within the UK life science ecosystem:

> *"Basically in industry, none of them, we can see as a competitor" (e8i)*

> *"We've looked at potential collaborations with other medical device, large medical device companies internationally, but we are the market leaders." (e9i)*

It is said, by another biological technology enterprise (next), that market research is very valuable to get insights from the public. Otherwise, they do not have access to patient advocates on their programmes. They are so far upstream from the end-user, that they feel quite removed, and they don't have the resources to close that gap. Although this is an interesting point, there is no comment on how this influences the concepts:

> *"Generally speaking, it takes a lot of time and effort to engage and find the right person and all of that type of thing." (e10i)*

Finally, a pharmaceutical enterprise (e16i) has identified the minimal service offering of their larger competitors. This SME has since designed a unique selling proposition, by (a) being more approachable: "we like to be a laboratory-down-the-corridor for our clients", (b) offer more in-depth interpretations of their clinical research results, and (c) charging lower costs.

The qualitative data coded to this emergent theme has demonstrated that market research is a beneficial influence for both concepts, but varies between the sampled UK life science enterprises. Therefore, it will be included in the final model of influences. The following emergent code considers the qualitative responses regarding the attitude and approach of management as influential of organisational resilience and open innovation.

Management Attitude

Although other management themes were considered as internal influences, the attitude of senior management only emerged (and is well-cited) within the qualitative data, with it being discussed in four survey responses and seven interview transcripts. Likewise, it is allocated as

an internal influence (F1). The attitude of the owner-managers is explored as influential, as a supportive attitude from the top of the enterprise may help them practice organisational resilience to threats, and also be more open in their innovation models. On the flip side, cautious attitudes may restrict both concepts within their business. To commence, the following multiple enterprises claim that owner-managers are motivated to support innovativeness:

> *"Key factor is motivation of the senior management/leadership team to support such innovations." (e12s)*
>
> *"Strong Leadership. All have an influence." (e52s)*
>
> *"To have true innovation in an organisation you need a person at the top of the buisness(sp.) that understands the capabilities of the business, and the markets around the business. So many businesses have un-powered Innovation Managers who can't really implement change." (e70s)*
>
> *"The management is one person, having the ability to discuss matters and bounce ideas around may have helped." (e89s)*

Two medical technology enterprises assert that the determination of their management is influential of their survival:

> *"I think we're determined not to fail." (e3i)*
>
> *"I think resilience, yes, we've been at it for five years, and basically, we still keep going, because at the end of the day, we can save one life, you know, that would make it much worthwhile." (e8i)*

The subsequent biological technology enterprise does not have any policies regarding organisational resilience. It is not concerned by it at all. They rely on flexibility to create new business plans per innovation, of which they have a diverse portfolio. Using an analogy to compare the management attitude of other businesses, to their flexible approach to problem-solving, the respondent owner-manager made the following description:

> *"What I want businesses to do: they've got a hammer and every single solution they're trying to fix is a nail. Whereas I'm very much the opposite, it's like I'm a claw hammer on the multi tool. But things are only a problem if you look at everything as having one solution. And one application." (e5i)*

Yet, not all enterprises are as flexible or ready. Another biological technology enterprise experiences barriers through a cautious attitude of internal stakeholders and senior management regarding their organisational resilience. Lower to mid-level managers are eager to practice open innovation but are under-powered to facilitate it:

> *"Senior management who has to take decisions and if they are not ready to do that, it will not happen. There is a limitation to the mid or lower level management people who can push these particular things or ideas into place, but it is a senior people who have to do so … When it comes to open innovation, ideas can come in from lower to top management. So it's a reverse idea which goes in, and if it is a really good idea, and if everyone is in line with that particular idea, there is nothing stopping that innovation from happening." (e6i)*

Also, the next biological technology enterprise is not so worried about their organisational resilience. They admire flexibility from their management, as their success is so turbulent. Yet, even though they have a strategic management team, they don't need to look externally as they have healthy levels of resources in-house to innovate:

> *"Organisational resilience for essentially a micro business, as an early-stage spin-out, you're not necessarily worried about it, you know. As a founder, I'm not worried about resilience ... You're up and you're down from any given day-to-day, week-to-week ... There needs to be a need, and a senior management focus … where they think about mitigating risk and how it plays a part. They then still need to go away and invest resources in that ... If you have got a super-duper sort of visionary management team [then you don't need to be open]." (e10i)*

It is claimed by two pharmaceutical enterprises that management attitude influences (a) organisational resilience, as they must have a tough attitude due to predatory life science actors taking advantage of an SME's vulnerability due to their limited resources (e12i); and (b) open innovation, as any open mindsets will influence open models of innovation and business (e16i).

It can be concluded from the qualitative data that the emergent code of management attitude, is a significant influence upon the combined concepts. With enterprises all being complex and unique, the management attitudes and their effects can differ in each organisation, but regardless, they do have an impact, and so will be included within the final model of this research. The following emergent theme of stakeholder diversity is considered as an influence of the combined concepts.

Stakeholder Diversity

Equal in total responses to the commonly-cited influence of Management Attitude (above), stakeholder diversity was discussed by three survey respondents and eight interviewees. This diversity spans across multiple actors in the UK life sciences, and can influence organisational resilience and open innovation in a variety of ways, as evidenced below. As it mainly related

to peripheral stakeholders, this influence is allocated to external influences (F3). The inclusion of a mix of stakeholders was first suggested as an influence within the open survey question. Participating owner-managers listed the parties that have a vested interest in their UK life science SMEs:

> *"Diversity of stakeholders. Multiple and networking. Growing diversity." (e23s)*

> *"[We] have a mix of stakeholders including academia patients regulators commercial pharmaceutical and medical device companies and to the NHS; We have multiple engagements with various stakeholders and members of multi and cross industry consortia." (e35s).*

> *"Collaboration and academic partnership … Industry, Academia, investors. Mutual and multiple. Diverse we are completely open." (e66s)*

The following business support and two medical technology enterprises have respectively explained that the UK government facilitates cross-stakeholder open innovation by mandating industry-academia life science collaboration, in order for them to receive funding. Either as a dual partnership or multi-actor competitions; both of which are quoted as being motivated by BREXIT and COVID. They also motivate cross-border open innovation:

> *"To get the [government] grant, you and a company often have to work with at least one academic institution to get it. There's also schemes whereby you have to work with a company in another country, but post-BREXIT, the government said it would sign up to the EU science thing, but that's not going through … Patient groups and health charities are things that's done in a much lesser scale. When you do one, it's considered quite exotic. It tends to be for underrepresented diseases." (e2i)*

> *"Welsh government said you need to support any sized organisation, not just growth organisations. And therefore, suddenly they had twice, and sometimes three times, as many clients as they'd had previously, so during lockdown, I was flat out." (e4i)*

> *"Grants have that aspect that pushes companies to go the academic route for open innovation. That's the way to get some help. The government don't know it's a bit of an artificial thing." (e9i)*

On a voluntary basis, not facilitated by government, a medical technology enterprise is an active member of the local community, building working relationships with their Chamber of Commerce, a regional bio-cluster, their nearest university, and the NHS, all to expand their capabilities (e3i).

However, it was COVID that taught the following biological technology enterprise that collaboration is key. Achieved with passion, as they not only collaborate with industry, but also, with multiple governments:

> *"Industry we have collaborated, yes, government we have collaborated, and that is during the COVID period, and now so, if there is a requirement where we have to collaborate, we are doing it, and not just government. If it is a bigger body than the government, like [a] consortium of governments trying to find a solution to a cost, we are there, we are helping them." (e6i)*

Equally, a medical technology enterprise lists their various stakeholders (below), both in the UK and European healthcare industries. This wide-ranging collaboration is for the benefit of their research, development, and innovation:

> *"What I ended up doing instead was building a foundation, so that we've got lots of future customers, distribution partners, collaborators in the healthcare industry, key opinion leaders that we've built." (e7i)*

Yet, it is claimed by a pharmaceutical enterprise, that SMEs must be organisationally resilient, otherwise they face major and diverse UK life science actors (cited as big institutions, hospitals, and universities) dominating over them, which is challenging (e12i). To close, another very collaborative pharmaceutical enterprise demonstrated their list of diverse stakeholders, including pharmaceutical SMEs, university research groups, government agencies and the Drug Metabolism Discussion Group (e16i). With so much evidence of influence, stakeholder diversity will be included in the final model. In a similar vein to the consideration of the external jolts of BREXIT and COVID, the following emergent influence of the Russia-Ukraine war is also explored within the qualitative data, next.

Russia-Ukraine War

The conflict began during the writing of this thesis, and so was not included in the first research phase of survey testing, alongside the other external forces of BREXIT and COVID. However, the Russia-Ukraine War did emerge enough in the qualitative dataset (one survey respondent and four interview transcripts discussed it) that it is considered as a possible influence of the concepts. Due to it being outside of the UK life sciences, it is allocated as an external influence (F3).

One enterprise has a key supplier in Russia, but they did not comment if they had been affected (e103s). An aquaculture enterprise (cited below) takes risk planning and mitigation seriously. Claiming that nobody could have had a scenario plan for the Russian invasion of Ukraine. They asked the following questions:

> *"Would most businesses actually invest the time for such events, with such a low likelihood of occurring really? You can under or overplay it, but at the same time, I think you just need to have the right balance, so that you can plan for what you can foresee, right? But beyond that, you just hope you have an organisation with resilience." (e1i)*

The following two medical and biological technology enterprises (respectively - sharing no similar characteristics from the baseline sample data) have had their supply chain and partnerships challenged in Eastern Europe. They suggest that BREXIT and COVID has softened the impact of the war upon the UK life sciences. More-so regarding supply chain resilience, but it is arguably still influential upon organisational resilience:

> *"If BREXIT hadn't happened, the Ukraine-Russian War would have been far, far more significant. But because of those channels of supply from Europe were already challenged and strained, I think it's had less impact than it would have had had we still been in the EU." (e4i)*

> *"It was more of an agile approach which we took, but the war and other scenarios, the global pricing and other scenarios, we have taken a proactive approach. When we saw this coming in, that time itself, we have done the things, and COVID also taught us that we have to do a bit more of a proactive approach." (e6i)*

Lastly, a medical technology enterprise, who practices internationalisation, specifically recruits both Russian and Ukrainian workers, but has found difficulty in now working with Russian research institutes, but not enough for it to impact either concept (e9i).

The above responses have demonstrated that the war has had a mixed impact, but it has prompted UK life sciences into realising that the world is interconnected and no enterprise is completely safe from such disruptions. Some of the sample have had their supply chains disrupted, forcing enterprises to access resources from elsewhere through open innovation, whilst others have been able to mitigate any negative influences by being proactive in their organisational resilience to endure the effects of the war.

Considering the above citations, this emergent theme will not be included within the final model. Due to it seemingly be more influential of supply chain resilience, rather than organisational, and it received no quotations of open innovation. The following emergent theme considers how the ownership and hierarchy of the UK life science SMEs may be influential of organisational resilience and open innovation.

Ownership

Due to models of human resource structure potentially being important to the two concepts, this influence of enterprise ownership is allocated as a demographic influence (F2). It received the discussion of only three of the sampled owner-managers of UK life science SMEs in the qualitative survey question. The socialised model of business ownership by employees is identified:

> *"We are an employee owned company and only have internal stakeholders. We are very self reliant." (e4s)*
>
> *"WE ARE EMPLOYEE OWNED." (e13s)*
>
> *"Employee owned company." (e44s)*

However, none provided a further comment to analyse, so it warrants further investigation. Especially in comparison to hierarchies in free market models. Ownership will, therefore, not feature as an influence in the final model. Next up, the influence of the very-recent developments of artificial intelligence is considered as an emergent influence of organisational resilience and open innovation.

Artificial Intelligence

Although the advancements of artificial intelligence (commonly 'AI') is deemed a "hot, hot topic" (e7i) for the UK life sciences at the moment, only two of the sampled owner-managers discussed it within the interview. Due to its potential impact coming from outside UK life science SMEs, it is allocated as an external influence (F3). Two enterprises (both male-led, and the enterprises aged under five years) are exploiting this new technology within their respective medical and biological technology business models. Only the latter enterprise considers its influence upon the concepts:

> *"It's a medical device, but also a type of software platform which we promote as an AI ... To me AI doesn't truly exist. It's more algorithms essentially but very, very good algorithms." (e7i)*

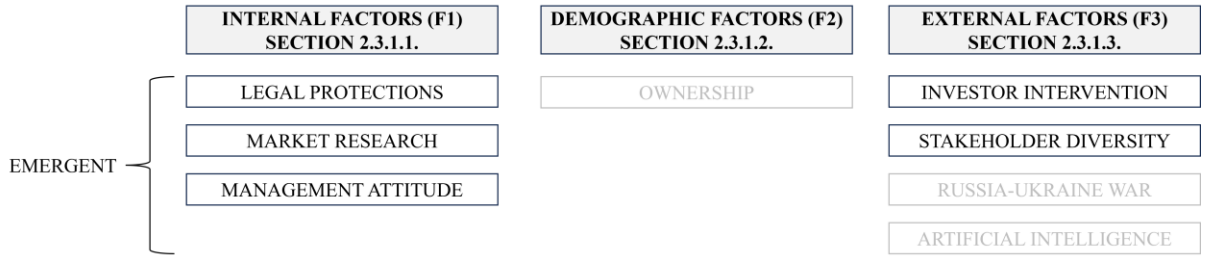
> *"[It] is not something that we really transfer either side of that permeable barrier that sits exclusively within the company and the things that go into that are ideas and disease targets." (e10i)*

Artificial intelligence is very topical, and certainly worthy of further investigation. However, despite having the capability to enhance UK life science SMEs' organisational resilience and models of innovation, this influence will be disregarded from the final model of influences. Due to the lack of citations. This ends the consideration of emergent themes.

Conclusion of Emergent Coding

In this second phase of thematic analysis, emergent coding was applied to eight commonly cited influences arising in the interview transcripts. They were then analysed to determine if they have significant influence of the combined concepts. Five of those eight emergent influences were validated, with three ('Ownership', 'Russia-Ukraine War', and 'Advances in Artificial Intelligence') being disregarded as insignificant. These results are displayed in the following version of the RQ2 model of influences (Figure 41).

Figure 41: RQ2: Model (Concluding Validation Stage 3: Emergent)



Conclusion of Qualitative Findings for RQ2

The qualitative stage of analysis contributes to the answer of RQ2, regarding influences of the two concepts, by firstly validate or invalidate the findings of the regression, in the previous quantitative method. This informed this phase of analysis as by using those nine statistically significant influences as a priori coding, this research found many of them were validated by the qualitative data. However, two were disregarded as insignificantly influential of the two concepts of organisational resilience and open innovation, which highlights the advantages of using an iterative, mixed method approach for accuracy (Figure 39). Additionally, to

supplement the a priori coding, nine commonly discussed themes were identified by the researcher, and assigned as emergent codes. Again, most were validated when using thematic analysis to determine if they are significant, however three were disregarded due to a lack of evidence of influence upon the dual concepts (Figure 41).

Therefore, it can be concluded that this qualitative phase of research for RQ2 emphasises the utility of a multifaceted approach, demonstrating that the significant influences of the combined concepts are not only diverse and complex, but also contingent **(**Lawrence & Lorsch, 1969; Tannenbaum & Schmidt, 1958) upon internal and external environments of the sampled UK life science SMEs, with demographics playing a lesser role. The following section concludes the overall analysis of the mixed method research findings.

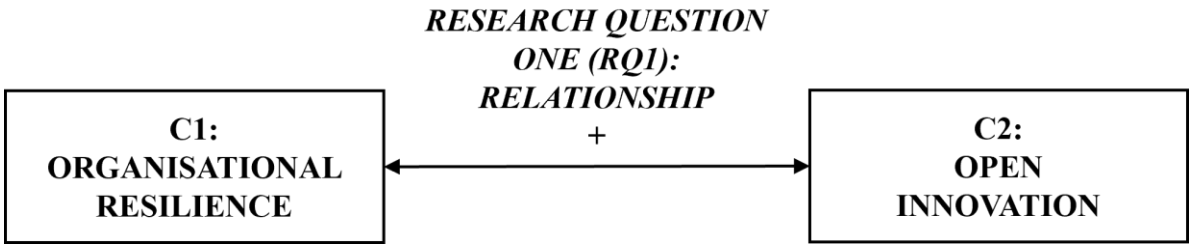
4.4. Concluding the Analysis of Findings

The purpose of this chapter is to report upon and interpret the data collected across the mixed methods, to answer the following two research questions, and provide a significant and original contribution to knowledge:

4.4.1. How are the Concepts Related? (RQ1)

After measuring the two concepts separately, their data was then analysed against each other to answer RQ1, through rigorous quantitative testing. The statistically calculated result was that the two concepts of organisational resilience and open innovation are independent of each other. With a P-value (P=0.085) that is higher than the standard alpha-value (A=0.05), it means that it is *not* a significant relationship. However, the underpowering of the sample justifies the need for the further qualitative testing to ensure the accuracy of accepting that null hypothesis. Moreover, although not statistically significant, there was an association present, and it had a positive direction, meaning that both concepts increase together. Complementing the empirical analysis, the qualitative analysis improved the strength and direction of the relationship between the concepts, leading to a more assured outcome that there is at least a moderate and positive connection (Figure 42). This provides an original contribution to knowledge regarding UK life science SMEs, and it will be compared to the literature in the following discussion chapter.

Figure 42: RQ1: Final Empirical Model



The findings for RQ1 connect to general systems theory in a two ways. Firstly, the initial quantitative analysis calculates the concepts' interdependence. Even though the results didn't show statistically significant dependence between organisational resilience and open innovation, the research acknowledges their potential moderate interaction, which also aligns with general systems theory that elements influence each other. The univariate analyses treat organisational resilience and open innovation as separate entities, aligning with the concept of subsystems within a larger system (the organisation itself).

General systems theory proposes the analysis of a system as a whole, not just its isolated parts, and so the need for the further qualitative analysis is due to the underpowered sample of the quantitative findings, reflecting the holistic principle. Here, the quantitative or qualitative data alone may not have captured the complete picture, so including both analyses strengthens the understanding of the relationship between these concepts within the system of UK life science SMEs. The combined effect of both organisational resilience and open innovation might lead to a more robust outcome for UK life science SMEs, even if a strictly cause-and-effect relationship wasn't established quantitatively. Finally, general systems theory suggests that systems are dynamic, and the findings here acknowledge that it is a cross-sectional snapshot. Significant to the UK life sciences and to now.

4.4.2. How are the Concepts Influenced? (RQ2)

With the above moderate relationship being determined by the mixed methods in the previous research question, the concepts were uniquely combined into one interaction variable (C1*C2) to answer RQ2, by efficiently measuring what influences them both in unison. After rigorously testing the various methods of variable selection, the most accurate technique calculated nine significant influences of the combined concepts. In order of significance, starting with the most, they are:

- Internationalisation (P=0.000)
- Management Qualifications: Science (P=0.001)
- Supply Chain: Manufacturer (P=0.006)
- Management Team Size (P=0.012)
- UK Country of Operation: Scotland (P=0.014)
- Enterprise Size: Medium (P=0.035)
- Supply Chain: Distributor (P=0.064)
- Enterprise Size: Small (P=0.072)
- Subsector: Business Support (P=0.076)

These nine influences were then used as a priori coding themes to extract quotations from the qualitative data, to interpret and validate the regression model. Internationalisation was also very frequently cited within the dataset, cementing itself as the most influential across the mixed methods. However, due to a lack of descriptive or experiential evidence, the following were disregarded from the final model of significant influences:

× Enterprise Size: Medium
× Supply Chain: Distributor

The statistical model of nine significant influences explained 30.3% of the combined concepts (C1*C2), which left an explanatory power deficit of 69.7%. To satisfy this deficit emergent coding was applied to extract further influences that were identified as commonly quoted within the interview responses. In alphabetical order, they are:

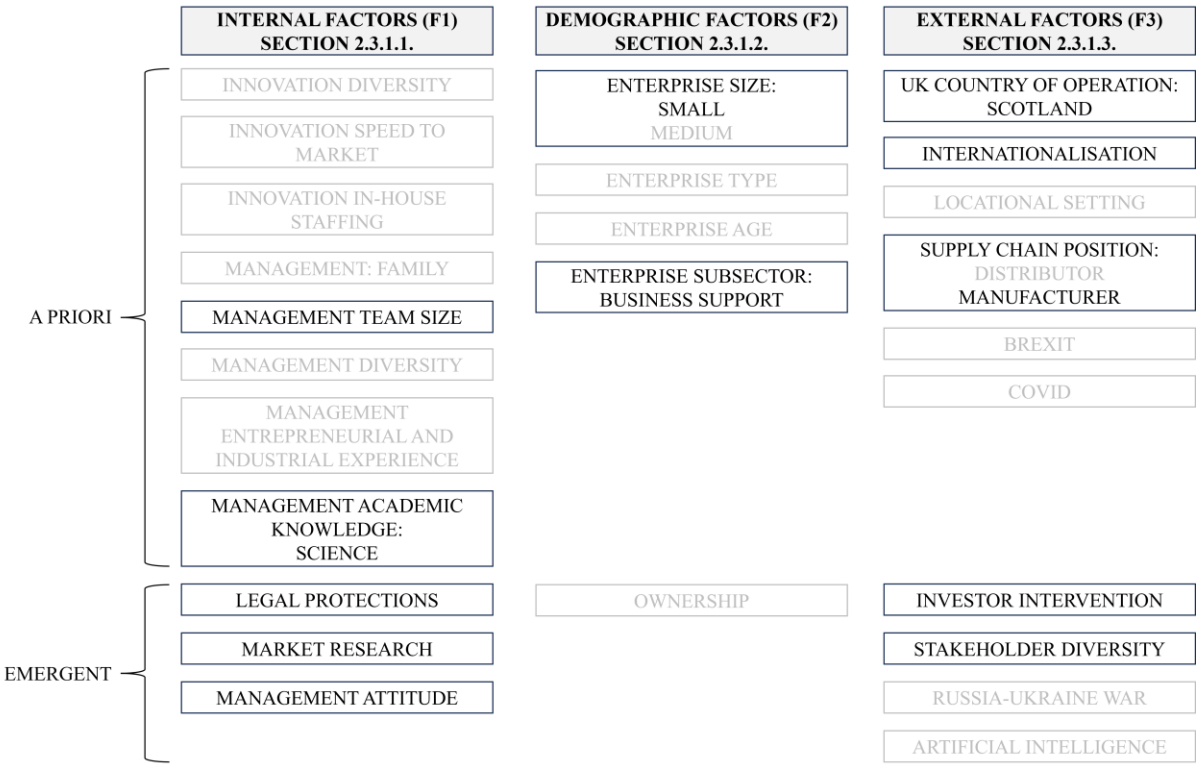
- Artificial Intelligence
- Investor Intervention
- Legal Protections
- Management Attitude
- Market Research
- Ownership
- Russia-Ukraine War
- Stakeholder Diversity

Legal Protections was very frequently quoted, and so its influence upon the combined concepts is deemed the most significant emergent code. Yet, again, this model of emergent influences was evaluated to determine if there was sufficient qualitative evidence that they are influential, which has led to the following being disregarded for the final model of influences:

- × Artificial Intelligence
- × Ownership
- × Russia-Ukraine War

The remaining a priori and emergent themes were allocated back into their relevant factors, with internal (F1) and external (F3) each having an equal number of significant influences, meaning that UK life science SMEs should allocate their limited resources to both inner and outer considerations, in order to achieve both organisational resilience and open innovation (Figure 43).

Figure 43: RQ2: Final Empirical Model



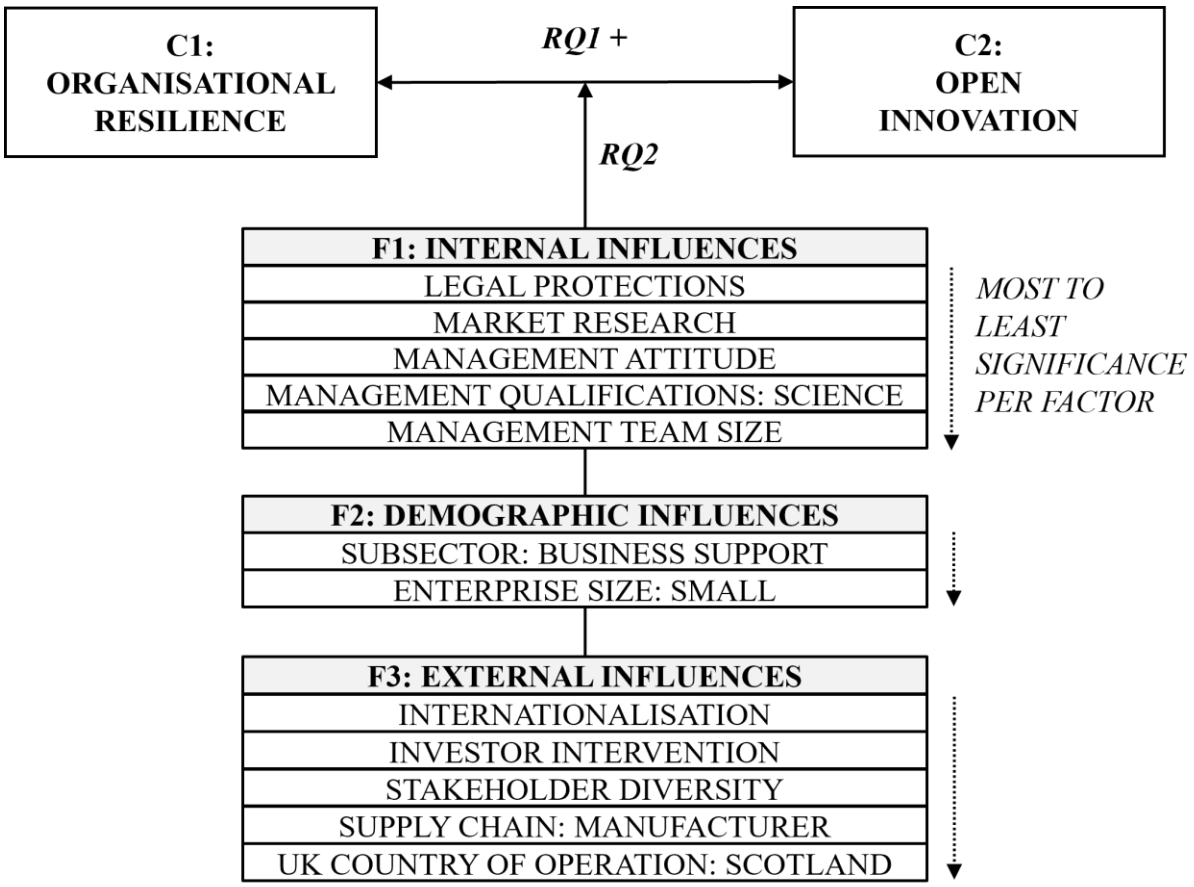
The findings for RQ2 contribute to contingency theory, by identifying 12 resultant diverse and complex influences of both organisational resilience and open innovation, reinforcing that there is not a one-size-fits-all approach. For example, the influence of UK life science SMEs

operating in Scotland, being of a small size, and functioning from within the business support subsector, all suggests that there is an optimal approach to practice the dual concepts, depending on the organisation's characteristics and context. Furthermore, the finding that both internal and external factors have equally represented influences emphasises the importance of considering both aspects equally, when enhancing organisational resilience through practicing open innovation. The unexpected lack of significance of BREXIT, COVID, the Russia-Ukraine war, and the advances in artificial intelligence, reinforces that such external forces may only contingent to specific sectors and systems.

*4.4.3. Conclusion to the Analysis for both Research Questions (RQ1*RQ2)*

In the formative measurement model for RQ1*RQ2 (Figure 13), the first question was represented by a dotted line due to not knowing the relationship between the concepts. However, the results of this research have provided a significant and original contribution to knowledge by measuring a moderate relationship, and so the final model has revised it to be a bold line. Furthermore, a plus sign (+) is added to represent the positive direction of their relationship, whereby they both increase together. For the second question, the resultant 12 influences, across the three factors are all displayed within the subsequent final model. Achieved by representing the results of the quantitative regression analysis, and qualitative thematic analysis (both a priori and emergent coding). Through the above multi-stage validation, Figure 44 displays the accurate, comprehensive, and diverse final model of relationship and influences of the combined concepts of organisational resilience and open innovation.

Figure 44: RQ1*RQ2: Final Empirical Model



The findings have revealed the complex relationship and diverse influences of the combined concepts, to provide a breadth and depth of knowledge, specific to UK life science SMEs. The results are interpreted and evaluated against the reviewed literature in the next chapter, to identify what agrees or disagrees with the existing body of theory. Otherwise, it can provide original knowledge by answering ongoing debates and unanswered questions, for the benefit of ascertaining recommendations for future research.

Chapter 5: Discussion

In the previous chapter, the two concepts of organisational resilience and open innovation were comprehensively measured, both quantitively and qualitatively, to answer the two research questions. This chapter synthesises the results with the previously review literature to determine if it significantly corroborates or conflicts with current research or contributes originality through unique findings not found elsewhere in other relevant studies. The format of this chapter will relate the analysed data to the reviewed literature to identify how this research provides a significant and original contribution. In relation to answering how the two concepts relate (RQ1) by first considering the two concepts independently (C1, C2), and then together (C1*C2). Then, it is considered how they are influenced (RQ2) by probing the resultant significant influences (F1-3) against the literature.

5.1. Discussing the Relationship of the Concepts (RQ1)

This section will first consider the measurement of the standalone concepts of organisational resilience and open innovation of United Kingdom (UK) life science small and medium-sized enterprises (SMEs), against the cited literature. Then, the research concepts will be considered as an interaction to answer the first research question (RQ1) of how the concepts relate.

5.1.1. Organisational Resilience (C1)

Encouragingly, for the first individual concept, 42 respondents (the majority, at 35.6% of the sample) quantitively rated themselves as practicing a medium level of organisational resilience (C1). From the measurement scale applied, this level of resilience is defined by British Standards Institute (2014, as cited in Pescaroli et al., 2020) as: “Strategic directions have been set, with understandings of the internal and external context, including its dynamics. Programs and practices are not fully coherent and consistent, but there are steps in place for improving” (p. 407). This definition is relevant, as the later investigation of influences aims to understand the internal and external context, as well as any demographic factors. Also, the steps for improving is cited as a fundamental aim of resilient enterprises “to engage in organization-building under conditions of extreme uncertainty” (Ries, 2011, p. 38).

In fact, it is encouraging that accumulatively, a vast majority (114 respondents, 96.6% of the sample) have at least *some* organisational resilience. Surprising, as it goes against the

pessimistic statistics of enterprise failures (Caliendo et al., 2009; Office for Life Sciences, 2011; Shaw, 2023). However, there may be an instance of survivor bias (Fortuin & Omta, 2008; Nikolić et al., 2019) whereby failed enterprises are more difficult to access to sample. Alternatively, it could be due to prideful owner-managers (Williams et al., 2017) not disclosing their true vulnerability. Unfortunately, four respondents (3.4% of the sample) stated that they have no organisational resilience. Due to the survey capturing a cross-sectional snapshot of their current rating of organisational resilience (Table 14), it is unknown if these four UK life science SMEs were just starting-up and yet to become resilient, or sadly, due to fail.

Table 14: Identified Levels of Organisational Resilience (British Standards Institute, 2014, as cited in Pescaroli et al., 2020)

None 3.4% **Least Identified**	**Low** 33.9%	**Medium** 35.6% **Most Identified**	**High** 27.1%

5.1.2. Open Innovation (C2)

For the second distinct concept of open innovation (C2), 47 respondents (a majority, at 39.8% of the sample) practice a 'partially open' model of innovation. This was the most frequently rated level of open innovation, whereby the "methodology and underlying science is disclosed so that external parties can suggest new and relevant opportunities. External parties can then contribute with rational ideas, to participate in 'sense making'" (Nilsson & Minssen, 2018, p. 774). This links to the transfer of valuable ideas across enterprise boundaries, which is fundamental to the original definition of open innovation by Chesbrough (2003, 2019). The least frequently cited is 'partially closed' models of innovation, identified by six respondents (5.1% of the sample). It is a surprising outcome that there is such a stark contrast between the most and least identified levels, situated next to each other, mid-scale (Table 15). This requires further investigation in the qualitative data.

Table 15: Identified Levels of Open Innovation (Nilsson & Minssen, 2018)

Completely Closed 10.2%	**Mainly Closed** 27.1%	**Partially Closed** 5.1% **Least Identified**	**Partially Open** 39.8% **Most Identified**	**Mainly Open** 11.0%	**Completely Open** 6.8%

*5.1.3. Their Interaction (C1*C2)*

Now that the two concepts have been discussed individually, this section now considers their interrelationship from a systems perspective (von Bertalanffy, 1928/1968), specifically as an interaction between organisational resilience and open innovation. Following the 2007-2008 global financial crisis, there was an upsurge in research upon the individual concepts of organisational resilience and open innovation (Annarelli & Nonino, 2016; Duchek, 2020; Korber & McNaughton, 2018; Lopes & de Carvalho, 2018). This unique research regarding their relationship contributes to another potential, contemporary upsurge of academic interest, triggered by the similar significant world events, including BREXIT, COVID, and the Russia-Ukraine war. Peer-reviewed sources do consider relationships between related business management concepts which informed ongoing debates into if these concepts are dependent upon each other (RQ1). For example, Acquaah et al. (2011) investigated the interrelationships of strategy, competition, and performance; Marom et al. (2019) studied the associations of size, innovation, and risk; and also, Santoro et al., (2020) examined the interlink between organisational resilience and success. However, it is only the recent research of Ju (2023) and Mirghaderi et al. (2023) that specifically address the relationship of these concepts, which is discussed next.

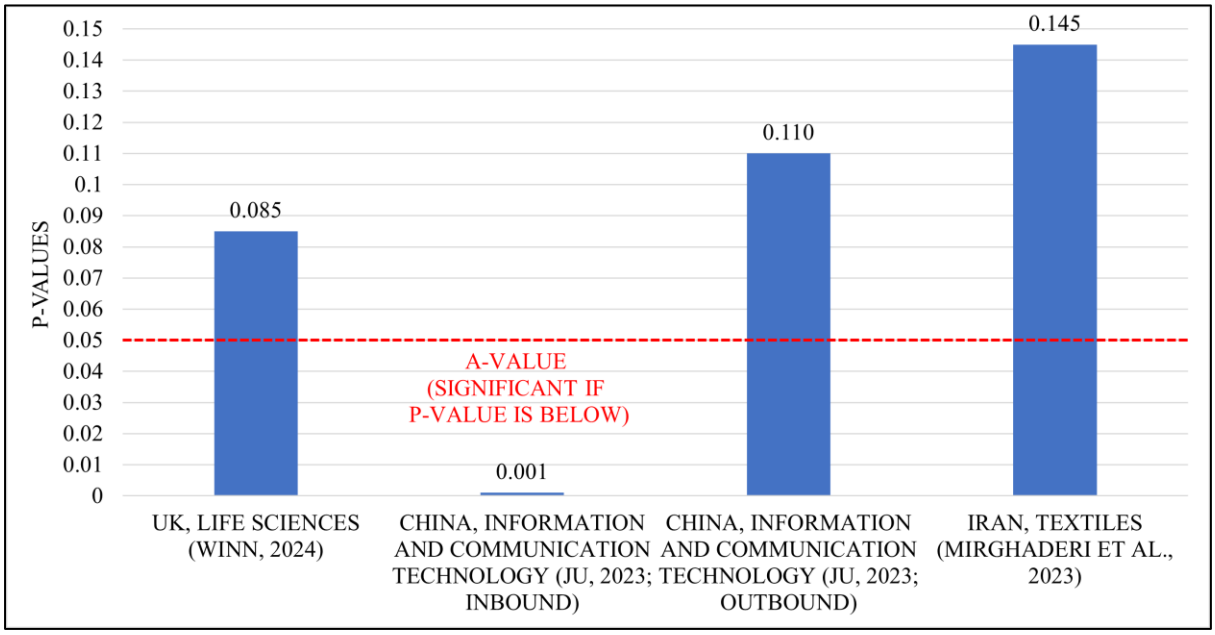
Strength: Moderate

The mixed methods research advises that a symbiosis of the concepts is somewhat true. As displayed against Ju (2023) and Mirghaderi et al. (2023) in Figure 45 and Appendix B: Quantified Relationship in Similar Research (P-values), the quantitative data for this research calculates the 'asymptotic significance' of P=0.085. For this research, P=0.085 is interpreted as being a statistically insignificant (8.5%) relationship between the two variables of organisational resilience and open innovation in the wider population. This P-value is benchmarked against the results of the similar research by Ju (2023, p. 14) which calculates the relationship of organisational resilience, and inbound (P=<0.001) and outbound (P=0.110) open innovation, separately. Also, Mirghaderi et al. (2023, p. 12) calculates their relationship as even less significant (P=0.145), which has the implication that there is a relationship between the two concepts, but it is not significant.

Although their research is based in different countries and sectors, their findings add validity to the results of *this* research, by the relationship for the UK life sciences being plotted within

a similar range. P-values, by nature, can only be between zero and one. By using the standardised alpha value (A=0.05) to determine significance, Ju (2023) has evidenced that there is only a significant relationship between organisational resilience and *inbound* open innovation. However, all three findings (Ju, 2023; Mirghaderi et al., 2023; and this research) are close to the standardised alpha value, predicting that there is in fact a general relationship that is moderate, if not statistically significant. This contributes to the work of Woodward (1965), whereby a common relationship is identified across systems, however, more research across other countries and sectors will be needed to validate this universal range.

Figure 45: Comparison of Significance of Concepts' Relationship Across Contexts



The qualitative data portrayed more connectivity, with eight enterprises (50% of the sample) confirming a relationship between organisational resilience and open innovation. This enhances the finding of their co-dependence, as it implies the notion that the concepts are more associated than the quantitative data promotes. It also reinforces the research of van de Vrande et al. (2009) which considered open innovation as a resilience-enhancing activity for enterprises "to open up new markets … to secure revenues and to maintain growth" (p. 435). Some enterprises suggest that the concepts are fundamentally "linked" (e1i, e3i, e5i – all male-led enterprises), which reflects upon the fact that due to their limited size and resources, enterprises are often *forced* to look elsewhere for resources to increase their organisational resilience (Branicki et al., 2018; Bak et al., 2020; Escoffier et al., 2016; Pal et al., 2014). One

enterprise argued for the ‘importance’ they have upon each other (e2i), which is true for the wider success of the currently fragmented life sciences ecosystem (Goldberg, 2020).

Four enterprises (25% of the sample) perceived no relationship at all between the concepts of organisational resilience and open innovation, which relates to all the above-cited literature of the individual, separate concepts. The remaining four enterprises (25% of the sample) were still unsure of the relationship between organisational resilience and open innovation. This connects to the research of Cormican and O’Sullivan (2004) who identified surviving enterprises being rigorous in their pursuit of efficient, effective, and profitable innovation – somewhat linking the two concepts. Yet there was also later comment that this uncertainty of a connection was present within the academic literature, as there is limited organisational resilience research on the “conceptual relationships and dynamic boundaries” (Verreynne et al., 2018, p. 1122) which are the fundamental features of open innovation.

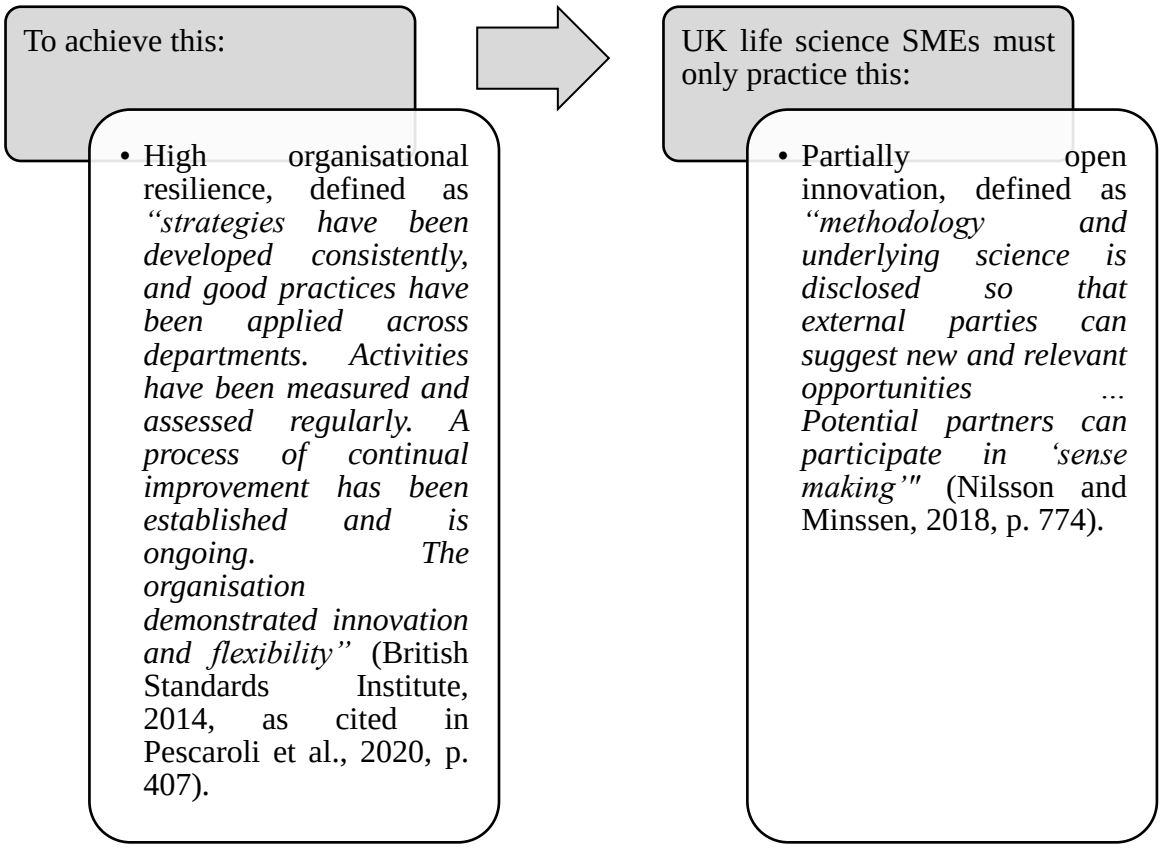
This hesitation from enterprises to open-up their models of innovation is represented in the literature, as being open is very much seen as a risk. Not only due to losing control (Enkel et al., 2009), but also a risk to imitation (Raymond and St-Pierre, 2010) which both enhance their risk of vulnerability. This “may nurture an obsessiveness with ownership” (Veer et al., 2013, p. 9) and keeping to a closed model of innovation. In a similar sample size, Tidd and Bessant (2021) found the same uncertainty of a dependence between the concepts, with four of their eight sampled UK life science SMEs experiencing an undecided relationship between similar themes, so there is no consensus. This has the implication that the concepts’ relationship is nuanced, and contingent on ‘trends’ (e3i) within the UK life sciences (Daft, 2001; Donaldson, 2001; Lawrence & Lorsch, 1969; Tannenbaum & Schmidt, 1958; von Bertalanffy, 1928/1968).

Direction: Positive

Although the relationship between organisational resilience and open innovation is calculated and cited as being moderate, the data also suggests that although there is a positive relationship between the concepts. The models of innovation do gradually open whilst organisational resilience increases. Also, due to where the trendline intercepts the y axis (Figure 27), it shows that the enterprises who practice mainly closed models of innovation have no organisational resilience at all and are vulnerable to failure. This adds validity to the similar research of Marangos and Warren (2017). They argue that UK life science SMEs who practice closed, linear models of innovation, with a focus on internal resources, risk failure within the

marketplace. Yet, it is calculated in this research, that for SMEs to achieve a high level of organisational resilience, enterprises must only practise partially open models of innovation (Figure 46).

Figure 46: Resulting Optimal Outcome with Measurement Definitions of Both Concepts



In terms of the *direction* of the concepts' relationship, eight of the 16 enterprises (50% of the sample) think that there is a positive linear relationship between the concepts (e1i, e2i, e3i, e5i, e6i, e7i, e12i, e13i). Meaning that organisational resilience and open innovation both increase together. This reinforces the positive association of related concepts by Varis and Littunen (2010), who found that during uncertain times, "growth, success and survival, all depend on the ability of firms' to innovate on a continual basis" (p. 129). Although their citation does not specifically address open models of innovation, it does suggest that organisational resilience is dependent, and grows with innovation to improve competitive advantage. Likewise, this adds to the organisational resilience research by Dahles and Susilowati (2015) who reported that "intra-sectoral and multi-sectoral business arrangements represent a longer-term adaptive mechanism" (p. 48). This implies a *positive* relationship between the concepts, later

corroborated by Tidd and Bessant (2021) too. The second research question regarding the influences of the combined concepts, is discussed against the reviewed literature, next.

5.2. Discussing the Influences of the Concepts (RQ2)

Having considered how the two concepts of organisational resilience and open innovation relate, this section considers how they are influenced. Despite being a statistically insignificant relationship, the calculated P-value identified in the mixed methods analysis of RQ1 still indicates a relationship that needs further exploration. The next question, therefore, uniquely investigates the influence of a combination of organisational resilience and open innovation (C1*C2) as a single interaction variable. A limitation of the English language is that there is not a single word or phrase that represents the conceptual synthesis of organisational resilience and open innovation. Instead, it can be described as UK life science enterprises being organisationally resilient but still having permeable boundaries (Howson et al., 2019; e10i). The following sections will compare the resultant influences across the internal (F1), demographic (F2) and external (F3) factors to the cited literature, to discuss how it compares or contributes new knowledge.

5.2.1. Internal Factor of Influences (F1)

This factor (F1) considered significant internal influences related to UK life science enterprises' innovation and management: (1) legal protections, (2) management attitude, (3) scientific qualifications within management, (4) management team size, and (5) market research.

Legal Protections

The first internal influence that has emerged as significant of the dual concepts is that of legal protections of UK life science enterprise data and intellectual property. The coded themes regarding this influence are diverse, with some recognising the influence of such General Data Protection Regulations (GDPR) upon the concepts (e20s, e6i, e7i, e10i). This was agreed and commented upon at-length by Escoffier et al. (2016). Even Marangos and Warren (2017) recommend a formalised contractual agreement of working with fellow SME partners, under the legal protections offered by their funding bodies (cited as the National Health Service or

the Technology Strategy Board[17]) who would be monitoring such facilitated partnerships, to mitigate risk and safeguard their desired outputs.

Acknowledging its influence, two participants had warned of the very high financial cost for UK life science SMEs to protect their data and intellectual property (e11i, e13i – both English and micro-sized enterprises) which is a point that did not appear in the literature. The unwillingness to share or commercialise their intellectual property was also cited in the responses (e144s, e4i) which implies a preference for *closed* innovation, for the "protection of critical know-how" (Veer et al., 2016, p. 1115). Also, due to a fear that partnerships with predatory and dominating larger enterprises will produce unfavourable outcomes for the SMEs (Fortuin & Omta, 2008; Marangos & Warren, 2017; Veer et al., 2016; Zobel and Hagedoorn, 2020). Furthermore, Escoffier et al. (2016) analogises any uncommercialised intellectual property fiercely protected, but sitting in drawers collecting dust, rather than being licenced to other actors to innovate, for social and economic benefit.

Two enterprises claim that some life science subsectors, including aquaculture, pharmaceutical, and medical technology (Life Sciences Scotland, 2023; Welsh Government, 2013, as cited in Howson & Davies, 2018) frequently patent their innovation, as it is impossible to raise investment without such legal protections. Yet, they claim that not everyone is said to understand or respect General Data Protection Regulations anyway (e2i, e6i), which implies that they prefer the freedom to practice openness without such legal restrictions. This bending of the rules was not found within the cited literature. Yet, the need to consider the legalities of protecting the intellectual property (e10i) and other resources, justifies the chosen measurement framework for open innovation by Nilsson and Minssen (2018). They proposed legal standards for life science open innovation, so that collaboration can be more clearly and legitimately defined for both/all partners. However, this comes at a financial cost, which is difficult for SMEs with low resources anyway (e11i, e13i), as this can leave them vulnerable to imitability

[17] Now 'Innovate UK'.

and predation by other UK life science actors. This, therefore, influences their organisational resilience.

Management Attitude

The attitude of the UK life science SME owner-managers was another emergent theme. Such coded responses suggest that the following top-down motivation and determination by management is influential for them to practice organisational resilience and open innovation. Firstly, management motivation (e12s, e70s, e14i) featured in the findings, which was picked up on by Caliendo et al. (2009) who cited nascent entrepreneurs as being motivated to take on risk to practice concepts, such as these. Management determination (e3i, e5i, e8i, e12i) was also well-cited in the responses, which relays the research of Williams et al., (2017) of enterprises determined to "maintain a posture" (p. 751) through a threat by being strategically consistent. And finally, top-down management influence (e6i), which is discussed as an approach for an enterprise to "muddle through" after a threat (Branicki et al., 2018, pp. 1255-1257; Sullivan-Taylor & Branicki, 2011, pp. 9, 11). A surprisingly negative influence of the concepts is that of a strong management vision: "If you have everything at home, you don't need to be going out on the town to kind of get it elsewhere. And so … if you have got a super-duper sort of visionary management team" (e10i), then there is no need to pursue open innovation. This was precisely addressed by Tidd and Bessant (2021), who argue that any previous in-house research and development success, may cause management to become arrogant and not consider technologies that were created externally, and therefore choose closed innovation instead. Managements' attitude to communication (e89s) was not cited within the associated literature, and so is novel to this research, whereby "management is one person [and] having the ability to discuss matters and bounce ideas around may have helped" (e89s).

Scientific Qualifications within Management

With an almost near perfect level of significance (P=0.001) upon the combined concepts, the presence of scientific qualifications within management of UK life science SMEs is deemed highly influential. Especially over business or engineering qualifications, which were also quantitatively tested, but excluded from the final regression model as insignificant. Arguably a positive influence upon open innovation, as although the SME owner-managers may be aware of the commercial potential of their innovation outputs, they are also keen to get external

business specialist knowledge to make up any deficit of entrepreneurial expertise (Ghio et al., 2015; O'Gorman et al., 2008; Wennberg et al., 2011). Equally, having scientists within management means allowing for a top-down approach to feed their highly technical knowledge into innovation strategy and impact (e6i), especially when they have decades of experience (e12i). Collaborative scientists also "tend to fire ideas off each other" with the same SME describing their collaborators as a scientific family (e16i). These strong and open channels to communicate technical information is of benefit to organisational resilience, both internally and externally. Regarding any scientific challenges encountered and the lessons learnt, which further increased their shared skillsets and expertise of SMEs in the field (Fearne et al., 2021).

One of the respondents teaches biotechnology entrepreneurship across multiple universities (e2i), and so this equips scientists to commercialise their expertise (Treanor et al., 2021). Although scientific qualifications being represented in management teams is identified as significantly influential of organisational resilience and open innovation, it is also vital that they supplement this with business management knowledge. Evidenced by the calculated influence of offering life science-specific business services, discussed within the next factor (F2) of demographic influences. However, directors of medical technology are very guarded of the knowledge in their enterprise, and therefore often practice closed innovation (e7i). One enterprise boasted a very strong scientific academic reputation, and that is what attracts their clients to their clinical research (e15i). This can be associated with the strong links kept with academia, for scientists to identify and make best use of knowledge spillovers (Audretsch & Belitski, 2013; Audretsch et al., 2004; Ghio et al., 2015).

Management Team Size

In the research of Romero & Martínez-Román (2012), it was identified that there is a lack of knowledge on whether management team size was influential of open innovation. This research found that it *is* influential of the combined concepts (P=0.012), providing an original contribution to knowledge. With a negative linear relationship (indicated by T=-2.556), the smaller the management team, the more they practice organisational resilience and open models of innovation. Yet, this is scarcely acknowledged within the subsequent qualitative data. Two enterprises have promoted that they conduct excellent communication across their personable small teams, who they affectionately and informally self-identify as a "very friendly bunch" (e12i), and equally reflected by a three-person management team who promote

themselves as effectively working together. Indicated in the following extract: “As a group we're, sort of, effective, and we're very open, and communicating with each other about what we're doing” (e14i). Consequently, the ease of communication across a small management team is a common theme, which corroborates the cited research of Li et al. (2011) who found that smaller teams have easier internal communication of knowledge. Yet, Jones et al. (2014) found that fewer employees can impact the internal “skills spread of the enterprise” (p. 48), so there is mixed research upon this topic, warranting further investigation. However, Gray and Jones (2016) found that owner-managers of Welsh micro-sized enterprises can lead a solitary working life, which could arguably prompt motivation to practice organisational resilience to grow and engage with open innovation to build a professional community.

The finding that the size of management teams is significantly influential of the concepts aligns with the tenets of systems theory, which view organisations as complex systems where elements interact and influence each other (von Bertalanffy, 1928/1968). Internal team communication to exchange knowledge and collaborate is studied by Tidd and Bessant (2021), and so this research contributes that smaller management teams of UK life science SMEs are optimal for the practice of their organisational resilience and open innovation. This enhances the theory of complex adaptive systems, which views organisations as complex systems where such internal (and indeed external) elements interact and influence each other. This finding (and others) highlights the multifaceted nature of teamwork within organisationally resilience and openly innovative enterprises.

Market Research

With it previously being discussed that it is fundamental for organisations to understand the market for resource allocation (Smith, 1776/1977), market research is the final internal influence, and is another emergent theme. It was first introduced by a respondent within the open survey question responses, by them having to “continually watch the behaviour of partners/competitors to maintain [their] resilience” (e4s). Such explicit distinctions were also made that market research was only influential of organisational resilience, and not open innovation (e2i, e6i – both Scottish enterprises). Discussed in the literature, Rothaermel and Deeds (2006) speak of the struggle to get life science innovation to market, and commercialised. Whilst Williams et al. (2017) argued that after a threat to an enterprise, it may mean the business is no longer suited to the new environmental context and require market

research to access other new customer segments. One of the sampled enterprises did agree, as "market research can bring forward concepts or opportunities that the organisation might not have been aware of" (e4i), even though Porter (2004) warns that SMEs may not be able to afford the heavy financial burden of such activities.

Identifying competition is high on the agenda for one enterprise (e3i) to keep their 'enemies' close for healthy rivalries, open collaborations, and validation of their innovation. This idea of co-opeting is well-cited (Carayannis & Campbell, 2011; Kmieciak & Michna, 2018; Porter, 1998), and provides an interesting perspective on competitive strategy for organisational resilience. Furthermore, some enterprises (e8i, e9i – both male-led, Scottish, micro-sized enterprises) do not believe that they have any competition, as they promote themselves as market leaders. Described in the literature as 'blue ocean thinking' (Kim & Mauborgne, 2005; Mirghaderi et al., 2023), and can be advantageous for freedom of openness, but also naïve to the threat of incumbents, and a lack of competition to motivate innovation.

5.2.2. Demographic Factor of Influences (F2)

This factor (F2) considers the demographic characteristics of the sample as influential of the dual concepts. It is identified as the least significant factor but is still populated with two influences: (1) enterprise size, and (2) subsector: business services. The research of Mirghaderi et al. (2023) similarly identifies the significance of demographic influences of the dual concepts.

Enterprise Size

Starting with enterprise size as an influence of the dual concepts, it was proposed that business growth is not linear. Evidenced by one of the sample enterprises, who said: "the company has been small, medium, tiny, nearly non-existent at several times" (e3i). However, the larger, and potentially later-stage, enterprises of small (P=0.076) and medium (P=0.035) sizes are deemed significantly influential of the two combined concepts of organisational resilience and open innovation. Notably, there is a lack of homogeneity within the SME bracket (Companies Act, 2006; Marom et al., 2019; Márquez & Ortiz, 2020), and so there could be definitional ambiguity with the sampled enterprises cited their 'small' enterprises. Oftentimes, 'small' covers all enterprise sizes within the SME bracket, and so it is difficult to qualitatively analyse per size-type.

It was often cited within the qualitative data, that UK life science SMEs are in a “classic startup scenario” (e1i), whereby such-sized enterprises suffer from a lack of resources. This deficit is often financial (e1i, e7i, e8i, e9i, e13i, e15i), whereby they want to offer more but can’t. Not until they have proven themselves (e7i, e8i – both male-led enterprises), particularly as they had a lot to learn (e15i). Two enterprises used marketing to help grow despite resource challenges, specifically mentioning social media (e13i) and a complete rebrand (e15i). Therefore, it can be interpreted that both finances and marketing are also influential of the concepts for small-sized enterprises. There was debate regarding size advantages for both organisational resilience and open innovation (van de Vrande et al., 2009; Xing et al., 2020). Some enterprises confessed that they were resilient as an organisation, due to a lack of bureaucracy (e3i), and a flexibility (e10i), to make policy or procedural changes. Yet several enterprises felt that they were more vulnerable, as there are less personnel to reflect on threats (e2i), they are more likely to fail (e5i), and have more commercial risk involved (e9i). Equally, there was also debate as to if their size was advantageous for open innovation, specifically with larger entities in the UK life science ecosystem (Forés & Camisón, 2016; Santoro et al., 2016).

For example, smaller enterprises were preyed upon by larger businesses to collaborate to disrupt patient pathways (e7i), to problem solve (e7i, e8i), to compete (e7i, e12i), to be cushioned against failure by being entitled to incentives that smaller enterprises aren’t (e12i), and to outsource (e16i). These reinforce the studied collaboration dynamic of large firms > UK small and medium-sized enterprises, who seek such partnerships “to evaluate, utilise and acquire knowledge” (Marangos & Warren, 2017, p. 212). Yet, if enterprises grow to become ‘large’ themselves, they are at risk of becoming “victims of their own success: as they grow and become successful, they lose some of their adaptive capacity. The search for efficiency drives flexibility out. Success dulls strategic sensitivity” (Doz & Kosonen, 2008, p. 6). This can therefore leave such enterprises vulnerable and closed.

Interestingly, early-stage micro-sized enterprises were not calculated as being a significant influence of the combined concepts of organisational resilience and open innovation. This may be due to their stage in the lifecycle, with limited growth, resources, and contacts needed to practice organisational resilience and/or open innovation. Despite some enterprises staying ‘small’ by design (Garengo & Bernardi, 2007; Jarvis, 2019), even if it is seemingly ineffective for their organisational resilience or open innovation.

Subsector: Business Support

Although the business support subsector of the UK life sciences was deemed the only subsector of influence upon the combined concepts (P=0.072). This finding is interesting, as it is the only non-scientific life science subsector measured, which really reinforces the high failure rate of UK *scientific* SMEs (Office for Life Sciences, 2011). However, what is more notable, is that due to its negative T-value (T=-1.820), its significance upon organisational resilience and open innovation can be interpreted as increasing only when it is more infused with the other subsectors' scientific activities. This affirms that the life sciences are most advantageous by blurring their intra-sector boundaries (HM Government, 2021; Pisano, 2011; Porter, 2004).

One of the sampled medical technology enterprises has recognised the success of their own business services within the UK life science sector. Specifically for their organisational resilience, they successfully operate a small consultancy for other SMEs, alongside their scientific research, development, and innovation (e3i). This conglomeration of scientific and business services is not present within the cited literature, but is suitable for further probing due to the success it brings to life science SMEs, as evidenced within the findings. Although much of the sample discussed the subsectors that each enterprise operates within, most SMEs spoke about them in isolation, independent from the concepts of organisational resilience and/or open innovation (e1i, e2i, e4i, e5i, e6i, e7i, e10i, e11i, e13i). This aligns with the quantitative findings and idea that not all the *scientific* subsectors of the life sciences (Life Sciences Scotland, 2023; Welsh Government, 2013, as cited in Howson & Davies, 2018) are significantly influential.

5.2.3. External Factor of Influences (F3)

The third and final factor (F3) considers external influences that are significant for the combined concepts: (1) internationalisation, (2) investor intervention, (3) stakeholder diversity, (4) supply chain: manufacturer, and (5) UK country of operation: Scotland. This factor is equally the most-frequently populated with influences, alongside F1. In the similar research of Mirghaderi et al. (2023), the following influences overlap with themes in this research: cultural changes, economic changes, competition of government and public organisations with other organisations, and government regulations.

Internationalisation

The first external influence, with a calculated perfect significance value (P=0), is internationalisation. This was quantitively determined as the most influential for the combined concepts of organisational resilience and open innovation, so it is therefore no surprise that it was also the most qualitatively coded influence too. One respondent said: “you really have to internationalise if your company's going to survive” (e12i), with many of the interview sample agreeing by implementing a globalised outlook to their enterprise operations (e1i, e3i, e6i, e7i, e8i, e9i – all male-led enterprises). Well-cited within the literature as an inevitable outcome of digital working (Bogers et al., 2018; Euchner, 2011). Two enterprises did intend on expanding cross-border (e5i, e10i – both male-led, biological technology, micro-sized enterprises), but this was despite the warnings of the complexities to transition from domestic to global operations (Hoang & Rothaermel, 2016; Nummela et al., 2006). One enterprise related internationalisation and survival, especially since the 2007-2008 global financial crisis (e12i), which draws a parallel with the upsurge in academic interest of organisational resilience from that same significant external shock (Annarelli & Nonino, 2016; Korber & McNaughton, 2018). However, interestingly, more-recent examples of external shocks were not identified as influential, including BREXIT, COVID, and the Russia-Ukraine War.

The UK government’s Department for International Trade has been quoted as providing vital support for one enterprise through ‘heavy-involvement’ in their grant-making and networking (e7i), yet the government as a driving force for the concepts was not addressed in the cited literature. However, their internationalisation assistance may be a reaction to BREXIT, whereby many enterprises have remarked upon its consequential complications for their enterprises. For example, enterprises noted the issues around collaborating with the European Union (EU) due to the Northern Ireland protocol (e2i, e10i – both micro-sized enterprises), the changes in life science regulatory approval as a barrier to their resilience (e3i, e11i – also both micro-sized enterprises), and finally, a lack of partnership with the EU (e3i).

Some of the cited literature raised that intercultural problems may also be a barrier, such as different (a) ways of working and competing (Porter, 1998), (b) different languages and culture (Fortuin & Omta, 2008; van de Vrande et al., 2009), and (c) scientific approaches (Tidd & Bessant, 2021). Whilst appreciating the benefits of internationalisation, not all enterprises are patriotic or loyal to their start-up location, with two of the interview sample establishing

themselves in more advantageous locations. Motivations to relocate are listed as a lack of UK investment, negative attitudes, and a lack of competitive advantage (e9i); and another enterprise lists eligibility of funding, networking, restrictions, and regulatory approval as stimuli to move (e11i). Taking other national or continental markets into account, one enterprise proposed that the UK is much more considerate about closed innovation and confidentiality (e2i). This was evidenced by Varis and Littunen (2010) who had foretold that smaller-sized enterprises lack the internal capabilities needed to operate globally anyway.

Operating nationally, one enterprise spoke of the difference in demand and pricing of operating within England's golden triangle of London-Oxford-Cambridge (e4i; The Lancet, 2018). An enterprise promoted closed, national innovation, "the whole country needs to be more self-reliant" (e14i) and "you have to be commercially sensitive" (e16i) to your specialist knowledge. Yet, paraphrasing Ridley (2011), self-sufficiency is said to lead enterprises away from prosperity. It therefore deems internationalisation as a worthy pursuit, despite the required resource allocation. The significant influence of internationalisation upon the organisational resilience and open innovation of UK life science SMEs has real-life evidence in the legacy of BUCANIER (Davies et al., 2020) and CALIN (2023) projects. They both facilitated cross-border (Wales in the UK and the Republic of Ireland in the EU) and cross-domain (industry-academia) collaboration for SMEs within the sector. This has the implication that other such similar UK life science SME projects, facilitating collaboration, could truly enhance the organisational resilience and open innovation of their members (Howson et al., 2019; Marangos & Warren, 2017; Zobel & Hagedoorn, 2020).

Investor Intervention

The next external influence of significance is that of investor intervention. Yet, despite it being so well-cited as an emergent theme within the responses, it was not cited within the considered literature. This means that a cross-reference is not possible for a discussion, however, it was not a *systematic* literature review, and so could have been overlooked. It does emphasise the originality of this finding though, requiring more academic attention to quantify the influence of investor interventions upon both concepts. Within the expanded definition of open innovation by Escoffier et al. (2016), money was one of the resources that was included to be transferred across SME boundaries, and so this emergent theme is connected to the investors

that can supply capital. Their involvement and intervention are what has emerged as influential of organisational resilience and open innovation.

Stakeholder Diversity

The inclusion of a diverse mix of stakeholders emerged as another external influence. The wide selection of UK life science stakeholders was listed as academia, patients, regulators, commercial pharmaceutical and medical technology businesses, the National Health Service (NHS), local Chamber of Commerce, bio-clusters, and government agencies - all of these allowing for multi- and cross- industry consortia (e23s, e35s, e66s, e3i, e7i, e12i, e16i). They each solidify the 'quadruple helix model of social innovation', and identifies the value of partnerships with government, industry, academia, and civil society actors (Carayannis et al., 2021). However, patient groups and health charities are less-so involved as stakeholders (e2i), which agrees with Bogers et al. (2018), who found that non-profits are only now being considered as open innovation partners within the literature. It was COVID that taught one enterprise that collaboration is key. Not only do they now collaborate with UK government, but a consortium of diverse nation governments to find cost solutions for global challenges (e6i). For example, the UK government facilitates cross-stakeholder open innovation by mandating industry-academia life science collaboration for funding – either as a dual partnership or multi-actor competitions (e4i). However, this is seen by one of the sampled enterprises, as a somewhat *artificial* alliance (e9i). This finding is unique to this research and was not mentioned in the reviewed literature. It is an interesting consideration, that certainly warrants further study as to understand if these forced partnerships are successful.

One biological technology SME reports that the UK Government motivates cross-border open innovation, by recommending collaboration with other countries, mainly in the EU. However, this is said to have reduced since BREXIT, and may not increase again until the Northern Ireland protocol is sorted. In Northern Ireland, that same enterprise has well-established links to local universities, and a willing flexibility to move location if their identified risk of the Northern Ireland protocol ever incurs any issues upon their SME (e10i). This strengthens the cited Northern Irish literature (Galbraith et al., 2017; Neale et al., 2007; Scott et al., 2015).

Supply Chain: Manufacturer

The UK life science supply chain position of manufacturer (P=0.006) features within the nine calculated significant influences. One enterprise took ownership of their supply chain, by delivering a strong three-year strategy to source bulk-supplies and develop in-house manufacturing capabilities. Because, as before, "there was no real understanding of what that necessarily meant upstream or downstream of the device" (e3i). This confusion and complexity regarding supply chains can leave SMEs with a need for clarity to address any vulnerabilities to organisational threats. However, Bak et al. (2020) suggest that "there is still no comprehensive definition and consensus on a roadmap to achieve" (p. 1) supply chain resilience for SMEs anyway. Open innovation and collaboration across the supply chain is cited as being "great for everyone" (e7i) because it efficiently and effectively meets the needs of the patient. Also, feedback is provided through clear lines of communication along the supply chain. Cited by Restuccia et al. (2016) as sharing such feedback with the enterprise means that they can act as 'problem informers' to create novel innovation. A different enterprise also works with manufacturers to get their life science innovation to market quickly (e8i). Agreed by Brunswicker and Vanhaverbeke (2015) as being beneficial in enhancing such processes and short-term commercial value.

After noting a fault with their supply impacting the longevity of their innovation shelf-life, one enterprise is now considering integrating their manufacturer as a management partner to better oversee the supply chain. They said the following in relation to their manufacturer. They are "producing our product for us, but we're very small in their [eyes], but if we make this product successful, I could see that they would be interested to get further" (e13i), in terms of integrating with their enterprise. Nonetheless, another enterprise expressed their concern that managing the life science supply chain is risky, as "you're at the beck and call of the retailers" (e14i) downstream. Risk was widely cited within the open innovation literature (Enkel et al., 2009; Raymond & St-Pierre, 2010; Rothaermel & Deeds, 2006; Veer et al., 2013), so this specific point is in need of further probing but does further justify the need for this research into organisational resilience.

UK Country of Operation: Scotland

The final external influence is that of UK country of operation: Scotland (P=0.014), which evidences that the initiatives of Scottish government have facilitated their life science SMEs to

successfully practice organisational resilience and open innovation. This northern location of UK life science enterprises is widely cited in the literature as being significantly influential (Conz et al., 2017; Herbane, 2020; Porter, 1998, 2004). As argued by one enterprise: “it's not what you do, it's where you do it” (e4i), and so another geography-based significant influence was that of enterprises operating in Scotland. Despite it only being the third-most represented UK country in the sample (Figure 19), Scotland was found to successfully provide a context that facilitates and supports organisational resilience and open innovation for UK life science SMEs. It could be suggested that the wider sample and population of English, Northern Irish, and Welsh life science SMEs could learn from their Scottish counterparts, and partake in knowledge exchange with them.

Scottish Government (2020) describes the potentially transformative power of health innovation for their social and economic outcomes. A benefit mentioned by one SME is the establishment of diverse partnerships (e3i). This correlate with the diverse Scottish life science collaborators of researchers, stakeholders, and collaborators cited by the Fraser of Allander Institute (2017) and acknowledged as social innovators in the quadruple helix model of government, industry, academia, and civil society (Carayannis et al., 2021). One enterprise favouring local, face-to-face Scottish collaborations to save time and money travelling south (e8i), down to the golden triangle (The Lancet, 2018). It was also cited by one medical technology enterprise that Scottish government not only offered them a beneficial start-up grant for their enterprise, which anchored them in the region, but also provided access to Scottish NHS boards were also described to deliver their life science outputs (e9i). For a pharmaceutical enterprise, the NHS in Scotland were also receptive to suggested changes to healthcare delivery, regarding their life science specialism (e12i). Further positive comments upon the Scottish life sciences were made by Henderson (2015) and Burnett and Dansen (2022). The other UK regions have much to learn from Scottish life science enterprises, regarding their organisational resilience and open innovation.

5.3. Concluding the Discussion

To answer RQ1, this chapter has first discovered that UK life science SMEs, on average, consider themselves to practice (a) medium levels of organisational resilience despite the 39% failure rate within their first three years (Office for Life Sciences, 2011), and (b) ‘partially open’ models of innovation, despite other indicators that the sector is yet uncollaborative (Rees

et al., 2021). Then to answer the research questions, firstly, the findings of this primary research corroborate with the recent investigations of Ju (2023) and Mirghaderi et al. (2023) regarding the relationship between organisational resilience and open innovation, but in different contexts. It is also found that it is a positive relationship, whereby both concepts increase together, with only partial open innovation is required to garner high organisational resilience. This has the implication that it is a universal strength of association, across countries and sectors, allowing owner-mangers of UK life science SMEs to consider them in unison for resource-allocation and strategy.

From the perspective of general system theory, these results shed light upon the complex interconnectedness (von Bertalanffy, 1928/1968) of organisational resilience and open innovation. Their moderate and positive relationship reinforces each other as they both grow within the system of the organisation, of UK life science SMEs. This concludes the discussion with the principles of advanced complex systems (Cole & Kelly, 2020; Daniel et al., 2022; Ramos-Villagrasa et al., 2018), where seemingly small variations in levels of open innovation, can have cascading effects on organisational resilience of the 'system'. Furthermore, the discussion contributes to contingency theory too, by suggesting an optimal level of open innovation can be dependent upon the limited resources of the sampled enterprises.

To answer RQ2, internationalisation was both quantitively and qualitatively calculated as the most significant influence overall. Furthermore, it is found that the combination of the concepts of organisational resilience and open innovation are equally influenced by both internal and external factors. This has the implication that UK life science SME owner-managers are to focus their resources on both endogenous and exogenous features in order to practice the concepts. Demographic factors are the least populated with significant influences. Therefore, owner-managers do not have to modify their enterprise to simultaneously practice both concepts, as they are universal across the sample. However, business demographics should not be completely disregarded, as they do hold *some* influence. The resultant significant influences of the final model were largely validated by the literature, but there were also some original ideas transpiring from the data too, as featured in Table 16.

Table 16: RQ2 Original Contributions to Knowledge from Discussion

Factor (F)	Significant Influence	Original Contribution to Knowledge
Internal Influences (F1)	Legal Protections	Very high financial costs for UK life science enterprises to protect their data and intellectual property, impeding proper protections, leaving their organisational resilience and open innovation vulnerable to larger, predatory actors.
		Not all UK life science actors understanding or respecting General Data Protection Regulations, leaving UK life science SMEs vulnerable to larger, predatory actors in the ecosystem.
	MGMT Attitude	Management attitude to internal communication, allowing for the freedom to express ideas and bounce ideas around without judgement, is said to increase both concepts.
Demo-graphic Influences (F2)	Enterprise Size	As an emergent tangent finding, finances and marketing are influential of the combined concepts for UK life science SMEs.
	Subsector: Business Support	It is advantageous for science-specific SMEs to offer business support services to the UK life science sector, for their own organisational resilience and open innovation.
External Influences (F3)	Investor Intervention	UK government facilitating cross-stakeholder open innovation by mandating industry-academia life science collaboration for funding. It was not deemed whether this was a positive or negative influence, but certainly warrants further investigation if such artificial alliances are of value to their stakeholders.

Multi-factor models have been used to measure influences of other business management concepts. However, the final model is a significant and original contribution to knowledge on its own, as the framework was uniquely created by the researcher identifying influences specific to the UK and life sciences sector in the literature.

The conclusion of the discussion regarding RQ2 aligns well with the principles of general systems theory, as the research highlights the complex interrelations (Daniel et al., 2022) of internal and external factors (Crowther & Green, 2004; Daft, 2001) influencing both concepts of organisational resilience and open innovation. This echoes the idea of open systems, where organisations interact with their environment. The finding that internationalisation is the most significant influence, aligns with the holistic principle (Cole & Kelly, 2020; Hatch & Cunliffe, 2006) of advanced complex systems, whereby operating across the whole world is more influential of the combined concepts, than operating in the sum of its parts. The discussion surrounding the demographic factors holding only some significance suggests that the optimised practices for fostering these concepts are more contingent upon specific

organisational contexts. This aligns with the principles of contingency theory (Lawrence & Lorsch, 1969; Tannenbaum & Schmidt, 1958), which emphasises the influence of environmental factors.

The original, final empirical model (Figure 44) has the implication of a valuable framework for further research and practical application within the specific context of UK life science SMEs and this time-period. The next chapter will consider the implications and contributions that these results and discussions have upon academic theory, industry practice, and methodology. It then considers what is next in the research agenda, before offering the concluding remarks.

Chapter 6: Conclusion

As the final chapter of this thesis, it is of value to review the research pathway made, before making the concluding remarks. Due the difficulty of sourcing a finite definition of the sector from both academic and contextual (grey) literature, this research attempts to define the United Kingdom (UK) life sciences. Achieved through the collectivisation of its subsectors, which aligns with the general systems theory, described within the theoretical foundations section. The objective of this thesis was to determine if and how open innovation enhances the organisational resilience of UK life Science small and medium-sized enterprises (SMEs). This has been achieved by answering the two research questions that were formed to address the gaps in the body of literature. The questions were rigorously addressed through a mixed methods research design. Firstly, measuring and analysing how the two concepts relate to each other, of which a relationship was found; and then secondly, how they are influenced, which was equal across both internal and external factors. This chapter is structured by first revisiting the aims and objectives first discussed in the introduction chapter. Then the findings and overview of the research is summarised, before identifying how the findings contribute to knowledge. Finally, the consideration of the agenda for future research is explored.

6.1. Revisiting the Aims and Objectives

The aim of this research was to provide a significant and original contribution to knowledge by investigating the relationship and influence of the following two business management concepts: organisational resilience and open innovation. Consequently, the objective was to determine if and how open innovation enhances the organisational resilience of UK life science SMEs. To address this objective, two research questions were formed out of ongoing debates and unanswered questions in the literature. The following section provides an overview of the key results of each question, as contributions to knowledge.

6.2. Overview of the Findings

6.2.1. How are the Concepts Related? (RQ1)

The first research question posed if the two concepts of organisational resilience and open innovation are related, so it was first necessary to investigate the concepts independently. This provided some surprising implications to academic theory, as despite suffering a high failure

rate (Office for Life Sciences, 2011), UK life science SMEs consider themselves as having medium levels of organisational resilience. This can be interpreted as them having self-confidence despite adversity. Furthermore, despite indicators that the UK life science sector is as yet uncollaborative (Rees et al., 2021), the sample of SMEs identify that they practice partially open models of innovation. When tested together, it was found that there is a relationship between organisational resilience and open innovation. However, whilst the strength of the association is not of significant dependence, the direction is positive. This means that they both increase together. Additionally, UK life science SMEs only need to practice partially open models of innovation to achieve high levels of organisational resilience.

6.2.2. How are the Concepts Influenced? (RQ2)

Due to a relationship being present, it was necessary to combine the concepts of organisational resilience and open innovation into a single interaction variable, to address the second research question. This research question asks how the concepts of organisational resilience and open innovation are influenced. The results of which found that internationalisation was both quantitatively and qualitatively the most significant influence of the two concepts of organisational resilience and open innovation. This was closely followed by the legal protections of their resources. More widely, both the internal and external factors were equally populated with significant influences within the final model. This implies that owner-managers of UK life science SMEs should allocate and balance their limited resources to both endogenous and exogenous factors, for organisational resilience and open innovation. Demographic factors were least populated, which implies that resources should not be allocated in modifying the characteristics of the enterprise to practice the concepts. External events such as BREXIT, COVID, and the Russia-Ukraine War did *not* significantly influence the concepts. The next section concludes how this new knowledge contributes to academic theory, industry practice, and methodology.

6.3. Contributions

6.3.1. Academia

Systems Theory

This research contributes how systems theory can be applied to understand and improve modern innovation management practices.

General Systems Theory

This section first explores the significant and original contributions made to system theories, which underpinned this research. A fundamental aspect of this theory is regarding interconnectedness within a system. However, as von Bertalanffy (1928/1968) discussed, an emphasis on interconnectedness leads to a fragmented scientific landscape with "innumerable disciplines continually generating new subdivisions" (p. 29). The limited existing literature upon the UK life sciences lacks a unifying definition for the sector, despite its national successes for the economy. Therefore, this research addresses the unanswered question of the industry's identity, by contributing a significant and original sector definition which incorporates the inherent complexity (Cole & Kelly, 2020) and connectivity of its subsectors. Supported by Life Sciences Scotland (2023) and Welsh Government (2013, as cited in Howson & Davies, 2018).

This research makes a contribution to von Bertalanffy's (1928/1968) notion of equifinality within open systems. Achieved by empirically demonstrating the interrelatedness of the concepts whereby open innovation enhances organisational resilience in the sampled UK life science SMEs. This finding not only validates the applicability of von Bertalanffy's principle within this business management domain, but also contributes general system theory, by identifying a way to achieve their goal of organisational resilience. Von Bertalanffy promoted the use of the positivist philosophy, by applying the scientific method and mathematical models to quantify the "organised complexity" (p. 33) of modern systems. Therefore, this research contributed originality to methodology by implementing a mixed method approach, which supplemented the above with a qualitative design. This captured a richness and nuance to the data, and multi-stage validation, to achieve an accurate final model. This has the implication

of preparing for further qualitative and mixed method advancements in general system theory, regarding such complex systems as the UK life sciences.

This research also makes a significant contribution to the advancement of knowledge for general systems theory by the finding of a moderate and positive relationship between the concepts. This offers quantifiable evidence within the UK life sciences context, and then benchmarking against the similar, emerging research of Ju (2023) and Mirghaderi et al. (2023), identifying universality. These conclusions align with von Bertalanffy's (1928/1968) principle of interconnectedness, and suggests a unifying framework of generalisability across diverse systems, spanning varying contexts across geographical and sectoral boundaries.

Complex Adaptive Systems Theory

Using the definition of Daniel et al. (2022), complex adaptive systems theory explores interactions between factors characterised by multi-level ecosystems. Therefore, this research contributes to the theory through the application of statistical regressions within the methodology to measure bivariate and multivariate relationships to answer the two main research questions (RQ1 and RQ2). The results of which produced a final model of 12 significant influences (or ‘inputs’ as the theory would conceptualise them as). These are allocated across three factors within the ecosystem, for adaptation and self-regulation by UK life science SMEs. Furthermore, due to the continuous improvement experienced from the feedback loop of complex adaptive systems theory, UK life science SMEs can adopt a resilient and growth approach through openly innovating with external partnerships and ideas within a dynamic environment (Ramos-Villagrasa et al., 2018). These experiences are then used to continually feedback and learn from failures and successes.

Using the trifecta of theoretical impact by Daniel et al., the empirical model of this research, that visualises the identified relationship and influences of the concepts, has implications for (a) academic research and methodology, (b) industry practice, and (c) government policymaking across the UK life sciences (each contribution being discussed throughout this section 6.3. Contributions). A suggestion for future research, to contribute to complex adaptive systems theory, is discussed in upcoming section 6.4. What is Next in the Research Agenda?. Next, and lastly, the contributions to contingency theory are examined.

Contingency Theory

Building on the principle of uniqueness (Donaldson, 2001) and "goodness of fit" (Daft, 2001, p. 24) within contingency theory, this research sheds light on the optimal balance between organisational resilience and open models of innovation. But with such variation in the enterprise ratings of both concepts, there is no single best approach for the sample. The research further strengthens this notion by revealing a moderate and positive relationship between the two concepts, which implies that a balanced level of both concepts might be crucial for organisational success to deliver social and economic benefits.

This research strengthens ongoing debates in contingency theory by highlighting the importance of interconnectedness within the diverse UK life science sector. The final model incorporates 12 significant influences (Figure 44), reflecting the unique characteristics, forces, and factors of each participating enterprise. This confirms the research of Cole and Kelly (2020) and Tannenbaum and Schmidt (1958). For instance, the sample includes representation across various strata: UK country of operation, life science subsector, enterprise size, enterprise age, and leadership gender (see section 4.1. Sample Representativeness). This diversity underscores the notion that optimal leadership styles depend on a complex interplay of factors, not a one-size-fits-all approach (Howson & Davies, 2018; Sullivan-Taylor & Branicki, 2011).

The findings further contribute to contingency theory by demonstrating interconnectedness, through the influences of ‘Management Qualifications: Science’ from the internal factor (F1), and ‘Subsector: Business Support’ from the demographic factor (F2). They both promote the blurring and integration of domains: technical scientific knowledge and business management acumen, to achieve equifinality (von Bertalanffy, 1928/1968) of the combined concepts. Arguably, this is further enhanced by all of the resultant significant influences of the external factor (F3). They each promote interrelations and the permeation of enterprise boundaries (Bogers et al., 2018; Howson et al., 2019; Porter, 2004; Rees et al., 2021; Tidd & Bessant, 2021; Zobel & Hagedoorn, 2020) with other countries and life science actors.

Interesting and Surprising Findings

From: How are the Concepts Related? (RQ1)

There are unexpected findings from the univariate analysis of each concept. Despite the Office for Life Sciences (2011) claiming a high failure rate of UK life science SMEs, attributed to scientific entrepreneurs not having business acumen, most of the sampled enterprises identified a medium level of organisational resilience. This was unforeseen, but also an encouraging finding, with the implication for the robustness of the sector to deliver social and economic benefits to the UK. Furthermore, despite Rees et al. (2021) suggesting that the UK life science sector is uncollaborative, most of the sampled enterprises identified practicing a partially open model of innovation. This noteworthy finding has the implication that there is at least some partnerships, networking, and interactions occurring for the purposes of scientific innovation by SMEs.

The bivariate analysis of RQ1, regarding the positive relationship of the concepts, found that UK life science SMEs risk having no organisational resilience if they practice mainly *closed* models of innovation. Conversely, practicing partially *open* models of innovation can achieve high levels of organisational resilience. This has the implication that it is detrimental to their survival to be completely closed off and secretive in their research and development, and it is not worthy of risking their commerciality to be completely open. Instead, a more restricted introduction to open innovation is the most effective for their longevity as an organisation. An example of how this can be achieved is the joining of a network, hub, or cluster. As this research is a legacy to BUCANIER and CALIN, it is a testament to their effectiveness to increase organisational resilience of their members, through the facilitated knowledge exchange between their members. Other sampled networks include the Bevan Commission, Life Sciences Hub Wales, and Association of British Pharmaceutical Industry.

From: How are the Concepts Influenced? (RQ2)

While the individual influences of organisational resilience and open innovation have been comprehensively analysed and discussed in previous chapters, the interrelations between the identified significant influences remains largely unexplored. Therefore, this section interprets the emerging contribution that pairings/groups of similar themed influences provide. This has

the implication that UK life science SMEs can leverage these to most effectively practice both concepts.

With a holistic approach, teamwork is discussed by von Bertalanffy as an interdependent and open system to exchange information with the environment. So firstly, a surprising pairing was that of ‘Management Team Size’ from the internal factor (F1), and ‘Enterprise Size: Small’ from the demographic factor (F2). These have the implication that organisational resilience and open innovation do not increase with business growth. Instead, smaller enterprise and management team sizes are optimal for the sample, with leaner SME structures allowing for faster internal communications, agility in decision-making, and easier adaptation to an ever-changing and highly-regulated sector. Additionally, smaller teams can often have less bureaucracy, making them more receptive to external ideas and collaborations, which motivates open innovation.

Secondly, an interesting pairing of influence is that of ‘Management Qualifications: Science’ from the internal factor (F1), and ‘Subsector: Business Support’ from the demographic factor (F2). Due to the claim of a high failure rate of UK life science SMEs (Office for Life Sciences, 2011) being attributed to scientist entrepreneurs lacking business acumen, this infused pairing of influences is important to their organisational resilience. The inclusion of scientific expertise within the management team allows leadership to make technically-informed decisions regarding their own policies and practice. Furthermore, it allows them to also deliver a business support consultancy. This can be achieved by licencing out their scientific *and* business expertise to external actors, to help others navigate and address the complexities of the UK life sciences. A prime example of how they can achieve *partial* open innovation for their commercial gain, whilst awaiting the lengthy regulatory approval. This pairing of significant influences positions them to not only weather industry disruptions, but to also become hubs for generating innovative sector solutions.

Lastly, the combined significance of ‘Market Research’ from the internal factor (F1) and ‘Stakeholder Diversity’ from the external factor (F3) creates a powerful loop. Market research informs stakeholder engagement, which ensures that diversity is relevant to current market needs. Conversely, a diverse group of stakeholders can contribute new insights to the market research of UK life science SMEs, leading to a more comprehensive understanding of trends and opportunities. These can include such previously-cited examples as challenges experienced

by the National Health Service: (a) increased demands and expectations, diversifying public health challenges, and a fragmentation of the system (Aylward et al., 2013; UK Parliament, 2018). Researching market needs allows the owner-managers to anticipate disruptions and adapt their strategies to enhance organisational resilience. This market knowledge also motivates open innovation by informing the sourcing of collaborations with diverse stakeholders for innovative solutions to the above problems.

Further discussion surrounding all of the disregarded influences which were deemed insignificant across the mixed methods (greyed out in the final model, Figure 43). For example, a surprising trend emerged regarding the substantial external forces of BREXIT, COVID, the Russia-Ukraine War, and advancements in Artificial Intelligence. None of these were predicted to significantly influence how the sampled UK life science SMEs practice the combined concepts of organisational resilience and open innovation. This confronts the established notion that global challenges necessarily influence SME strategy, policy, and practice, as it instead suggests that they have an inherent strength, allowing them to navigate such disruptions through openness.

The research has also found that they are equally influenced by internal and external factors, rather than by their demographics. Given the value of this, it relieves the SMEs of concerns about having to modify characteristics to influence their organisational resilience and open innovation. Instead, they can refocus the allocation of their limited resources on their innovation and management (endogenous influences, F1), and the environment of which they operate (exogenous influences, F3). While these unexpected results raise intriguing questions for further investigation, the next section discusses how this research builds upon, and contributes to, existing findings within the academic literature.

Expanding the Field of Research

Marangos and Warren (2017)

The similar research by Marangos and Warren (2017) on open innovation in UK life science SMEs offers unique insights for managers. Specifically regarding mapping their organisational research and development. However, there are still ongoing debates and unanswered questions identified. Therefore, this research builds upon their work by focusing on a significant and original contribution: how open innovation enhances the organisational resilience of the same

sampled enterprises. An initial contribution of this study is its timeliness. Published in the mid 2020s, it provides a more up-to-date perspective on UK life science SMEs, compared to Marangos and Warren, who published their findings in the late 2010s. However, there are more substantial contributions from the answering of the two research questions (RQs):

RQ1 as a Contribution to the Advancement of their Research

Although not the emphasis of their research, Marangos and Warren identify a relationship between closed innovation and failure for UK life science SMEs. Therefore, their research is seminal to the justification of this research. Attributable to determining if the opposite of their claim is true: if open innovation enhances organisational resilience in the same context. The findings of this research has validated their claim by answering the first research question (RQ1) regarding the relationship between the concepts. This validation is achieved by contributing that vulnerable UK life science SMEs, with no[18] level of organisational resilience, do indeed practice mainly-closed[19], linear, and internally-focussed models of innovation. They attributed this to increased fragmentation of the sector. In contrast, and how this research builds upon the above claim, is by identifying that in order to achieve high[20] levels of organisational resilience, they must only practice partially open[21] models of innovation. Marangos and Warren predicted this to be the case for under-resourced SMEs in the UK life sciences, by attributing the claim to the importance of insourcing vital resources for their research and development, and commercialising their highly technical knowledge by outsourcing.

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[18] "No measures have been implemented in the organization, lack of coherence, no innovation or flexibility" (Pescaroli et al., 2020, p. 407, **Error! Reference source not found.**).

[19] "Allowing external partners a glimpse into an innovation need or goals, sometimes presented as a challenge or request. While some parts or details are disclosed, they ask for a solution from an unspecified party" (Nilsson and Minssen (2018, p. 773, **Error! Reference source not found.**).

[20] "Strategies have been developed consistently, and good practices have been applied across departments. Activities have been measured and assessed regularly. A process of continual improvement has been established and is ongoing. The organization demonstrated innovation and flexibility" (Pescaroli et al., 2020, p. 407, **Error! Reference source not found.**).

[21] "Methodology and underlying science is disclosed so that external parties can suggest new and relevant opportunities … Potential partners can participate in 'sense making'" (Nilsson and Minssen, 2018, p. 774, **Error! Reference source not found.**).

RQ2 as the Contribution to the Advancement of their Research

Although not investigating the same secondary concept, they still contributed relevant discussions regarding the multivariate influences of open innovation, within the scope of their research. Citing the final RQ2 model of influences (Figure 43), this section adds how this research has expanded the research of Marangos and Warren.

Starting with the most significant influence across both mixed-methods, Marangos and Warren discussed 'Internationalisation'. By observing the creation of international collaborations, they asserted that UK life science SMEs can "capture potential know-how and leverage their investment portfolio" (p. 218). This research builds upon this, by recommending the owner-managers to apply for membership in such facilitated cross-border networks as BUCANIER and CALIN to partake in just the *partial* open innovation needed for *high* levels of organisational resilience.

Marangos and Warren also discussed the significant influences of 'Legal Protections' and 'Investor Intervention' has upon open innovation by UK life science SMEs. Attributed to such funder-imposed safeguards mitigating risks to their organisational resilience when openly innovating with fellow SMEs. Sometimes, this is under a contractual partnership agreement, which is monitored by the funders who are facilitating the relationship, to ensure a productive outcome. This research contributes to this point by promoting that applying and enforcing such protections as UK patents is expensive and complex. Therefore, SMEs with limited resources, and without such generous investors who can supply such legal protections, are left vulnerable to predatory or dominant life science actors and imitability of their innovation. This can lead to reduced organisational resilience and more closed models of innovation.

Finally, Marangos and Warren discussed 'Enterprise Size' as significantly influential of open innovation. Larger, again-predatory, actors seeking "discoveries, tools and target compounds which have been licensed-in from smaller firms" (p.212), who are otherwise forced into such collaborations, due to their lack of resources to self-sufficiently innovate in their early-stages. This research contributes by asserting that not all of the sampled enterprises felt disadvantaged by their smaller-size, as some suggested that they were flexible and less restricted by bureaucracy to make strategic, policy, or procedural changes for commercial and competitive advantage.

However, not all influences raised by Marangos and Warren were corroborated by this research. For example, they found the following influences of open innovation to be significant: (a) innovation diversity, (b) speed to market, (c) enterprise type, and (d) enterprise age. Yet, the contribution of this research is that the above influences were identified as insignificant of the combined concepts. Therefore, they were greyed-out and disregarded from the final RQ2 model (Figure 43).

Ju (2023) and Mirghaderi et al. (2023)

This research also builds upon the two recently published papers of Ju (2023) and Mirghaderi et al. (2023) who also studied the concepts of organisational resilience and open innovation, but in very different contexts. These papers validate the relevance of this research topic and indicate the novel contribution of the findings to understand the concepts in the context of UK life science SMEs.

Furthermore, as each used regression techniques to calculate and analyse the quantified relationship of the concepts, it is of value to make direct comparisons of the outcomes. Each papers' results are calculated within a similar range, and therefore, it can be argued that this range of relationship between the two concepts is universal and generalisable across countries and sectors. Further investigations are required in additional countries and sectors to validate this finding.

Methodology

The implication of this research to methodology is that it contributes to the identified lack of empirical research upon the concepts of organisational resilience (Alderson et al., 2015; Whitman et al., 2013) and open innovation (Bessant & Tidd, 2015). Whilst it also adds to the qualitative body of research exploring their influence on SMEs. Mixed methods (Bell et al., 2022; Fielding et al., 2017; Hausman, 2005; Meyer, 1982) were applied to the data collection. This came in the form of online surveys to gather a breadth of quantitative data (Garengo & Bernardi, 2007; Kirkpatrick et al., 2023; Shore et al., 2023; ten Ham et al., 2018), and online interviews to gather a depth of qualitative data (Conz et al., 2017; Hausman, 2005; Iborra et al., 2020; van de Vrande et al., 2009).

Applying mixed methods offered extensive understanding of the concepts through the efficient and effective modes of data capture. They were also used to validate each other's results, which allowed for an iterative process of disregarding, validating, and emerging themes from the datasets. This then formulated a comprehensive and accurate final empirical model (Figure 44) which confidently answers both research questions. Firstly, by identifying and measuring the strength and direction of the relationship of the concepts of organisational resilience and open innovation. Then, due to this association, by combining the concepts to test their influences, it allows practitioners to understand where the limited resources of UK life science SMEs should be efficiently and effectively allocated.

The final model contributes to the body of existing knowledge, due to its scalability, as it has already handled a large dataset. Consequently, expanding the model would increase the power of the dataset to answer both research questions, for two reasons: Firstly, an increase in tested variables would contribute to the calculated 69.7% explanatory deficit. Secondly, an increase in sample size would fulfil the power deficit. Satisfying both of these deficits would increase the accuracy of the final model if it were to be repeated.

Driven by the external force of the COVID restrictions (interestingly, *not* calculated as significantly influential of the concepts), 'e-social science' (Fielding et al., 2017) strategies were applied. This was as part of a modern trend to increase the efficiency and efficacy of the data collection methods. The use of auto-transcription through Microsoft Teams to automatically write out the qualitative interviews was somewhat of a contribution to methodology. This was motivated by the efficiency of these technological advancements, which was tested to be very accurate across the broad range of diverse UK accents, so only required light cleaning of the data due to redacting identifying information for anonymity. This research took the unique approach to include micro-sized enterprises within the umbrella sample of small and medium-sized enterprises (SMEs), therefore notably referred to as MSMEs. Micro-sized enterprises are sometimes excluded, or simply not labelled, within academic 'small business' literature, this allowed a wider and more inclusive sample of all enterprises within the UK legal ceiling maximums of: turnover of £36m, balance sheet totals of £18m, and 250 employees (Companies Act, 2006).

6.3.2. Industry

As previously raised in the research philosophy of axiology, this research delivers phronesis by providing a potential contribution to the industry practice of UK life science owner-managers of SMEs, by bringing awareness to the two concepts independently and their observed relationship. By analysing subsets of the main quantitative survey data, as per the catchment areas of CALIN and the Life Sciences Hub Wales, two industry reports were created (Appendix L: Research Outputs). These summarise and disseminate the preliminary survey results to their member SMEs, for practical application (Table 17).

Table 17: Sample Countries for Industry Reports

Industry Recipients	Wales, United Kingdom	Republic of Ireland, European Union
Celtic Advanced Life Science Innovation Network (CALIN)	✓	✓
Life Sciences Hub Wales	✓	✗

The Irish SME members of CALIN were sampled within the main quantitative survey. However, their data was extracted for separate statistical analyses, as they were not eligible for the UK sample of the main research. These reports were translated into both English and Welsh language for maximum access and impact with their member enterprises. Both reports were shared widely: (a) CALIN and the Life Sciences Hub Wales emailed the reports directly to their member SMEs, (b) they were shared with academic peers at Swansea University via the Faculty of Humanities and Social Sciences postgraduate research newsletter, and (c) they were also posted by the researcher on LinkedIn for public access (all seen within Appendix R: Dissemination of Non-Traditional Research Outputs).

Contributing these research findings to the British Standards Institute's (2021) next Organisational Resilience Index Report will provide a nuanced understanding of how SMEs can build a high-level of organisational resilience by leveraging just partial open innovation for their competitive advantage, and what significantly influences that relationship too. The concept of open innovation has not been included in previous reports, and so would be an original contribution to industry knowledge.

6.3.3. Government

The UK government's Office for Life Sciences (2011) contributed to the rationale of this research by describing a 39% failure rate for UK life science SMEs within their first three years of operation. Yet encouragingly, through the primary, univariate quantitative research, the average level of organisational resilience was medium for the sample. Furthermore, the external forces of BREXIT, COVID, and the Russia-Ukraine War were *not* statistically significant and were cited opportunities for growth within the qualitative responses.

This is hopeful for Welsh government especially, as the life sciences are an economic priority, alongside the renewable energy and the food and drink sectors (Bowen, 2017; Davies et al., 2020; Mayho et al., 2024). With the Scottish location being a significant influence for enterprises to practice both organisational resilience and open innovation, it is an implication for Wales (and other devolved governments) to engage in knowledge exchange with Scottish government. Learning from their effective government policy and procedures to benefit the sector. The Office for Life Sciences (2023) has ambitions to become a global scientific superpower, with reference to resiliency and openness as means to achieve this. Therefore, this research can inform governments by demonstrating their relationship and influences for economic and societal benefit of the nation:

> *Building on the UK's collective expertise in research, academia, industry and healthcare to deliver benefits to the UK economy, health, [National Health Service], and patients. … The sector is also crucial to the resilience of economies and societies, with a shift to preventative and population health against trends of ageing populations with multiple long-term conditions." (para. 3)*

The UK government can facilitate diverse stakeholder collaboration (industry-academia) and cross-border (UK-EU-global) open innovation by mandating life science collaboration. Despite this, this can feel artificial, and may not be as beneficial to life science innovation as the government hopes. Some of the sampled SMEs have highlighted that this forces SMEs to practice organisational resilience due to the dominating and predatory natures of larger actors in the UK ecosystem.

Although this research is significant to recent times, there is the opportunity to make long-term implications of this research. It can inform the next UK government SME action plan, due in 2026+. The current SME Action Plan by Department for Business Energy and Industrial

Strategy (2023) is due to expire in 2025, but this department has since disbanded, and so it is uncertain if, and by whom, it will be renewed.

6.4. What is Next in the Research Agenda?

Whilst this research project has contributed to the understanding of organisational resilience and open innovation, there are a number of opportunities to enhance the research agenda further. The first is to quantitatively test the emergent influences from the qualitative data, to provide the same level of scrutiny as the a priori influences, that were also quantitively tested.

This research used an inductive approach to theory development, and although multi-factor frameworks have been present within business management literature (Branicki et al., 2018; Marangos & Warren, 2017; Rees et al., 2021; ten Ham et al., 2018), the identification of potential influences was exploratory. This was purposeful to measure components specific to the UK life sciences, and capture data regarding the recent significant events of BREXIT and COVID. However, due to the originality of combining the concepts, explanatory literature only existed of influences upon either organisational resilience or open innovation.

The explanatory power of these influences calculated as 30.3%, leaving a large deficit of unrepresented influences. This was somewhat rectified through the emergent influences in the qualitative interview data. A change in sequence of firstly conducting qualitative interviews, with a deductive approach to theory development, would ask the respondents to freely identify influences of the concepts, and then request they each be rated in a quantitative survey. This approach would have allowed for quantitative testing of the emergent concepts that emerged through the interviews, providing much more accuracy to the results.

The response rate of the pilot study of the quantitative survey, was lower than in the cited studies included within the equation for the sample power analysis. This would have reduced the number of enterprises to a more achievable target for the main survey. Equally, the researcher could have been less stringent about the cleaning of the quantitative data to include more responses. However, this would be at the detriment of validity of cases, so a balance is needed in such future business management research. The time-consuming task of creating such a large sample frame of over 2625 UK life science SMEs provided a healthy 158 responses, without incentive. Yet, after cleaning the data, this reduced to 118 useable cases, which meant that the sample was further underpowered. An incentive was successfully applied

to the second phase of the sequential research (the qualitative interviews), which surpassed the sample target. Therefore, a financial incentive could have also been offered for participants in the first phase (the quantitative survey) of the research. This would have had the consequence of likely encouraging a higher response rate to increase the sample power. However, incentive bias would have needed to be mitigated.

To ensure accuracy and a reduction in sample bias, it would also be of value to repeat this research with enterprises that had low representation within the sample for a more comprehensive analysis of the landscape of UK life science SMEs: (a) operating from Northern Irish, (b) operating in the aquaculture subsector, (c) medium-sized enterprises, (d) enterprises aged 40+ years[22], and (e) female-led enterprises.

Although generously funded through Swansea University's Research Excellence Scholarship, this research still experienced budgetary restrictions. With extra funding, this research could be repeated in a cross-border alliance of life science SMEs in both the UK and the Republic of Ireland. Due to this research being a legacy of Swansea University's BUCANIER and CALIN anyway, this expansion could seek to understand the concepts across the whole of the British Isles. This was somewhat achieved with the inclusion of Irish enterprises in the CALIN sample for their corresponding industry report. However, a wider-scale Republic of Ireland sample would be very of value to investigate alternative geographies and cultures (Ju, 2023; Mirghaderi et al., 2023) for further significance and originality.

Finally, this research proposes an significant and original contribution to Complex Adaptive Systems Theory by conducting a longitudinal (Mayho et al., 2024) investigation into the relationship between the concepts. By repeating the study in the future, the relationship between entropy (Ramos-Villagrasa et al., 2018) and the concepts' interconnectedness (von Bertalanffy, 1928/1968) can be measured, in a new time period and then compared. To sustain

[22] Although they may meet the legal criteria of an SME by the Companies Act (2006), they may be disregarded due to their age, as they are no longer in the early stages of entering the marketplace (Márquez & Ortiz, 2020).

the significant contribution, the external forces will must be adapted to whatever is appropriate for the new time period it is being repeated in.

6.5. Concluding Remarks

To conclude this chapter and the wider thesis, the objective of this research has been met to understand how open innovation can enhance organisational resilience. This was fulfilled by finding a moderate and positive relationship between the two concepts, whereby it is optimal to only practice a partially open model of innovation for a high-level of organisational resilience. This original discovery for UK life science SMEs challenges General Systems Theory, which promotes that open systems require complete openness for the most ideal functioning for survival and growth within the demanding sector. The identified moderate and positive relationship between the concepts strengthens the idea of organisations as 'open systems' (von Bertalanffy, 1928/1968) that are resilient through adaptation, and exchange with their environment through open innovation. By efficiently increasing both organisational resilience and open innovation together, life science SMEs can continue to deliver social benefits to the NHS and wider public health, and economic benefits to UK trade and industry.

Furthermore, after discovering this relationship, this research is significant in its exploration of the influences upon the combined concepts. The results of which is in an equal distribution of significance between internal and external influences, which assists UK life science SME practitioners with where to allocate their limited resources. Internationalisation is the most significant influence, from both the quantitative and qualitative datasets, and so it is vital for the enterprises to globalise business operations in order to achieve organisational resilience and open innovation. This could be accomplished through membership of such cross-border and cross-domain UK life science SME networks as BUCANIER and CALIN. This corroborates with the core principle of general system theory literature, by highlighting the interconnectedness of internal and external factors influencing both organisational resilience and open innovation. The sampled SMEs are not isolated actors within the UK life sciences sector, but rather active participants in a complex system, constantly interacting with their dynamic health ecosystem and demanding national economy to survive and grow.

In conclusion, this research strengthens the academic understanding of UK life science SMEs as complex systems by demonstrating the moderate and positive interrelationship of organisational resilience and open innovation, and of their complex and nuanced model of

significant influences. Equally represented across internal and external factors of influences, suggesting a complex, nuanced, and contingent approach needed to optimise their enterprises. With internationalisation being the most significant influence of the combined concepts, implying the benefits of a global outlook for UK life science SMEs.

Chapter 7: Appendices

Appendix A: Concept Measurement Frameworks

Levels of Organisational Resilience (C1)

Level	Label	Cited Definitions by British Standards Institute (2014, as cited in Pescaroli et al., 2020, p. 407)
Immature	None	No measures have been implemented in the organization, lack of coherence, no innovation or flexibility.
Basic and Managed	Low	Some measures have been implemented but most of the practices remains informal with limited coordination and fragmented actions.
Established	Medium	Strategic directions have been set, with understandings of the internal and external context, including its dynamics. Programs and practices are not fully coherent and consistent, but there are steps in place for improving.
Predictable and Optimising	High	Strategies have been developed consistently, and good practices have been applied across departments. Activities have been measured and assessed regularly. A process of continual improvement has been established and is ongoing. The organization demonstrated innovation and flexibility.

Levels of Open Innovation (C2)

Level	Label	Cited Definitions by Chesbrough (2019, p. 30) and Nilsson and Minssen (2018, pp. 773-774)
1	Completely Closed [23]	Traditional vertical integration model, where internal innovation activities lead to internally developed products and services that are then distributed by the firm.
2	Mainly Closed	Allowing external partners a glimpse into an innovation need or goals, sometimes presented as a challenge or request. While some parts or details are disclosed, they ask for a solution from an unspecified party.
3	Partially Closed	Offering external parties' access to specific resources or assets … This effectively creates a (one-way) extension of the research of the company by allowing others to explore novel science and opportunities … Regularly accompanied by an agreement from the external innovation provider to waive any rights to novel [Intellectual Property].
4	Partially Open	Methodology and underlying science is disclosed so that external parties can suggest new and relevant opportunities … Potential partners can participate in 'sense making'.
5	Mainly Open	Encourage participation and reduce the hurdle of exploring scientific overlaps, it is important not to impose premature restrictions or business constraints ... After an initial and open exploration phase has been achieved, the continuation can be more traditional, with confidentiality and patentability.
6	Completely Open	Generated data is made publicly available. This set-up embraces full participation in the life science ecosystem and can equally benefit someone external to the partnership … Generated data will be publicly disclosed and made available without any restrictions on usage. The fundamental realization is that completely novel and unpredictable innovation will come your way as you share everything openly. By sharing obstacles, methods, data, and desires willingly, one maximizes the potential and speed of an idea.

[23] Definition provided by alternative source (Chesbrough, 2019) due to the minimum level being set, but not defined, by the authors of the framework (Nilsson & Minssen, 2018).

Appendix B: Quantified Relationship in Similar Research (P-values)

The following research is first raised in the Chapter 2: Literature Review, but their results are explained in Chapter 5: Discussion, regarding the relationship of organisational resilience and open innovation (highlighted in the red boxes below).

Ju (2023)

Legend: IOI = Inbound Open Innovation, OOI = Outbound Open Innovation, OR = Organisational Resilience

Hypotheses	Path	Standardized path coefficient	*p*-value	Remark
H1a	IOI→OR	0.421	***	Passed
H1b	OOI→OR	0.316	0.110	Refused
H2a	HC→OR	0.175	0.035	Passed
H2b	OC→OR	0.275	0.010	Passed
H2c	SC→OR	0.353	***	Passed
H3a	IOI→HC	0.597	***	Passed
H3b	OOI→HC	0.005	0.597	Refused
H4a	IOI OC	0.584	***	Passed
H4b	OOI OC	0.151	0.097	Refused
H5a	IOI→SC	0.259	0.002	Passed
H5b	OOI SC	0.452	***	Passed

Note(s): ***$p < 0.001$

Mirghaderi et al. (2023)

Variables	Open Innovation	Organizational Resilience	Dynamic Competitiveness
Open Innovation	0.748		
Organizational Resilience	0.145	0.738	
Dynamic Competitiveness	0.567	0.674	0.724

Appendix C: Tables of Evidence and Codebooks

How are the concepts related? (RQ1)

Concepts (C)	**Citations (Measurement Frameworks in Bold)**	**Measurement Codes (with Scales and Question Types)**
C1: Organisational Resilience	Annarelli and Nonino (2016); Aylward et al. (2013); Bak et al. (2020); Beynon et al. (2020a); Branicki et al. (2018); British Standards Institute (2021); Department for Business Energy and Industrial Strategy (2023); Duchek (2020); Fearne et al. (2021); Garengo and Bernardi (2007); Green et al. (2021); Herbane (2010); Jarvis (2019); Ju (2023); Korber and McNaughton (2018); Lai et al. (2016); Lengnick-Hall et al. (2011); Meyer (1982); Mirghaderi et al. (2023); Niemimaa et al. (2019); Nietzsche (1889/1997); Office for Life Sciences (2011, 2019, 2023); Oliver (2017); **Pescaroli et al. (2020);** Reinmoeller and van Baardwijk (2005); Rees et al. (2021); Richter et al. (2018); Ries (2011, 2017); Rothaermel and Deeds (2006); Santoro et al. (2020); Schabacker et al. (2019); Shaw (2023); Sullivan-Taylor and Branicki (2011); Syed (2015); The Lancet (2018); Tidd and Bessant (2021); UK Parliament (2018); Williams et al. (2017); Wishart (2018)	None; Low; Medium; High **(Ordinal, multiple choice, select one)**
C2: Open Innovation	Aylward et al. (2013); Almirall and Casadesus-Masanell (2010); Bogers et al. (2018); Brunswicker and Vanhaverbeke (2015); Carayannis and Campbell (2011); Carayannis et al. (2021); Chesbrough (2003, 2019); Chiesa et al. (1996); Enkel et al. (2009); Escoffier et al. (2016); Faulkner and Kent (2001); Forés and Camisón (2016); Goldberg (2020); Health Research Authority (2021); Howson and Davies (2018); Howson et al. (2019); Ju (2023); Kumar et al., (2021); Lettieri et al. (2013); Lopes and de Carvalho (2018); Omachonu and Einspruch (2010); Marangos and Warren (2017); Mirghaderi et al. (2023); Morrison (2021); **Nilsson and Minssen (2018);** Pontika et al. (2015); Porter (1998, 2004); Rees et al. (2021); Ridley (2011); Salge et al. (2013); Syed (2019); Tidd and Bessant (2021); Trott and Hartmann (2013); UK Parliament (2018); Veer et al. (2013, 2016)	Completely closed; Mainly closed; Partially closed; Partially open; Mainly open; Completely open **(Ordinal, multiple choice, select one)**
C1*C2: Combined Influences	Acquaah et al. (2011); Almirall and Casadesus-Masanell (2010); Bak et al. (2020); Carayannis and Campbell (2011); Chesbrough (2003); Conz et al. (2017); Cormican and O'Sullivan (2004); Dahles and Susilowati (2015); Duchek (2020); Enkel et al. (2009); Escoffier et al. (2016); Fearne et al. (2021); Goldberg (2020); Howson and Davies (2018); Ju (2023); Keizer et al. (2002); Kmieciak and Michna (2018); Liu et al. (2020); Malerba and Orsenigo (2015); Marangos and Warren (2017); Marom et al. (2019); Márquez and Ortiz (2020); Mirghaderi et al. (2023); Nikolić et al. (2019); Pal et al. (2014); Porter (1998); Radziwon et al. (2022); Raymond and St-Pierre (2010); Reinmoeller and van Baardwijk (2005); Ridley (2011); Rothaermel and Deeds (2006); Santoro et al. (2020); Syed (2019); Tidd and Bessant (2021); van de Vrande et al. (2009); Varis and Littunen (2010); Veer et al. (2013); Venkatesh et al. (2013); Verreynne et al. (2018); Wishart (2018)	Calculated from the above measurements.

How are the concepts influenced? (RQ2)

Internal Influences (F1)

Citations	Influences	Measurement Indicators (with Scales and Question Types)
Acquaah et al. (2011); Almirall and Casadesus-Masanell (2010); Audretsch and Belitski (2013); Audretsch et al. (2004); Barão et al. (2017); Beynon et al. (2020a); Bogers et al. (2018); Caliendo et al. (2009); Cormican and O'Sullivan (2004); Equality Act (2010); Equality and Human Rights Commission (2021); Escoffier et al. (2016); Euchner (2011); Fearne et al. (2021); García-Vidales et al. (2019); Gauriot and Page (2019); Ghio et al. (2015); Gray and Jones (2016); Hausman (2005); HM Government (2021); Iborra et al. (2020); Kmieciak and Michna (2018); Marangos and Warren (2017); Mirghaderi et al. (2023); O'Gorman et al. (2008); Pal et al. (2014); Porter (1998, 2004); Ries (2011, 2017); Romero and Martínez-Román (2012); Santoro et al. (2020); Shore et al. (2023); Smith (1776/1977); Steedman and Taylor (2019); Syed (2015); Taylor (1911/2004); Tidd and Bessant (2021); Treanor et al. (2021); Wennberg et al. (2011); Williams et al. (2017); Xing et al. (2020)	Innovation Portfolio Diversity	Single product or service; Multiple products or services of a single theme; Multiple products or services of multiple themes **(Ordinal, multiple choice, select one)**
	Innovation Speed to Market	**(Nominal, text entry - numerical)**
	Innovation In-house Staff	Yes; No, integrated; Not innovating **(Nominal, multiple choice, select one)**
	Management: Family	Yes; Somewhat; No **(Nominal, multiple choice, select one)**
	Management Team Size	**(Scale, text entry - numerical)**
	Management Diversity	<u>Ages</u> Up to 20 years; 21 to 40 years; 41 to 60 years; 61 to 80 years; 81+ years; Unknown / prefer not to answer **(Ordinal, multiple choice, select multiple)**
		<u>Sexes</u> Female; Male; Other; Unknown / prefer not to answer **(Nominal, multiple choice, select multiple)**
	Management Experience	<u>Entrepreneurial</u> Present, just this enterprise; Present, concurrent enterprises; Past, successful enterprises; Past, failed enterprises; Past employment; Unknown / prefer not to answer **(Nominal, multiple choice, select multiple)**
		<u>Industry</u> **(Scale, text entry - numerical)**
	Management Knowledge	Business Management; Engineering; Life Science; Other **(Nominal, multiple choice, select multiple)**

Demographic Influences (F2)

Citations	Influences	Measurement Indicators (with Scales and Question Types)
Bernstein (2015); Bogers et al. (2018); Caliendo et al. (2009); Doz and Kosonen (2008); Forés and Camisón (2016); Garengo and Bernardi (2007); Green et al. (2021); Jarvis (2019); Jones et al. (2014); Lawrence and Lorsch (1969); Li et al. (2011); Malerba and Orsenigo (2015); Marangos and Warren (2017); Marom et al. (2019); Márquez and Ortiz (2020); Mirghaderi et al. (2023); Nikolić et al. (2019); Pisano (2011); Porter (2004); Reid (2020); Ries (2017); Santoro et al. (2016); Steedman et al. (2019); van de Vrande et al. (2009); Xing et al. (2020)	Enterprise Size	Micro; Small; Medium **(Ordinal, multiple choice, select one)**
	Enterprise Type	Public Limited Company (PLC); Private Limited Company (LTD); Non-Profit **(Nominal, multiple choice, select one)**
	Enterprise Age	**(Scale, text entry - numerical)**
	Subsector	Agricultural Technology; Animal Health; Aquaculture; Biological Technology; Medical Technology; Pharmaceuticals; Business Services **(Nominal, multiple choice, select one)**

External Influences (F3)

Citations	Influences	Measurement Indicators (with Scales and Question Types)
Asthana et al. (2019); Bak et al. (2020); Belussi et al. (2010); Beynon et al. (2020b); Bogers et al. (2018); Brunswicker and Vanhaverbeke (2015); Burnett and Dansen (2016, 2017, 2022); Conz et al. (2017); Dahlander and Piezunka (2014); Davies et al. (2017); Dayan (2020); Euchner (2011); Florida et al. (2017); Fortuin and Omta (2008); Fraser of Allander Institute (2017); Galbraith et al. (2017); Ghio et al. (2015); Gough (2021); Gray and Jones (2016); Herbane (2020); Henderson (2015); Hoang and Rothaermel (2016); Howson and Davies (2018); Howson et al. (2019); Marangos and Warren (2017); Mina et al. (2007); Minari et al. (2020); Mirghaderi et al. (2023); Moore (2016); Neale et al. (2007); North and Smallbone (2000); Nummela et al. (2006); Pickernell et al. (2009, 2019); Plummer and Acs (2014); Porter (1998, 2004); Pugh (2017); Restuccia et al. (2016); Rezaei (2020); Ridley (2011); Salge et al. (2013); Scott et al. (2015); Scottish Government (2020); Smith (1776/1977); Syed (2015); The Lancet (2018, 2020); Tidd and Bessant (2021); van de Vrande et al. (2009); Varis and Littunen (2010); Woodward (1965); Yawson (2017); Zobel and Hagedoorn (2020)	UK Country of Operation	England; Northern Ireland; Scotland; Wales **(Nominal, multiple choice, select one)**
	Internationalisation	Not yet or currently trading; Local or regional; National (UK); Continental (Europe); International; Unknown / prefer not to answer **(Ordinal, multiple choice, select one)**
	Locational Setting	Operate online-only; Isolated, remote; Rural; Suburban; Urban; Unknown / prefer not to answer **(Ordinal, multiple choice, select one)**
	Supply Chain	Supplier; Manufacturer; Distributer **(Scale, slider)**
	BREXIT	**(Scale, slider)**
	COVID	**(Scale, slider)**

Appendix D: Design Audits

Survey

Version	Date	Reviewers	Feedback
1	06 December 2021	Academics	Reword, restructure, add new questions
2	08 December 2021	Faculty	Reword, clearer figures
3	14 December 2021	Academics	Reword, a new question
4	15 December 2021	Academics and faculty	Reword, reformat, amend indicators
5	06 January 2022	Support staff	Reword, reformat
6	07 - 28 February 2022	Pilot Sample	*"Good length" (e1p)* *"Very usable survey and easy to answer without the need for reading the questions several times" (e2p)* *"Very easy Innovative survey model" (e3p)* *"Quite straightforward" (e4p)* *"Hope this will help with what you are creating" (e5p)* *"Easy, simple, straightforward" (e6p)* *"Simple enough" (e7p)* *"Very easy to complete" (e8p)* *"Straightforward" (e9p)* *"Very straightforward survey – engaging" (e10p)* *"Very easy, except that the last question about openness is ill-defined" (e11p)*
7	28 February 2022	Academics	Restructure
8	28 February - 01 July 2022	Survey is active	

Interview

Version	Date	Reviewers	Feedback
1	07 October 2022	Academics	Recommendations for briefing; rewording and making questions more concise to avoid leading; remove the parts
2	13 December 2022		Feedback of Microsoft Teams as instrument; review of questions
3	09 January 2023	Pilot with academic with industry experience of UK life science enterprise	Feedback of Zoom as instrument; incentive consideration; cut definitions into briefing
4	11 January 2023	Academics	Review of questions, email invite, consent form, data protection form
5	27 January - 30 March 2023	Interviews are active	

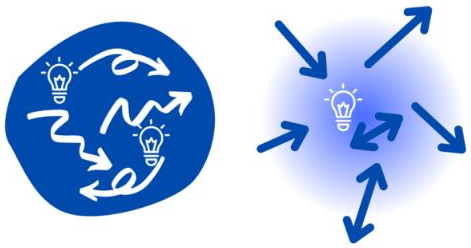
Appendix E: Qualtrics Survey Screenshots

Organisational Resilience (C1) and Open Innovation (C2)

USING THE RANKINGS BELOW, RATE THE RESILIENCE OF YOUR ENTERPRISE:
(Select one)

- ○ **NONE:** No resilience strategies, policies or procedures have been drafted, introduced or implemented. Low flexibility.
- ○ **LOW:** Some resilience measures but mostly informal with limited coordination and fragmented actions.
- ○ **MEDIUM:** Formal strategies for both internal and external threats. Policies and practices are still not comprehensive, but progress is being made.
- ○ **HIGH:** Comprehensive resilience strategies, policies and practices - regularly reviewed for continual improvement. Innovation and flexibility are prioritised.

USING THE RANKINGS BELOW, RATE THE OPENNESS OF YOUR INNOVATION PROCESS:
(Select one)



CLOSED INNOVATION
USING ONLY INTERNAL RESOURCES
CULTURE OF CONFIDENTIALITY

OPEN INNOVATION
USING INTERNAL & EXTERNAL RESOURCES
BLURRING ENTERPRISE BOUNDARIES

- ○ **COMPLETELY CLOSED:** All innovation conducted internally. Outputs belong to enterprise.
- ○ **MAINLY CLOSED:** Allow external partners insight into an innovation need, as a challenge or request for a solution. Some details openly disclosed.
- ○ **PARTIALLY CLOSED:** Allow external access to internal resources to explore innovation opportunities; waiving any rights to novel intellectual property.
- ○ **PARTIALLY OPEN:** Science disclosed so external parties can suggest new opportunities for innovation. External parties can then contribute ideas.
- ○ **MAINLY OPEN:** Encourage participation and reduce scientific overlaps, by not imposing premature restrictions or business constraints.
- ○ **COMPLETELY OPEN:** Research made public without usage restrictions. Full participation in the ecosystem. Mutually benefit from external partnerships.

Internal Factor of Influences (F1)

HOW DIVERSE IS YOUR PRODUCT/SERVICE PORTFOLIO?
(Select one)

- ○ **SINGLE** product/service
- ○ **MULTIPLE** products/services of a **SINGLE** theme
- ○ **MULTIPLE** products/services of **MULTIPLE** themes

ACKNOWLEDGING THE OFTEN PROLONGED REGULATORY PROCESSES OF THE LIFE SCIENCES, ABOUT HOW MANY YEARS DOES IT TAKE FOR YOUR INNOVATION TO GO TO MARKET?
(If not yet experienced commercialisation, please type either 'not yet innovated' or 'not yet got to market')

DO YOU HAVE STAFF DEDICATED SPECIFICALLY TO YOUR INNOVATION?
(Select one)

- ○ **YES,** an individual role/team
- ○ **NO,** integrated into other roles/teams
- ○ **NO,** as not currently innovating

ARE YOU A FAMILY BUSINESS?
(Defined as a single family as owner/managers; Select one)

- ○ **YES:** Family are involved
- ○ **SOMEWHAT:** Family actively support the enterprise, but are not owner/managers
- ○ **NO:** Family are not involved

IN YOUR ENTERPRISE, HOW MANY OWNER/MANAGERS ARE THERE?

WHICH AGE-GROUP APPLIES TO THE OWNER/MANAGER?
(If multiple owner/managers, select all that apply; estimates are accepted)

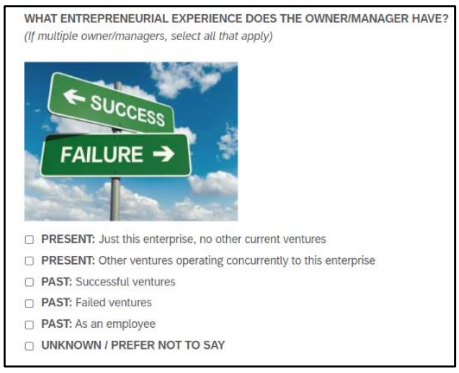
- ☐ ≤ 20 YEARS
- ☐ 21 - 40 YEARS
- ☐ 41 - 60 YEARS
- ☐ 61 - 80 YEARS
- ☐ 81 YEARS ≥
- ☐ UNKNOWN / PREFER NOT TO SAY

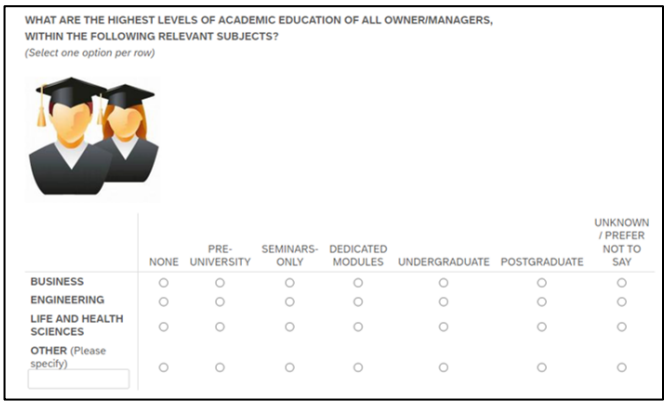
WHAT IS THE SEX OF THE OWNER/MANAGER?
(If multiple owner/managers, select all that apply)

- ☐ FEMALE
- ☐ MALE
- ☐ OTHER
- ☐ UNKNOWN / PREFER NOT TO SAY

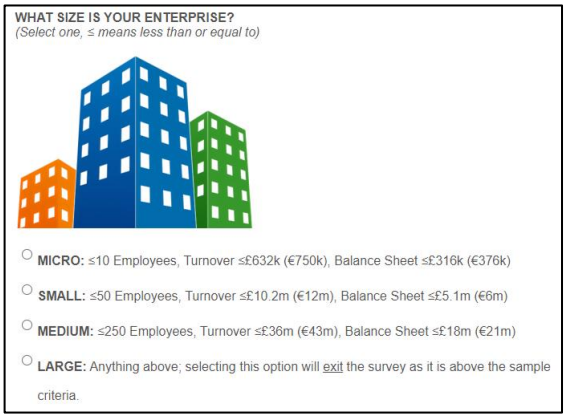
ABOUT HOW MANY YEARS OF INDUSTRY EXPERIENCE DOES EACH OWNER/MANAGER HAVE?
(Estimates will suffice)

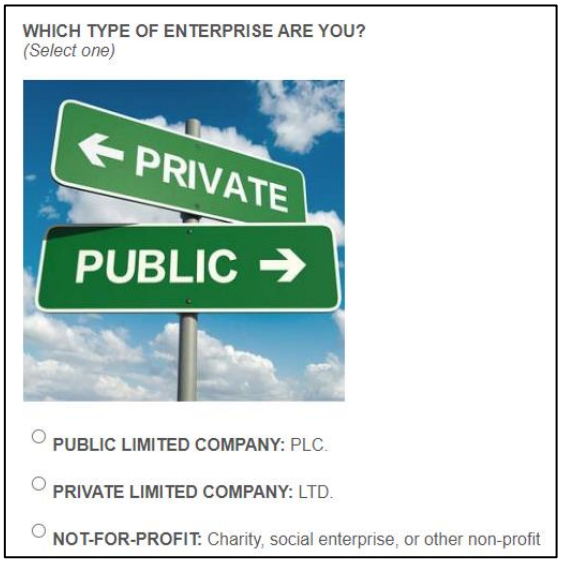
- ⋆ OWNER/MANAGER #1
- ⋆ OWNER/MANAGER #2
- ⋆ OWNER/MANAGER #3
- ⋆ OWNER/MANAGER #4
- ⋆ OWNER/MANAGER #5



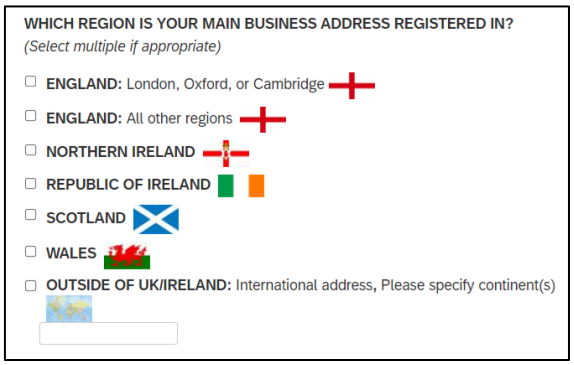


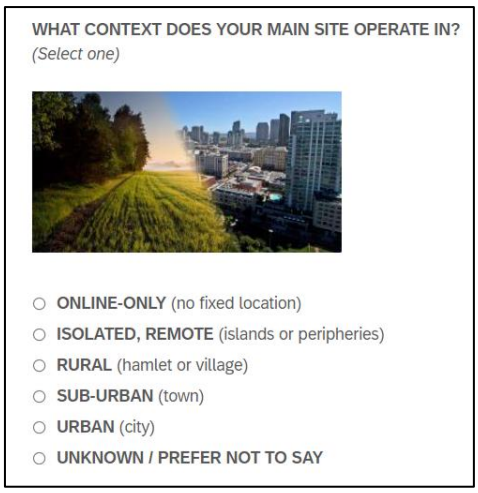
Demographic Factor of Influences (F2)

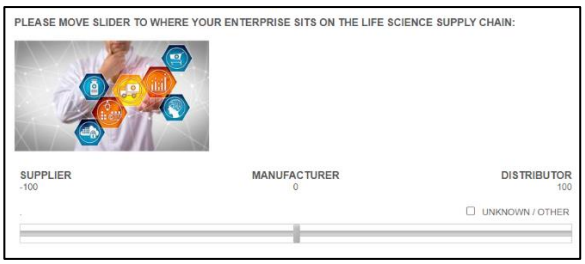


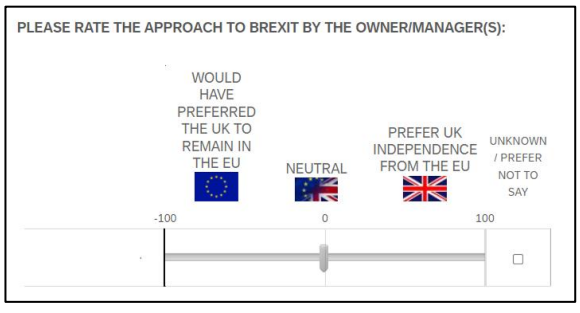


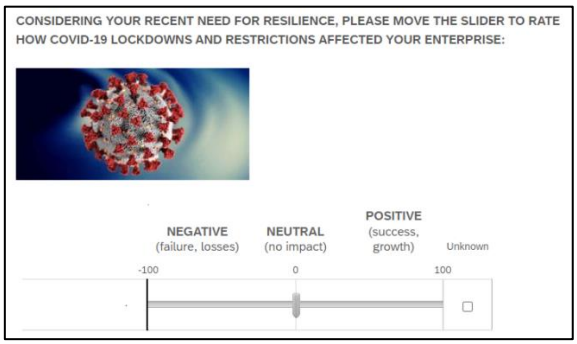
External Factor of Influences (F3)











The Qualitative Question

This question captures any additional influences that were otherwise not previously asked within the survey.

WHAT DO YOU THINK ARE INFLUENTIAL FACTORS OF OPEN INNOVATION AND RESILIENCE?

(Optional question - prompts are provided below to inspire, but can skip if all irrelevant; one-word answers will suffice)

Appendix F: Sampling

Sampling Methods

Method	Discussion	Source	Frame
Purposive	Funded by Swansea University's Research Excellence Scholarship (SURES), this research is designed as a legacy to their UK life science SME networks: BUCANIER and CALIN. A purposive sample (de Vaus, 2014; Mirghaderi et al., 2023) is applied to invite their members to participate in this research. Member SMEs will have pre-established links to Swansea University, encouraging a higher response rate. Furthermore, enterprises of the Bevan Commission (as previously sampled by Howson & Davies, 2018; Howson et al., 2019) and any surplus UK life science enterprises known to the Medical School have been included. Yet these three networks will not be solely relied upon as for the sample. Due to the associated bias of already being supported by the university, hence the need for further sampling, below.	Bevan Commission	Unknown
		BUCANIER	6
		CALIN[24]	95
		Medical School, Swansea University	149
Random, Cluster	Random cluster sampling of Welsh life science enterprises was achieved through the social media promotion by the Life Sciences Hub Wales. Such sampling is promoted, as it is "quick, but has reduced precision" (Saunders et al., 2023, p. 306). As they are open marketing channels, any of their followers can view the online invitation, which randomises the results, and risks the validity of responses. However, measures were taken to identify appropriate participant SMEs who fit the necessary criteria for inclusion. This was through clear eligibility instructions on the invitations and briefings, as well as filtering questions at the start of the survey. Participation of the interviews was also promoted on the researcher's LinkedIn social media (screenshot below, LinkedIn Advert for Random Cluster Sample).	Life Sciences Hub Wales; LinkedIn	Unknown

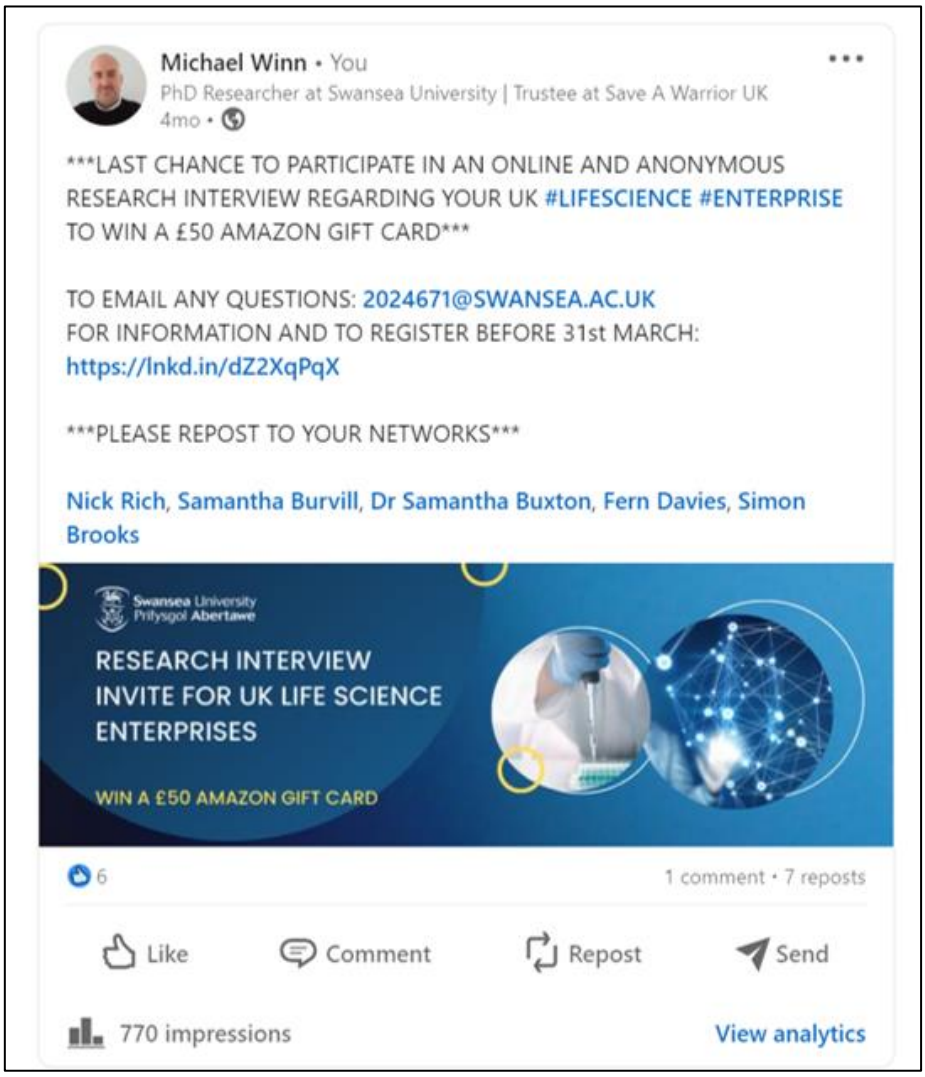
[24] The enterprises registered as members of CALIN are a blind sample, for data protection of the live project. A member of their staff will invite their members on the researcher's behalf.

Stratified, Non-Probability	There is a wealth of UK online publicly accessible directories of life science enterprises, all accessed in November 2021 to create a stratified sample. A non-probability sample can be applied to invite all of their members to participate, as using such diverse and comprehensive directories means that they are representative across the four UK countries and life science subsectors. By "dividing the population into a series of relevant strata means that the sample is more likely to be representative" (Saunders et al., 2019, p. 310). A stratified sample frame was created from the UK Government's Company House publicly accessible data download (updated monthly) and filtered by the following life science Standard Industry Classifications of economic activities. The researcher filtered the data by the identified seven life science classifications for sampling and enterprise size, to ensure the sampling criteria was met. Due to it being e-social science research (Fielding et al., 2017), an email address per enterprise was vital to invite them to participate, and yet this contact information is not featured within the download. Although a very time-consuming exercise, an online search per enterprise had to be conducted to source an email addresses or contact forms, reducing the number available to invite to participate, leaving 1062 to contact as a non-probability sample. To expand the sample further, micro-sized enterprises (which aren't always explicitly included within SME research) and non-human life science subsectors (which aren't always explicitly included within life science sector definitions) were included.	Association of British Pharmaceutical Industry	107
		BioPharmGuy	489
		Companies House[25]	1062
		Invest Northern Ireland	71
		MediWales	70
		Scottish Industry Directories	576
		Minimum Total[26]	2625

[25] 03210: Marine aquaculture, 03220: Freshwater aquaculture, 21100: Manufacture of basic pharmaceutical products, 21200: Manufacture of pharmaceutical preparations, 26600: Manufacture of irradiation, electromedical and electrotherapeutic equipment, 32500: Manufacture of medical and dental instruments and supplies, 72110: Research and experimental development on biotechnology

[26] Minimum total, due to the unknown frame size for the Bevan Commission and Life Sciences Hub Wales.

LinkedIn Advert for Random Cluster Sample



Following the posting of this advert on LinkedIn, there was an upsurge in registration due to the inclusion of a banner with the university logo for legitimacy. Although not a significant contribution to methodology, this simple endorsement could help validate the research to prospective participants, therefore increasing response rates of future business management research. At the time of writing had 773 impressions on LinkedIn, with 29.6% cited as being seen by micro and SMEs.

Appendix G: Interview Scheduling

Availability of Participant:

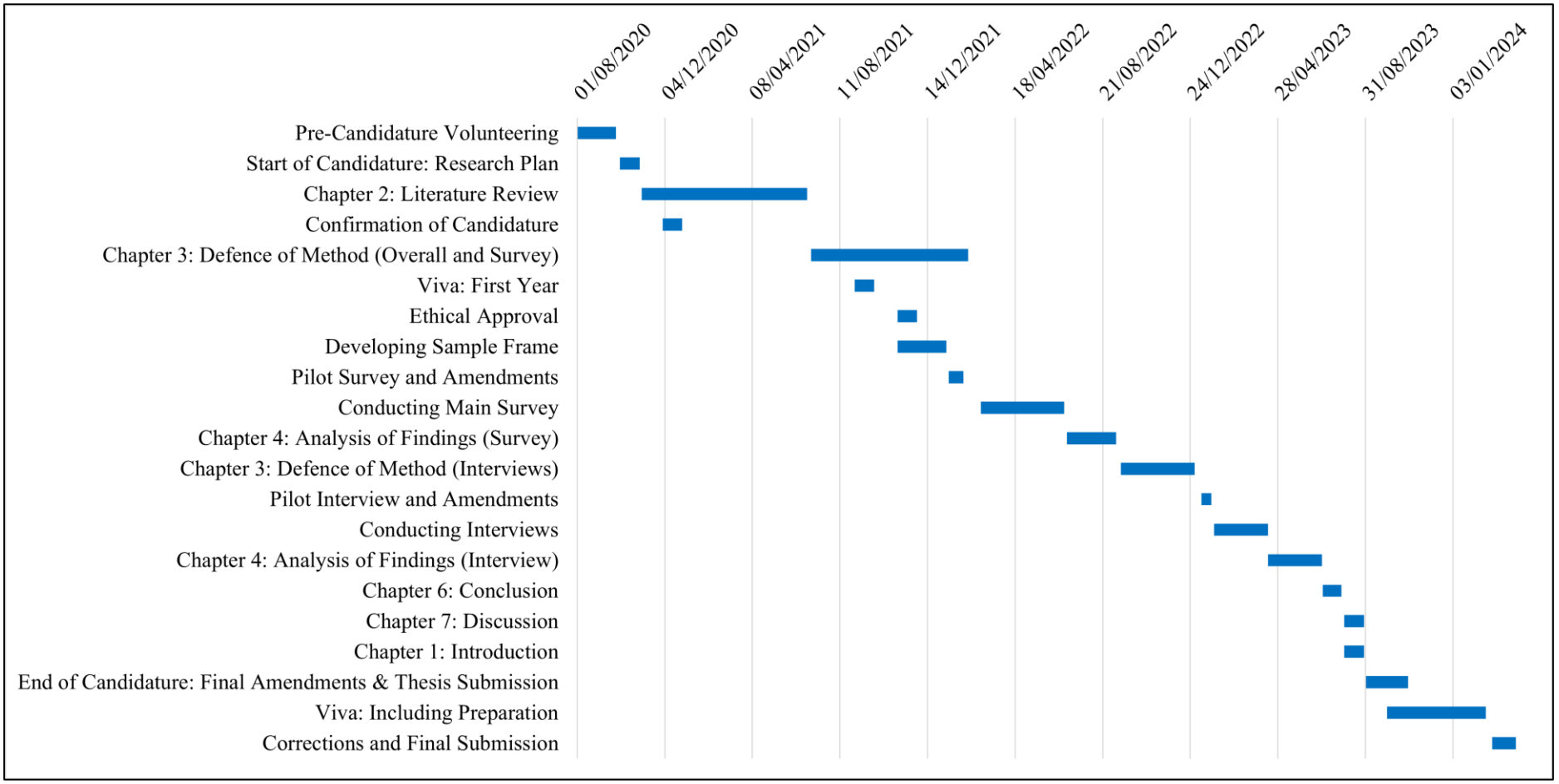
The interview will be conducted on Microsoft Teams, but a Microsoft account is not necessary. It will last approximately 30-45 minutes, but an hour timeslot will be scheduled to provide extra time, if needed.

Please select your general availability, and a timeslot will be emailed to you. This can be easily rescheduled or cancelled, upon request. All interviews to be conducted by 31/03/2023.

	Morning (09:00-13:00)	Afternoon (13:00-17:00)	Evening (17:00-20:00)
MONDAYS	☐	☐	☐
TUESDAYS	☐	☐	☐
WEDNESDAYS	☐	☐	☐
THURSDAYS	☐	☐	☐
FRIDAYS	☐	☐	☐
SATURDAYS	☐	☐	☐
SUNDAYS	☐	☐	☐

Appendix H: Gantt Chart

Task	Start	Days (Needed)	Completion	Days (Adjusted)
Pre-Candidature Volunteering	01/08/2020	40	25/09/2020	55
Start of Candidature: Research Plan	01/10/2020	20	29/10/2020	28
Chapter 2: Literature Review	01/11/2020	170	25/06/2021	236
Confirmation of Candidature	01/12/2020	20	29/12/2020	28
Chapter 3: Defence of Method (Overall and Survey)	01/07/2021	160	10/02/2022	224
Viva: First Year	01/09/2021	20	29/09/2021	28
Ethical Approval	01/11/2021	20	29/11/2021	28
Developing Sample Frame	01/11/2021	50	10/01/2022	70
Pilot Survey and Amendments	13/01/2022	15	03/02/2022	21
Conducting Main Survey	28/02/2022	85	27/06/2022	119
Chapter 4: Analysis of Findings (Survey)	01/07/2022	50	09/09/2022	70
Chapter 3: Defence of Method (Interviews)	16/09/2022	75	30/12/2022	105
Pilot Interview and Amendments	09/01/2023	10	23/01/2023	14
Conducting Interviews	27/01/2023	55	14/04/2023	77
Chapter 4: Analysis of Findings (Interview)	14/04/2023	55	30/06/2023	77
Chapter 6: Conclusion	01/07/2023	20	28/07/2023	27
Chapter 7: Discussion	01/08/2023	20	29/08/2023	28
Chapter 1: Introduction	01/08/2023	20	29/08/2023	28
End of Candidature: Final Amendments & Thesis Submission	01/09/2023	42	31/10/2023	60
Viva: Including Preparation	01/10/2023	101	19/02/2024	141
Corrections and Final Submission	28/02/2024	47	03/05/2024	65


01/08/2020
04/12/2020
08/04/2021
11/08/2021
14/12/2021
18/04/2022
21/08/2022
24/12/2022
28/04/2023
31/08/2023
03/01/2024
Pre-Candidature Volunteering
Start of Candidature: Research Plan
Chapter 2: Literature Review
Confirmation of Candidature
Chapter 3: Defence of Method (Overall and Survey)
Viva: First Year
Ethical Approval
Developing Sample Frame
Pilot Survey and Amendments
Conducting Main Survey
Chapter 4: Analysis of Findings (Survey)
Chapter 3: Defence of Method (Interviews)
Pilot Interview and Amendments
Conducting Interviews
Chapter 4: Analysis of Findings (Interview)
Chapter 6: Conclusion
Chapter 7: Discussion
Chapter 1: Introduction
End of Candidature: Final Amendments & Thesis Submission
Viva: Including Preparation
Corrections and Final Submission

Appendix I: Ethical Approvals

Medical School

Ethical Approval

Ethics Committee Use Only

Principal Investigator	Gareth Healey
Title of Proposed Research	How business-academic collaboration within the Life science sector in Wales supports business resilience
RESC Project reference number	2020-0007

Application approved	Yes	X	No			
Conflict of interest	Yes		No	X		
If yes, please supply details						
Chair of SUMS RESC	Deya Gonzalez Professor of Molecular Medicine CNH, ILS2 building, room 009 Swansea University Medical School Singleton Park, Swansea, SA2 8PP, UK. Email d.gonzalez@swansea.ac.uk Tel +44 (0)1792 295384					
Date 08/02/2020	Signature DG					

This application **has been granted ethical approval** in its current form.

Please ensure that you quote project reference number 2020-0007 in any correspondence with the SUMS RESC

School of Management

Signature of first supervisor (if appropriate)			ALL THREE SUPERVISORS ARE AWARE OF THE PROPOSED INCENTIVE AND ARE COPIED INTO THE EMAIL TO SUBMIT THIS UPDATED FORM.
Decision of SOM-REC			
Ethical Risk Assessment	Green ☒	Yellow ☐	Red ☐
Signature of SOM-REC Chair or SOM-REC deputy Chair Date			20/09/2021
SOM-REC Reference number (office use only)			SOM-REC-PGR 060 UPDATED (28/12/2022)

Appendix J: Risk Assessment

Adapted from template by Swansea University (2023)

Hazard and Risk			Actions		
What?	**Who?**	**How?**	**What?**	**When?**	**Done?**
Physical	Researcher, Respondent	Eye strain, poor posture	Keeping the survey short with easy-read questions, images to represent each variable, diverse question formats. Allow for breaks in the interviews.	During design	Yes
Smart devices and computer equipment	Respondent	Faulty electrical equipment	Respondents will be using their own devices and equipment to participate, which is either their personal or workplace responsibility.	Before responding	Responsibility of the respondents to check.
Disclosing information that puts their enterprise at risk	Respondent and their participant enterprise	Distress of loss of integrity	Anonymise the data to not be traceable back to any enterprise, state this in the briefing. No invasive or controversial questioning. Offer right to withdraw.	During design	Yes, but also responsibility of the respondents to find privacy within their workplace to freely discuss topics, away from any influence or monitoring by colleagues.
Distress	Respondent	Inaccessibility from disability	Qualtrics and Microsoft Teams has flexible, accessible formats and features available.	During research	Researcher to adjust as needed.
COVID	Researcher, Respondent	Spreading	Online data collection, so no social distancing or Personal Protective Equipment (PPE) required.	During design	Yes. All restrictions since lifted.

Appendix K: Briefings and Informed Consent

Survey

Owner/Managers (or someone on their behalf) are invited to participate in this simple survey, which investigates:

OPEN INNOVATION AND RESILIENCE

This survey samples enterprises sourced from public online sources and pre-established links with our Medical School. This research meets the legal requirements of the University's Research Privacy Notice, in the following ways:

- This survey is **anonymous** as no identifiable personal data is collected, but some diversity data is optionally requested. Be assured that your responses cannot be traced back to your enterprise. The questions are designed to be **non-invasive**, so there is no risk to your personal or professional integrity.
- The data will be stored **securely**, behind password-protected areas, and only processed by the researcher, with supervisory support. The individual data will not be passed on to any third party, but the anonymised results will be published through academic outputs, and used to influence industry engagement with our Celtic Advanced Life Science Innovation Network (CALIN).

For any questions or comments, or to later withdraw your data, please email the researcher or their supervisor.

I CONSENT TO PROCEED
(Selecting this will go to survey)
○

I DO NOT CONSENT TO PROCEED
(Selecting this will exit survey)
○

Interview

Swansea University
Prifysgol Abertawe

School of Management

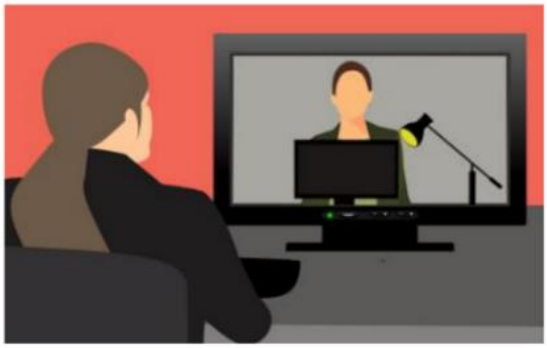
Thank you for expressing interest in participating in research into organisational resilience and open innovation by UK life science enterprises.

The interviews are approximately 30-45 minutes, but an hour will be scheduled for flexibility. It will be conducted on Microsoft Teams, but no account is required as you can join as a guest.

Your participation in the interview will be anonymised within the published data, so please be open and honest, as there is no risk to your personal or organisational integrity. Participation is voluntary, and you have the right to withdraw from the research, without reason or judgment. However, only completed interviews will be analysed and included in the prize draw to win a £50 Amazon gift card on 03/04/2023, witnessed by Swansea University staff, and contacted thereafter.

The interview will be recorded and auto-transcribed, and saved in accordance with Swansea University's Privacy Notice and General Data Protection Regulations; only to be accessed by the researcher and immediate supervisors, and not to any third party.

This short form collects data for communication, scheduling, consent, and monitoring the representativeness of the sample.



Signature of Participant:

If you consent to proceed, please sign below and submit the form. The researcher will then send you a calendar invite for the interview:

× SIGN HERE

Appendix L: Research Outputs

Journal Papers in Development

Applied to the following journals, including their ratings by the Chartered Association of Business Schools' Annual Journal Guide:

- R and D[27] Management (3)
- International Journal of Entrepreneurial Behaviour and Research (3)
- International Journal of Entrepreneurship and Innovation (2)

Constructive feedback received, and so simplifying next attempt by splitting the papers by research question. In 2024, aiming to submit to:

- Technovation (3)

[27] Research and Development

Conferences

Beyond the results reported, this research has also contributed to wider academic discourse. Preliminary insights and results were contributed to conferences, which allowed early visibility and facilitated dialogue of this research to peer and esteemed academics, and career-researchers, contributing to enhancing the quality of the investigation. The approval across these diverse conferences offers peer-review, validation, and tangible contributions to the dissemination of this research.

Postgraduate Research Conference, School of Management, Swansea University (June 2021)

'Resilience through the COVID pandemic: Welsh Academia-Industry Collaboration for Life Science Small-to-Medium Enterprises (SMEs)'

Abstract

The aim of this literature review is to establish the role of academic-industry collaboration, particularly in relation to SME resilience in the Life Science sector, against the economic threat of the COVID pandemic. The significance of this paper is to introduce relevant themes by synthesising the current literature to influence future research and policy-development, under the domain of business management. The paper will first introduce the modern problem of fragmentation of the sector, and then move onto the three key themes established within the current literature that are integral to academia-industry collaboration and SME resilience to help bond the Life Sciences through (a) government support, (b) knowledge transfer, and (c) network facilitation. The results were mainly positive, with many of the social actors encouraging collaboration in Wales; however, not all enterprises in the university-led networks were satisfied with the effectiveness of supported communication or collaboration, which provides an ongoing and unanswered question about how universities can best facilitate such openly innovative activities.

Keywords

Open innovation; life science; small business; SMEs; resilience; academia; collaboration; knowledge.

Introduction

The aim of this short literature review is to discover the impact the phenomena of the COVID pandemic has had upon openly innovative activities, between Welsh academia (specifically Swansea University) and the Welsh Life Science sector. The objective is to contribute a concise and synthesised overview of knowledge, whereby unanswered and ongoing questions can be recommended for future research. This literature review uses a more specific, but complementary, ontology of a wider piece of doctoral research, but the epistemology remains the same, as it uses a cross-discipline approach to study the Life Science sector from a business management perspective. Only qualitative sources have been reviewed, covering both academic literature (which includes peer-reviewed and/or open-access articles and conference papers) and grey literature (which includes university, industry, and government reports). These sources have mainly been identified through the wider literature review of the related doctoral thesis.

Literature Review

Fragmentation of the Life Sciences against COVID Pandemic

During any pandemic, the Life Sciences are in a unique economic position, as they are responsible for creating diagnostics and treatments for the very viruses which are causing an economic impact upon their enterprises. Published just before the COVID outbreak, Smietana et al. (2020) released a peer-reviewed, but corporately-funded, article blaming a lack of interconnection for the vulnerability of the biopharmaceutical industry, which has an implication of a decline in Research and Development productivity across the breadth of the Life Sciences, which was later discussed to impact "expertise, global reach, regulatory capability and reputation …[to] create a substantial advantage" (p. 18) and, therefore, resilience. Resilience itself is considered a poorly-defined concept by Korber and McNaughton (2018) and following their own systematic review of resilience literature, they came to the conclusion that it is a "used to connote a wide range of concepts… [including] success, survival, persistence, and optimism" (p. 1130).

In a co-authored article from 23 international academics, Mohamed et al. (2020) recommend a borderless approach for global scientific collaboration between Life Science students (academia) and enterprises (industry) to build resilience against the COVID pandemic. As the

open-access and peer-reviewed article suggests, borderless-ness not only applies to national borders, but it could also be argued to include individual enterprise borders or across sectors, as demonstrated through ‘open innovation’ in the next section.

The Role of Academia in Life Science Sector Resilience

Government Support for Academia-Industry Collaboration

Founded by Chesbrough (2019) at the start of the millennium, the concept of ‘open innovation’ characterises an enterprise’s use of “external ideas and technologies as a common practice in their own business (outside-in Open Innovation) and [the allowance of] unused internal ideas and technologies to go to the outside for others to use in their respective businesses (inside-out Open Innovation)” (pp. 28-29). Such innovation is supported by the Welsh Government (2017) who published the ‘Prosperity for All’ economic action plan, committing to “develop engagement between universities, industry and the NHS… to drive economic growth through applied research and innovation …for transformational partnerships to develop and thrive” (p. 34), for the purposes of open innovation, and more widely, to boost the Welsh economy. On a continental-level, open innovation has also been applied by the European Commission (2013) who, during the UK’s (United Kingdom) membership, also implemented an entrepreneurship action plan, whereby open innovation with higher education was encouraged, as such universities go beyond just transferring knowledge, but actual participate in alliances with industry. So, they created a framework with the aim to endorse “successful mechanisms of university-driven business creation …and emerging university-business ecosystems around key societal challenges” (pp. 7, 29), of which COVID is undoubtedly one.

Academic Spin-offs and Spillovers

As a Doctor of Medicine, Cohen (2019) wrote in an editorial introducing the increasing flow of knowledge from academia (listed as students and fellows) and professionals (listed as practicing surgeons and resident physicians) “engaging in the development of novel devices, diagnostics, therapeutics, digital health solutions, and process or policy innovations to improve care of surgical patients” (p. 142). This flow of academic knowledge into industry can be categorised as: (a) purposeful - a spin-off entrepreneurial venture by an alumnus or current academic, or (b) accidental - a spill-over, utilising otherwise-unused knowledge by enterprises.

Both categories unify the enterprises which use universities as a centralised knowledge hub, to interconnect and absorb information for the purposes of assimilation, innovation, and commercialisation. Although a now somewhat-dated article, Rothaermel and Deeds (2006) investigated the strategic alliances between biotechnology enterprises and academia, and asserted caution that this upstream knowledge transfer was "characterized by high uncertainty and frequently involve the transfer of tacit, ambiguous and complex knowledge of uncertain value … [and yet] embody leading-edge scientific discoveries" (p. 437) to be commercialised upon by Life Science enterprise, despite the risk. For the European Conference on Innovation and Entrepreneurship, Davies et al. (2017) upheld the strong tradition of academia-industry collaboration in Swansea, whereby the city's universities have played a vital role in their region's development of (openly) innovative ecosystems, and so have well-established support mechanisms in place for local economic activity. In recognition of the benefits of this, the recent Swansea Bay City Deal has invested in the development of a Life Science village and campuses to encourage such interconnection and innovation. Next, the literature will be reviewed regarding how Welsh academia facilitate Life Science industry networks, encouraging resilience during the COVID pandemic.

University-Facilitated Life Science Networks

In an open-access paper published by Oxford University, Morrison (2019) investigated the 'promises and challenges' of the UK Life Sciences, and described the sector as being effective due to a triple helix model of innovation: (a) government via the National Health Service (NHS), (b) academia via "world-class academic research", and (c) industry via "a commercial sector that ranges from pharmaceuticals to data analysis" - making the country an "advantageous location for developing new regenerative medicines" (p. 1).

Through the application of this helix model, Pugh (2017) examined the support for Welsh enterprise by academia, and found that despite their voluntary participation, such support did not always provide positive feedback, with one Life Science entrepreneur responding that: "university–industry programmes are a waste of time and not valued at all by businesses" (p. 989). Previously, and published in the Industry and Higher Education journal, Jones et al. (2014) studied Welsh tech-enterprises, and similarly discovered that not all entrepreneurs had a positive experience of working with other enterprises in such academia-facilitated networks, naming a loss of control and difficulty in communication, resulting in prospects for future

closed, rather than open innovation, which was defended by universities having a "different agenda …compared to commercial organisations" (p. 47). Conversely, some did have positive experiences with the networks, due to the universities keeping a "finger on the pulse" (p. 47) for funding opportunities and relevant contacts, promoting interconnectedness.

Such positive and negative perspectives provide unanswered and ongoing questions around the effective facilitation of networks to increase value (and resilience) for their Life Science partners. Amongst the current Welsh Life Science networks supporting enterprises in the region, such as those hosted by the Life Science Hub Wales, Swansea University also facilitates industrial networks to encourage knowledge transfer between otherwise-competing enterprises, commonly known as co-opetition; three examples follow next. Swansea University has both recently hosted, and is currently hosting, such Life Science industry networks; the first two providing cross-border support in Wales in the UK, and the Republic of Ireland in the European Union (EU), and the last facilitating truly international open innovation:

Firstly, although closed in January 2021, 'Building Clusters and Networks in Innovation Enterprise and Research' (BUCANIER) was extended by six months for their partners to be supported in building resilience during the pandemic, through innovation and transition to online trading. For the same conference as cited above, Davies et al. (2020) evaluated BUCANIER and found that a key outcome was the sheer "strength of ties and ecosystem structure" (p. 210), citing 72% of their industry partners repeatedly interconnecting and transferring knowledge through open innovation. Secondly, 'Celtic Advanced Life Science Innovation Network' (CALIN) is a live project, which has had a mid-term evaluation conducted by James and Stevens (2019), prior to COVID. Their report cited the UK leaving the EU as the primary threat to sustainability (and therefore, resilience) at the time; this external force can arguably now be replaced with the bigger economic threat of COVID lockdown restrictions upon the Life Science sector. It is therefore conceivable that the goal of CALIN to "unite …to expand the economy" (p. 22) through building close academic and industrial relationships, is now more relevant than ever to build resilience against such a threat as COVID. Thirdly, 'Physiologically Anchored Tools for Realistic Nanomaterial Hazard Assessment' (PATROLS) facilitates intersectoral open innovation, utilising all three of the helices cited above: academia, industry, and government. Despite being EU funded, PATROLS (N.D.) operates internationally, and their strategy is to "ensure their data [knowledge] is accessible to the various PATROLS stakeholders" (p. 1) for their use to openly innovate with and

commercialise; however there has been no mention in regard to building resilience for the sector, especially during COVID.

Conclusion

This short literature review asked if collaboration between academia and industry, can help build the resilience of the Life Science sector, using the context of Wales during the COVID pandemic. To answer this research question, this paper provided a brief overview of the themes considered, through a concise synthesis of knowledge. This paper is unable to provide an in-depth analysis of the topics, however but it does provide recommendations for future research, which would be extendable to a wider ontology.

Firstly, this review considered how governments can support such collaboration, which was evidenced at all levels of government, through open access and grey literature, which not only proved comprehensive support for interconnecting the Welsh Life Science sector, but also provided scope for future academic research into economic policies and initiatives, in a post COVID era. Secondly, the paper considered how academic knowledge can be transferred into industry. It argued that such knowledge flow can be challenging for industry to interpret, as it is so complex and technical. However, it could also be argued that improved interconnectedness can be achieved using universities as open and centralised hubs that promote knowledge transfer and resilience, and so future research would be beneficial as to how the knowledge flow can be more-easily communicated and interpreted for effective commercialisation in the industry. Finally, it was contemplated how Swansea University facilitates Life Science industry networks, using the examples of BUCANIER, CALIN and PATROLS. Through evaluation of their efforts, future research could investigate how effectiveness regarding encouraging communication and collaboration could be increased, regarding support for their Life Science collaborations, through academic policy and procedures.

To address the issue of a fragmented, and therefore vulnerable, Life Science sector, this review of literature has accomplished giving a brief appraisal of some of the methods used by the social actors in the triple helix model: (a) government, (b) academia, and (c) the Life Science industry. Swansea University has evidenced their role in increasing effective interconnection and resilience across the Life Science sector, however it does raise the ongoing and unanswered question of how universities can best facilitate these networks effectively, which should be

addressed in future research. This is for the wider benefit of increasing the Welsh economy and social health outcomes of the nation, post COVID; with the ontology used being extendable for future research.

References

Chesbrough, H. W. (2019). Open Innovation Results: Going Beyond the Hype and Getting Down to Business (1st ed.). Oxford University Press. https://doi.org/10.1093/oso/9780198841906.001.0001

Cohen, M. S. (2019). Innovation Series. Surgery, 166(2), 1. https://doi.org/10.1016/j.surg.2018.04.060

Davies, F., Howson, T., Boy, F., Joyce, N., & Davies, G. (2020, September). BUCANIER: A Cross-Border Innovation Ecosystem. European Conference on Innovation and Entrepreneurship, Reading.

Davies, G., Roderick, S., & Williams, M. (2018, September). A Sub-Regional Innovation Ecosystem? Life Sciences and Health in the Swansea Bay City Region. European Conference on Innovation and Entrepreneurship, Reading.

European Commission. (2013). Entrepreneurship 2020 Action Plan. (795). Brussels: European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52012DC0795

James, C., & Stevens, S. (2019). Mid-Term Evaluation of the CALIN Project [External Evaluation]. Celtic Advanced Life Science Innovation Network.

Jones, P., Patz, R., Thomas, B., & McCarthy, S. (2014). Micro-Sized Enterprises, Innovation and Universities: A Welsh Perspective. Industry and Higher Education, 28(1), 39-49. https://doi.org/10.5367/ihe.2014.0192

Korber, S., & McNaughton, R. B. (2018). Resilience and Entrepreneurship: A Systematic Literature Review. International Journal of Entrepreneurial Behaviour & Research, 24(7), 1129-1154. https://doi.org/10.1108/IJEBR-10-2016-0356

Mohamed, K., Rodríguez-Román, E., Rahmani, F., Zhang, H., Ivanovska, M., Makka, S. A., Joya, M., Makuku, R., Islam, M. S., Radwan, N., Rahmah, L., Goda, R., Abarikwu, S. O.,

Shaw, M., Zoghi, S., Irtsyan, S., Ling, I., Cseprekal, O., Faten, A.-B., Hazar Sayar, E., Soloukey, C., Grancini, G., & Rezaei, N. (2020). Borderless Collaboration is Needed for COVID-19: A Disease that Knows No Borders. Infection Control & Hospital Epidemiology, 41(10), 1245-1246. https://doi.org/10.1017/ice.2020.162

Morrison, M. (2019). The Promises and Challenges of Biomodifying Technologies for the UK [Profile]. Oxford University Research Archive, 1-2. https://www.openaccessgovernment.org/biomodifying-technologies/68041/

PATROLS. (N.D.). Overview. [Academic Poster]. European Union. https://www.patrols-h2020.eu/PATROLS-Overview-Poster-003.pdf

Pugh, R. (2017). Universities and Economic Development in Lagging Regions: 'Triple Helix' Policy in Wales. Regional Studies, 51(7), 982-993. https://doi.org/10.1080/00343404.2016.1171306

Rothaermel, F. T., & Deeds, D. L. (2006). Alliance Type, Alliance Experience and Alliance Management Capability in High-Technology Ventures. Journal of Business Venturing, 21(4), 429-460. https://doi.org/10.1016/j.jbusvent.2005.02.006

Smietana, K., Quigley, D., Van de Vyver, B., & Møller, M. (2020). The Fragmentation of Biopharmaceutical Innovation [News and Analysis]. Nature Reviews: Drug Discovery, 19(1), 17-18. https://doi.org/http://dx.doi.org/10.1038/d41573-019-00046-3

Welsh Government. (2017). Prosperity for All: Economic Action Plan. Crown. https://gov.wales/prosperity-all-economic-action-plan

Institute of Small Business and Entrepreneurship (October 2021)[28]

Conference Theme: Bridging Enterprise, Policy, and Practice: Creating Social and Public Value

Session Theme: Networks and Innovation

Presentation and Paper Title: UK Life Science Open Innovation for Small-to-Medium Enterprise Resilience.

Abstract

Despite the importance of the Life Science sector to the nation's health, their 5.9 million small-to-medium enterprises (SMEs) in the United Kingdom (UK) face a 39% failure rate within their first 3 years of operation (Office for Life Sciences, 2011), compared to a 50% failure rate of general SMEs within their first 5 years of operation (European Commission, 2014). Significantly, due to COVID lockdown restrictions, 50% of all UK businesses are "temporarily closed or paused trading" (Gough, 2021), but these restrictions are now lessening, but with untold economic outcomes. Only 37% of UK SMEs are described as "innovation active" (Achur, 2020) and there is a reported decline in returns on investment for UK Life Science research and development (R&D) (The Lancet, 2018). This is all despite the term 'organisational resilience' being a contentious term in the Life Sciences due it incorrectly directing blame upon its entrepreneurs, rather than the faults of the wider systems it sits within (Oliver, 2017).

The sector also suffers from fragmentation too, which allows for increased sector vulnerabilities. Firstly, due to an ever-increasing diversity of demographics to serve, Life Science enterprises are isolating to specialise in their own R&D of specific diagnostics and treatments, rather than providing a unified response to cater to public health (Lettieri et al., 2013); secondly, the identity of the Life Science sector is fragmented, due to no agreed upon

[28] Cited as Winn (2021) in Chapter 8: References. Accessible via https://cronfa.swan.ac.uk/Record/cronfa66387/.

academic definition existing, and so the sector definition relies upon the union of its subsectors (Howson, 2019), or a reference to grey definitions.

Considering the above, endurance is a huge challenge for UK Life Science SMEs and there is a real justification for a review and synthesis of academic knowledge regarding how, or indeed if, opening the borders of an enterprise (otherwise known as 'open innovation') affects their resilience and innovation capabilities. The concept of 'open innovation' is defined as the utilisation of external ideas and technologies, and the licencing for any internal ideas and technologies to be utilised by other enterprises (Chesbrough, 2019). This concept is scrutinised as it may be integrated by UK Life Science SMEs as a route to their enhanced resilience, but which factors influence it?

To answer this, the aim of this literature review is to systematically evaluate the current knowledge to determine what factors influence SME resilience, and how they might be optimised to support sector growth. The methods used to source and review the current literature is through a search of major research databases, for keywords such as 'UK Life Science', 'SMEs', 'organisational resilience' and 'open innovation', alongside some other relevant synonyms. This is to produce a synthesis of knowledge to build recommendations for industrial policy and practice to consider openness within their innovation strategies. The results were filtered, prioritising peer-reviewed academic literature, and in line with the theme of openness, some open-access literature was also examined. Recent literature was also preferred, although older articles are cited to provide a historical context and evolution of key concepts.

The results of this paper seek to understand the various factors which influence the formation of strategic alliances (individual or networks) for collaboration and open innovation, and how that would affect the organisational resilience of UK Life Science SMEs. This literature review forms a chapter of a wider, ongoing piece of doctoral research which identifies the multi-level factors influencing open innovation. This preliminary paper provides scope to form ongoing and unanswered questions to be answered through the subsequent mixed method primary research. The literature review concludes that there is a lack of research regarding UK Life Science SMEs' organisational resilience and the factors influencing their open innovation. Therefore, this synthesis of knowledge provides a significant contribution to academic

knowledge, industrial practice, and government social policy, all to create sustainable value in public health through medical R&D, which is relevant to the theme of this conference.

Keywords

Life Science, SME, Organisational Resilience, Open Innovation, Failure, Fragmentation

Introduction

With a 39% SME failure rate, and the recent external shocks to the UK Life Sciences (such as BREXIT and COVID), there is a need to enhance and sustain their resilience, to which open innovation is explored as a possible solution for this. The sector is one of the UK's most productive, so this research is important for it to remain a global market leader. There has been previous research upon open innovation by UK Life Science SMEs, but not in relation to organisational resilience, and so this literature review examines past and current research upon the key themes, with the aim of producing a concise synthesis of academic knowledge to gauge a new understanding. The chapter structure is as follows (2.) a brief introduction to the context, (3.) theories of organisational resilience, (4.) the need for resilience within the sector, (5.) considering solutions for resilience, (6.) open innovation, and (7.) its influential factors.

Context: UK Life Sciences

The Office for Life Sciences (2017) demonstrate that pharmaceuticals are the UK's most productive sector, well above the national average; later, the Office for Life Sciences (2020) identify a substantial 82% SME representation within UK Life Science businesses. From an academic standpoint, Morrison (2021, p. 1) glowingly presents the sector and indicates how collaboration is necessary to translate medical knowledge into innovative products or services:

> *The UK has a well-established life sciences sector, with world-class academic research, a commercial sector that ranges from pharmaceuticals to data analysis and contract manufacturing, a National Health Service with multiple research-intensive hospitals and an established system of regulatory oversight. It is in many respects an advantageous location for developing new regenerative medicines.*

Organisational Resilience for UK Life Science SMEs

Early organisational resilience theory by Meyer (1982, pp. 515, 535) considered "threats, crises, and catastrophes" as 'jolts' (a term still used by academics today), each revealing vulnerabilities to health infrastructure. Although a dated and American study, it is still relevant as "by plunging organizations into unfamiliar circumstances, jolts can …revitalize them, [and] teach lessons that reacquaint them with their environments" to provide benefits to the patient. Using a linear three-phase temporal model of before, during, and after environmental jolts, Meyer provided a conceptual framework to visualise his theorem, as seen in Figure 1.

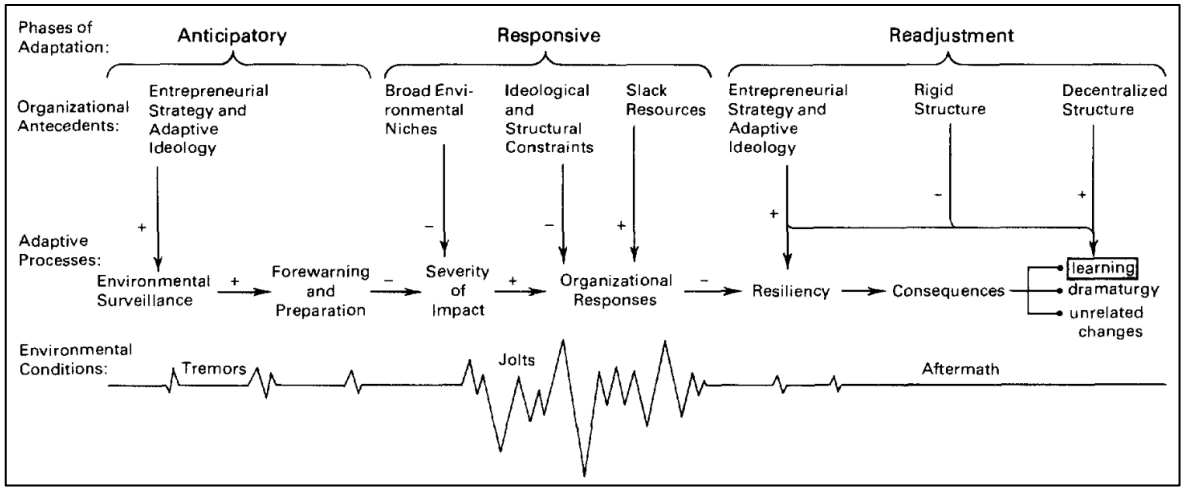


Figure 1: Organisational Adaptations to Environmental Jolts (Meyer, 1982, p. 534)

More recently and taking a more positive spin on the otherwise-negative subject of organisational threats, Lengnick-Hall et al. (2011, p. 244) highlighted the opportunities that such jolts offer, as they recontextualise and strengthen an enterprise into "a new reality while simultaneously avoiding or limiting dysfunctional or regressive behaviors." They insist jolts are a chance for the enterprise's human resources to develop new capabilities, which enhances their organisational resilience and outcomes.

In 'The Lean Startup', Ries (2011, p. 38) suggests that a fundamental aim for an entrepreneur to learn, and grow a sustainable enterprise, is "to engage in organization building under conditions of extreme uncertainty". Such notable examples of modern and external uncertainty are acts of terrorism, the financial crash of 2007-2008, BREXIT and COVID; each causing disorder and instability for UK Life Science SMEs.

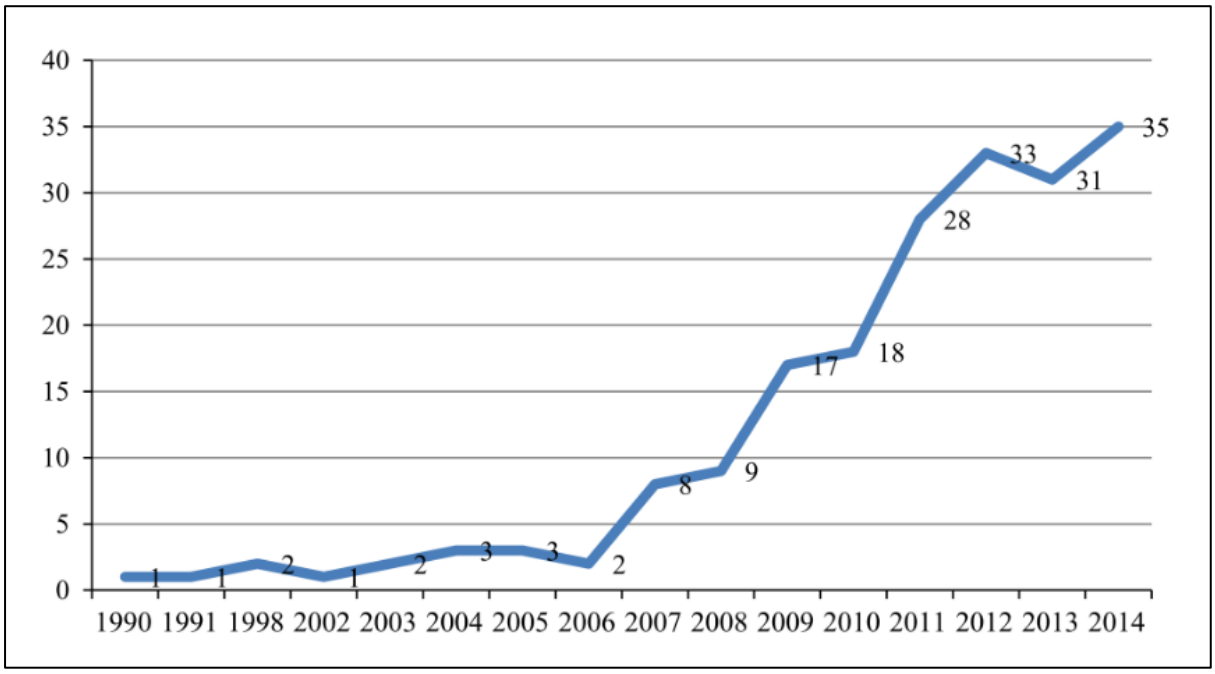


Figure 2: Selected Publications per Year (Annarelli and Nonino, 2016, p. 4)

In their systematic review of organisational resilience literature, Annarelli and Nonino (2016, p. 2) found that there is a historic lack of interest on the matter, yet "since the global financial crisis of 2008, the topic has aroused a higher level of interest," see Figure 2. Yet, for the British Medical Journal, Oliver (2017, p. 1) labelled resilience as a contentious term within the Life Sciences due to it creating entrepreneurial blame, rather than accusing the "often over-politicised, understaffed, underfunded, badly-organised systems".

Drawing parallels to the various scientific states of matter, Williams et al. (2017) propose that 'crisis management' (resilience) should also be considered in its different states: (a) a formulaic and sequential process, (b) an activity to restore equilibrium, (c) a capacity, (d) an ability, and finally, (e) an outcome. These different states of being was also picked up in a systematic literature review conducted by Korber and McNaughton (2018, p. 1130), who concluded that resilience is actually a poorly defined concept anyway, "used to connote a wide range of concepts… [including] success, survival, persistence, and optimism." They also believed resilience to be a process used to enhance an enterprise's transformation to new market conditions, following a period of uncertainty.

Using the context of the modern threat of cyber-bio-security upon the Life Sciences, Schabacker et al. (2019, p. 3) also provided an academic definition, as an organisational capability to "reduce vulnerability to various threats and hazards through protective measures

that improve an organization's ability to resist an event or absorb its effects with minimal impact." Schabacker et al. also created temporal framework of before (vulnerabilities) and after (consequences) a crisis, to demonstrate the risk-based decision-making process for organisational resilience. Yet, promoting their strength, Beynon et al. (2020a, p. 2) placed SMEs at the forefront of "driving economic recovery globally" due to their sheer number and representation within the marketplace.

Justifications for Organisational Resilience

By applying these such theories and models to the UK Life Science SMEs, it has become evident that there are two main justifications for the UK Life Sciences to enhance their resilience capabilities, both of which are explored below.

Failure

The Office for National Statistics (as cited in the Office for Life Sciences, 2011) reported that 39% of UK Life Science SMEs failed within their first three years, but, as pessimistic as that statistic may be to entrepreneurs, it is now over a decade old, without any update provided since. Also, the data did not include high-tech R&D SMEs, which are now more prevalent in the Life Sciences. More generally, in a study of 'second chance' previously non-resilient entrepreneurs for their policy development, the European Commission (2014) asserted that 50% of all new enterprises, of any sector, fail during their first five years of operation.

From an academic perspective, Syed (2015, pp. 12, 204) promoted learning from failure, despite it being a cliché. This is especially the case for the Life Sciences, whereby he suggests that the sector has a long and rich history of evading learning from failure, which is "a cornerstone for success for any institution". Despite the very-real prospect of failure for enterprises, Syed proposes that it could "spark creativity." Recognizing that no-one, especially entrepreneurs and scientists (or a combination of the two), wants to fail, but they should at least attempt to create a culture where it is safe to do so.

Using the context of economic recessions to promote the advantages SMEs have over larger firms, Lai et al. (2016) asserted that smaller enterprises have flexibility and adaptability, allowing them to survive and thrive during hard times. Conversely, Ries (2017) identifies that finance is the reason why start-ups fail so frequently, due to the inadequate monetary decisions

made by the entrepreneurs. This is even before the SME has become profitable, with a lack of investors and limited resources to raise any further capital to save themselves.

On top of the high failure rate of UK Life Science SMEs, it is suggested by Tidd and Bessant (2018, p. 410), that there is also a high failure rate of their collaborative, strategic alliances. Therefore, once entrepreneurs experience failure (or at least, the prospect of it), then open innovation may not be such an exciting prospect for them to partake in, as it'll be too much of a risk for them. Citing other (somewhat-dated) studies, Tidd and Bessant confirm a failure rate of about 50% within the organisation's first seven years of collaboration. They then cite reasons for failure as: (a) strategic divergence, (b) procedural problems, or (c) a cultural mismatch.

Even if their aim is to improve social health, Life Science enterprises are still businesses in pursuit of profit to avoid failure. This can cause debates in morality, as evidenced in a Life Science industry report by Richter et al. (2018, p. 20), which controversially questioned if curing patients is a sustainable business model: "The potential to deliver 'one shot cures' is one of the most attractive aspects of gene therapy… [but] it could represent a challenge for genome medicine developers looking for sustained cash flow." This comment was later scrutinised by Consumer News and Business Channel (CNBC, cnbc.com/...business-model.html) and even made into a meme to mock the audacity of it. Yet, the solutions for sustainable profits, presented by the Goldman Sachs report, include continuous innovation and portfolio development.

In his study of entrepreneurialism, Jarvis (2019) suggests that failure and success can only really be subjectively defined by the entrepreneurs, and so even if one partner defines their alliance a failure, it does not mean the other partner does too, especially if one of the parties' objectives have been met. At the time of writing, Gough (2021, p. 2) used a positivist approach to report that about 50% of UK businesses were "temporarily closed or paused trading" due to the COVID lockdown restrictions, and so it is certainly a worrying time for UK SMEs, but restrictions have since lessened, with unknown long-term outcomes for the national economy.

Fragmentation

The UK Life Sciences suffer from this too, both in terms of its fragmented identity and outputs, which allow for increased sector vulnerabilities. Although recognising that the UK has advanced health sector capabilities, Lettieri et al. (2013) observes that due to a lack resources

and an ever-increasing diversity of demographics to serve, Life Science enterprises are isolating to specialise in their own innovation of specific diagnostics and treatments, rather than providing a unified response to cater to wider public health.

Although there are arguably positive connotations to innovation, Bogers et al. (2018, p. 8) contended this by implying that it can actually provide inequality and even be considered as a "great divider." Although they gave no further explanation for this statement, it does raise the issue that such a high-tech and innovative sector as the Life Sciences may be divided, fragmented, and therefore vulnerable. In an anonymous editorial by the esteemed medical journal, The Lancet (2018, para. 2) suggests that it is time to 'burst the biomedical bubble' as society has benefitted from a "golden age of biomedical research", but this is soon due to end, with 12 global Life Sciences companies reporting a decline in R&D returns, from 10.1% in 2010 to 3.2% in 2017. One reason being that the UK sector is having to cater for an ever-increasing complexity and multimorbidity of the aging population.

There is even fragmentation of the Life Sciences' identity, with no academically agreed-upon definition of the Life Sciences; instead, descriptions rely upon using the vague sector identity as an umbrella term for an assemblage of medical sub-sectors. This has been applied by Howson (2019, p. 17), who defined the industry by splitting it into three main sub-sectors: (a) Medical Technology, (b) Biological Technology, and (c) Pharmaceuticals. Later, Howson agreed that sub-sector boundaries were becoming progressively blurred, due to a "technological convergence between scientific realms, as knowledge and technology become increasingly complex" within the Life Sciences. Without a finite or leading definition, there is a blurring and confusion of sectoral boundaries and infrastructure, which could arguably lead to difficulties in Life Science enterprises identifying and accessing academic contributions to knowledge, policy, and practice for the sector, which would benefit their resilience.

Using the example of the recent 10-year vision report for the UK Life Sciences by HM Government (2021), there is no clear grey definition presented either. Not in the foreword by the Prime Minister, nor in the foreword co-authored by five senior Life Science representatives of government, academia, and industry, nor even in the main text of the strategic report. As a substitute, they each list and promote successes in the general area of UK medicine and healthcare, which are significant achievements but are likely biased to encourage trade and, so do not provide clarity over its identity.

Considering Solutions for Organisational Resilience

Following justification for organisational resilience, this chapter explores two such solutions for the UK Life Sciences to enhance their resilience capabilities, below.

Openness

Identifying a trend within academic literature and industrial operations, Veer et al. (2013, p. 3) found openness to be, very much, an "en vogue topic". Therefore, there is an abundance of research upon the concept, but a lack regarding its impact upon organisational resilience, hence the justification for this research. Nilsson and Minssen (2018) set out to clarify the different types of 'open' found within Life Science R&D, from two different perspectives regarding the sharing of an enterprise's assets: (a) the inbound 'seeker' transfer, and (b) the outbound 'provider' transfer. Their clarification was for the specific purpose of determining an enterprise's level of openness, and to create standardised terminology to increase the ease of legal collaborative contracts between alliances, see Figure 3.

Defining levels of openness in life science research collaborations					
Degree of openness	**Disclosing innovation need**	**Open access to resources**	**Open science, open source**	**No terms or commitment**	**Open data, waived rights**
Not open	–	–	–	–	–
Level 1	X	–	–	–	–
Level 2	X	X	–	–	–
Level 3	X	X	X	–	–
Level 4	X	X	X	X	–
Level 5	X	X	X	X	X

Figure 3: Levels of Openness in Life Science Collaborations (Nilsson and Minssen, 2018, p. 773)

Within a Life Science industry report, Goldberg (2020, pp. 2, 17) announced that we are currently living through a transformative period for medical innovation. Yet, for this to happen, Goldberg believes it will take elements of openness, such as "an unprecedented level of cooperation, a willingness to share information and a high degree of trust … [which] is a recipe for resilience." This is for Life Science enterprises to not only survive through uncertainty, but to gain competitive advantage and create value for social health. Goldberg elaborated upon the open versus closed debate, which goes against the recommendations of (a) Tidd and Bessant, and (b) Nilsson and Minssen for nuance. However, it must be noted that his report did have a corporate bias, as it all led to promoting their own brand 'open' software:

> *Fluidity versus silos. Data sharing versus data ownership. Process and algorithm versus product. The ecosystem of the future will be connected and open, blurring traditional distinctions among the players in the …value chain. Organizations will focus less on owning and monetizing data and more on connecting and combining it to drive valuable insights that can transform health care.*

Innovation

Using the early study of competition as a starting point, Porter (1998, pp. 409, 429) suggested innovation is a key factor in achieving advantage, but asked: "What will it take to foster entirely new approaches to disease prevention and treatment…?" Porter warned that without incentives to sustain life science innovation, and the increased needs for an ageing population, it will ultimately lead to an unwanted reduction in quality and quantity of provision. At the time, due to its cost, technology was seen as the enemy to the health and life sciences, yet Porter cited that "pharmaceutical, biotechnological, and medical device companies [began] to deliver cost-reducing innovations," removing finances as a barrier to sector reform and medical provision. This reform was later reanalysed by Porter (2004b), who found that any evolution of industry is accompanied by a shift in structural boundaries, with innovation expanding sector limits to include more competition; but it is the opening up of enterprise boundaries which will be considered for this paper. Whilst discussing such enterprise structure, Toni and Nassimbeni (2003, p. 678) believed that SMEs approached their innovation with much less formality than their larger competition, due to their "managerial competencies [being] limited, availability of financial resources is lower, the attraction towards skilled labour weaker and the propensity for interaction with other firms is limited." Yet, it is this interaction with other firms which open innovation is founded upon and will be considered within this paper.

In his study of the Life Sciences from a business management perspective, with a particular interest in sustainability, Sasson (2005, p. 20) recognised the positive impact that start-ups and SMEs have made with their innovation, with "most of the innovation in medical biotechnology … done by small companies." Yet, there is an apparent academic consensus that innovation helps organisational resilience, but comes at a cost of resources, which SMEs are often cited to lack. It is therefore a concern that The Lancet (2018) suggests a decreasing financial incentive for biomedical enterprises to innovate, as there is a reported decline in returns on investment for UK Life Science R&D.

Open Innovation

As the founder of the concept, Chesbrough (2003, p. 43) raised that: "valuable ideas can come from inside or outside the company and can go to market from inside or outside the company as well", which was supplemented by Figure 4. There is a common trend within the literature to use the 'innovation funnel' to demonstrate open innovation within conceptual models. However, the definition and model has developed over time and across his prolific publishing career.

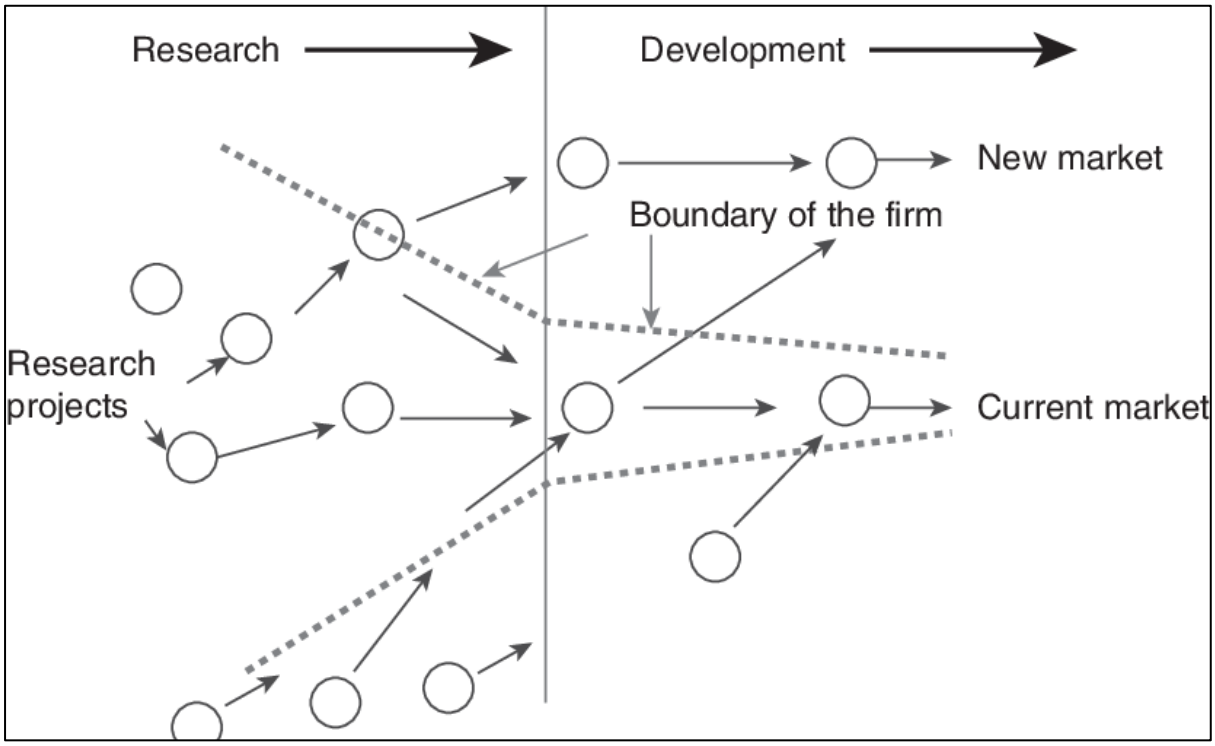


Figure 4: Open Innovation Paradigm (Chesbrough, 2003, p. xxv)

For example, Escoffier et al. (2016) expanded Chesbrough's original diagram, and provided a more thorough visualisation, see Figure 5, which encompasses all the various assets transferred inbound and outbound of the enterprise's boundaries.

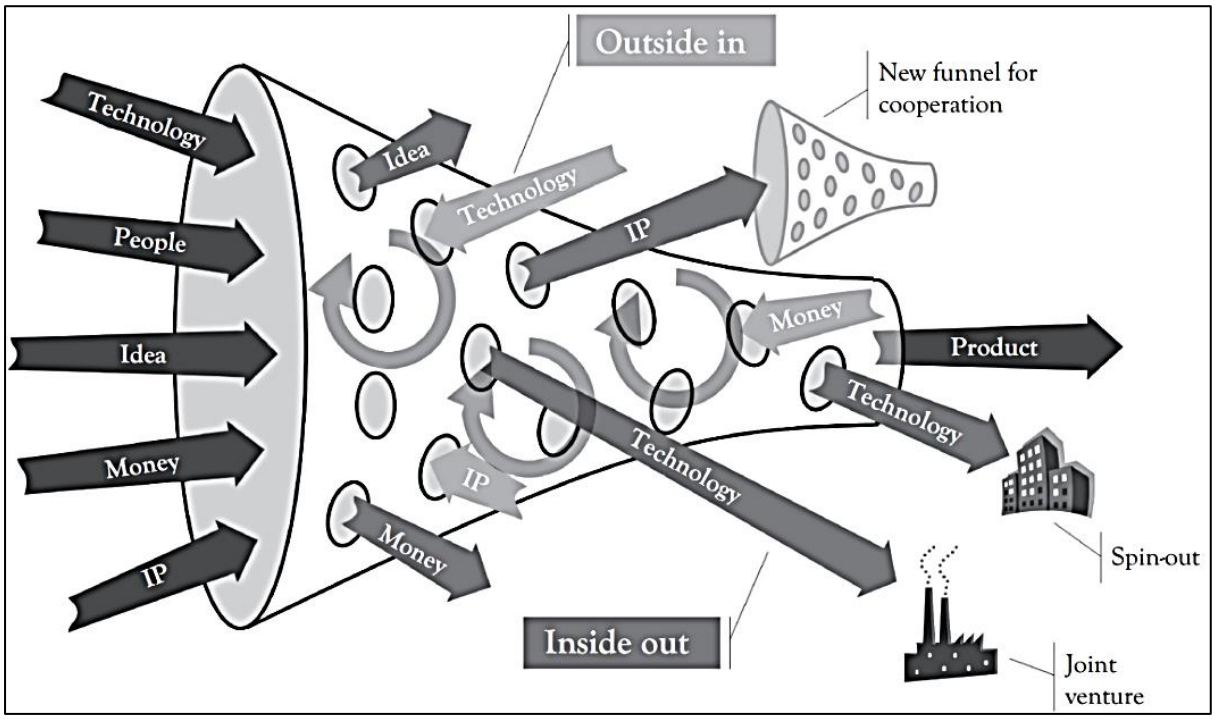


Figure 5: Open Innovation (Escoffier et al., 2016, p. 6)

**Intellectual Property (IP)*

Using the same context of open innovation in the UK Life Science SMEs, Marangos and Warren (2017) maps their R&D, rather than exploring its relationship to organisational resilience. By fulfilling both justifications of organisational resilience, they saw that early Life Science innovation was a "linear and internally-focussed or closed process." This can lead to them being "fragmented, leading to an increased risk of market failure" (pp 211, 219). Hence the justification to open up their R&D to address the specialisation for increasingly complex healthcare requirements. Using a micro to macro structure, as seen in Figure 6 (and applied to this paper later), Marangos and Warren list 'barriers' (negative influential factors) to open innovation: (a) time pressure, (b) payments/cash flow, (c) regulatory hurdles, (d) finance and funding, (e) product failure, (f) operational governance, (g) loss of contracts, and (h) commercialisation hurdles. Unfortunately, there was no such list for factors which facilitate (positive influential factors to) open innovation.

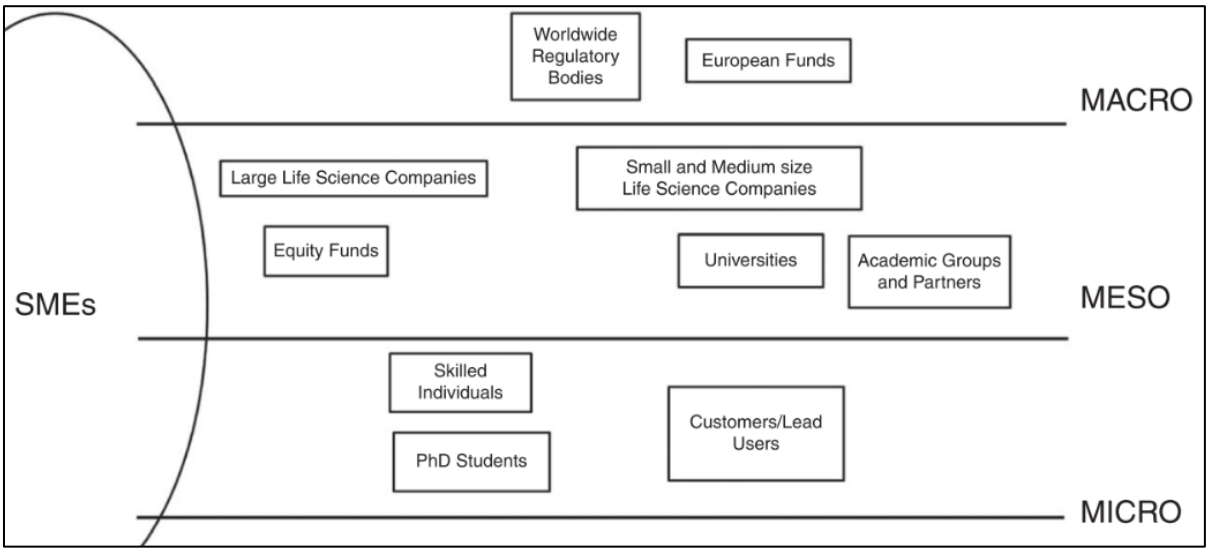


Figure 6: Multilevel Approach (Marangos and Warren, 2017, p. 214)

Although their research was not regarding resilience per se, Williams et al. (2017, p. 745) suggests that "in the context of adversity, relational capabilities – the social connections that enable access to and exchange of resources – play an important role in … enabling positive functioning." Then, without acknowledging the concept of open innovation, Williams et al. have described the resilience benefits of exchanging resources with their 'social connections,' permeating organisational boundaries. In their book 'Managing Innovation', Tidd and Bessant (2021, pp. 395, 428) present multiple justifications as to why enterprises should make such social connections (or 'alliances'): (a) to reduce the cost of technological development or market entry, (b) to reduce the risk of development or market entry, (c) to achieve scale economies in production, (d) to reduce the time taken to develop and commercialise new products, and/or (e) to promote shared learning. They later confess that academic research upon open innovation is popular and still growing but accuse the concept of just being vague, too easily applied, and "a repackaging of existing research and practice". Tidd and Bessant even contested the open versus closed innovation dichotomy, instead preferring to examine the levels or degrees of openness, which is further reflected by the previously cited, Nilsson and Minssen (2018). In his book 'Rebel Ideas', Syed (2019, p. 142) was full of support for what would be considered as open innovation, promoting the 'outsider mindset' and 'internal expertise' as powerful assets of any enterprise:

> *We need both conceptual depth, and conceptual distance. We need to be insiders and outsiders, conceptual natives and recombinant immigrants. We need to be able to understand the status quo, but also to question it. We need to be strategically rebellious.*

Although not a novel discussion-point within open innovation, Chesbrough (2019, p. 28) recently added 'technology transfer' to his definition of the concept and suggests that "no one organization has a monopoly on great ideas, and every organization, no matter how effective internally, needs to engage deeply and extensively with external knowledge networks." Returning to Morrison (2021, p. 1), he believed that innovative science was important, but not enough to deliver new therapies for patient benefit. Instead, to produce novel medical products and services, collaboration is needed to translate and transfer knowledge and technologies between "academics, companies, healthcare professionals, regulators, funding agencies, hospital managers and health economists, [all] working together to develop solutions," hence the proposal for openness within the innovation pipeline.

Influential Factors of Open Innovation

Next, this paper explores the current influential factors of open innovation, which is the key theme of the paper, and so by returning to the early founding work of Chesbrough (2003, p. 45), the past influential factors to end "knowledge monopolies" were concluded to be: (a) an increase is research excellence and its diffusion, (b) an increase in distribution of patent awards, (c) an increase in knowledge diffusion beyond national borders (d) a decrease in size of enterprises which generate most knowledge (which is directly relevant to this SME research), and (e) an increase in graduates entering the workforce.

This paper will now review the current literature upon the factors which influence openness of enterprise boundaries for innovation. Whilst some factors will facilitate the transfer of ideas (knowledge) and technologies, Acs et al. (2013) recognised that some may equally act as a filter for entrepreneurs. Following their systematic review of open innovation literature, and subsequent development of a comprehensive conceptual framework of factors (Figure 7), Lopes and de Carvalho (2018) justifies the exploration of factors by stating that open innovation:

> *has multiple facets …and it is a multi-level phenomenon… On the one hand, identifying the key variables and factors affecting open innovation is still a research challenge. Innovation openness can involve several features… On the other hand, understanding the key aspects is not enough. It is also important to understand the implications of open innovation on performance [contributing to organisational resilience].*

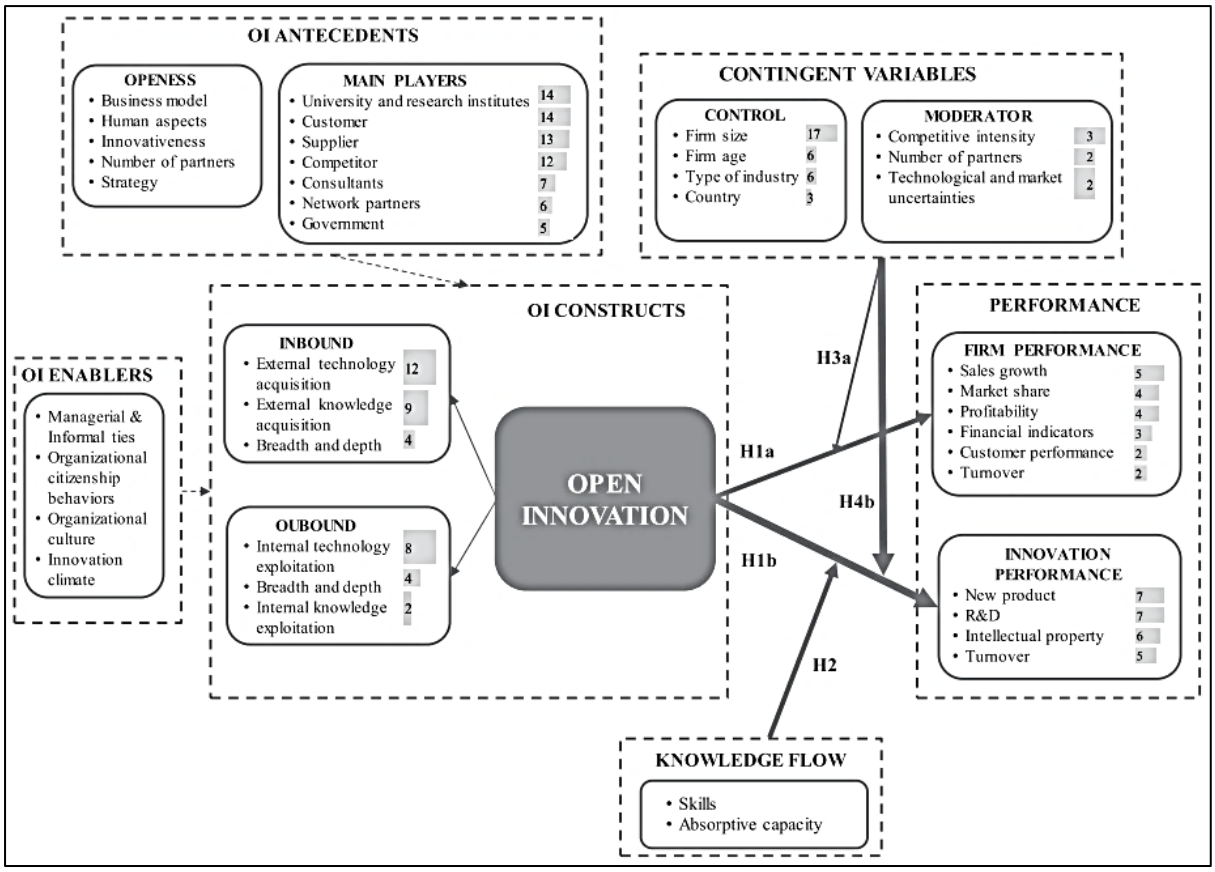


Figure 7: Factors of Open Innovation (OI) Performance (Lopes and de Carvalho, 2018, p. 295)

Due to the identified knowledge gap, Herbane (2019) emphasised the justification of SME research upon "factors that are known to influence the adoption of resilience enhancing activities", potentially, such as open innovation, which Beynon et al. (2020b, p. 87) added that the review of separate, individual factors may be insufficient for SMEs to "support growth and innovation alone" but will actually require a combination of them to influence open innovation.

On behalf of UK Government's Department for Business Energy and Industrial Strategy, Achur (2020) monitored both the motives (Figure 8, below) and barriers to innovation, across a six-year period of the UK Innovation Surveys. Although not concerned with open innovation, it is from a substantially large sample of 14,040 UK enterprises. Improving the quality and

replacing outdated products were the two most prominent reasons to innovate. Regulations being third, speedily increasing in prominence across the time-range. The barriers to innovation were also featured and grouped into (1) financial, (2) knowledge, and (3) regulatory-based obstructions for the UK SMEs to be actively innovating, with finances being the majority factor. Interestingly, regulations are highlighted as being both a motive and barrier to innovation.

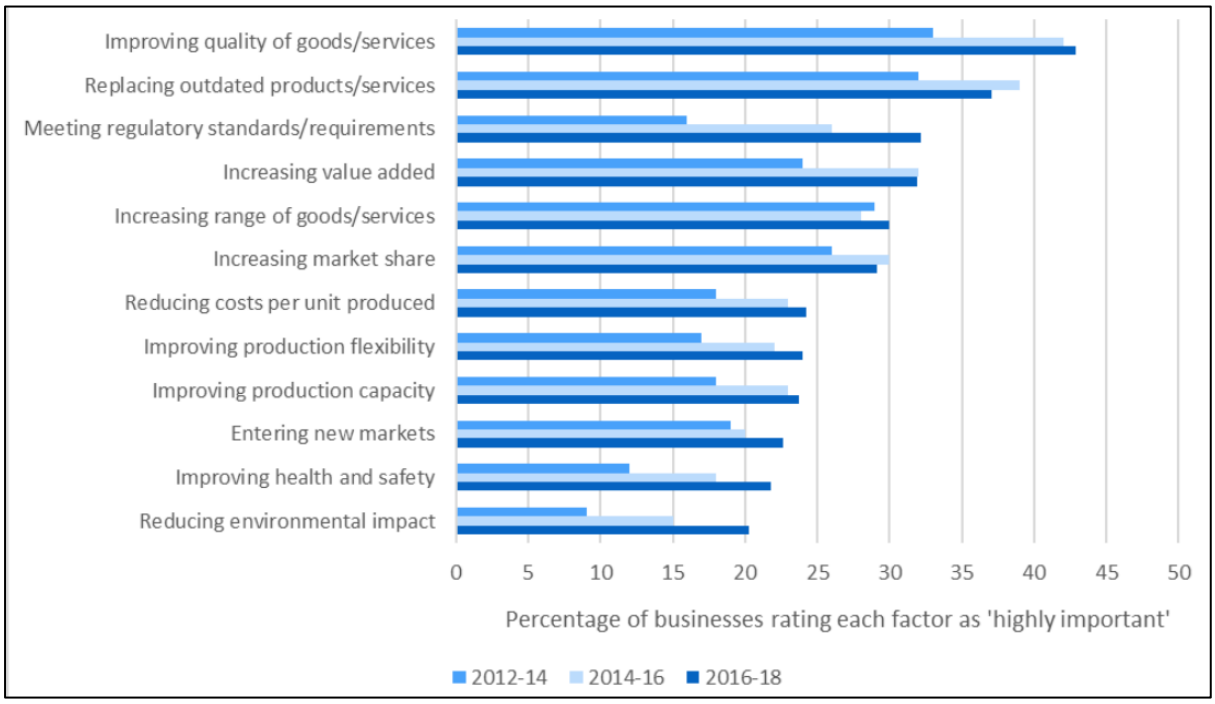


Figure 8: Motivations for Businesses to Innovate (Achur, 2020, p. 17)

Using the above-cited micro to macro structure, the factors are now split for discussion.

Micro: Entrepreneur

Appreciating the high risk and expense of innovation ventures conducted by healthcare and pharmaceutical entrepreneurs, Cormican and O'Sullivan (2004) suggested that it demonstrates resilience due to their functioning despite low levels of success and high levels of termination, and so this section focuses on entrepreneurial experience and knowledge.

Using an unconventional data collection method, Caliendo et al. (2009, p. 155) surveyed nascent entrepreneurs to investigate how much of a hypothetical lottery-win would "invest in a risky asset" to demonstrate their attitudes to risk and concluded that previously employed entrepreneurs have are more positive relationship with risk, born out of coming from stable

employment, in comparison to the previously-unemployed. Whilst considering the 'dark side' of open innovation, Veer et al. (2013, p. 9) also asserted that such an activity as open innovation is a "a risky strategy as critical knowledge may spillover to outsiders. …[which] may nurture an obsessiveness with ownership."

Considering previously failed ventures, Stam et al. (2008, p. 495) labels those returning to entrepreneurship as 'renascent,' and found that their re-entry is "systematically related to their ability to absorb knowledge," potentially from outside their new venture's boundaries. More recently, Iborra et al. (2020, p. 2) found that in turbulent times, an entrepreneur's venture can become more resilient when "relying on their past success at investing in risky projects," such as open innovation, which would have uncertain outcomes for them.

Another experience-level to consider is that of successful entrepreneurs who run concurrent ventures, with Doz and Kosonen (2008, p. 6) actually warning that they can "become victims of their own success: as they grow and become successful, they lose some of their adaptive capacity. The search for efficiency drives flexibility out. Success dulls strategic sensitivity," and so may not be motivated to look for open innovation alliances. Opposing this complacency, Salge et al. (2013, p. 664) suggest that experienced "leaders are expected to have better opportunity recognition and knowledge recombination capabilities …[and] higher expectations for creativity …for the creative recombination of external knowledge inputs," which is directly relatable to open innovation. Furthermore, claiming that success breeds success, Malerba and Orsenigo (2015, p. 671) suggest that entrepreneurs that enjoy prosperous innovative collaborations, "may have more resources to invest in R&D and therefore higher probabilities to [openly] innovate again as compared to non-innovators."

Highlighting a lack of literature regarding the specific academic background of entrepreneurs, Ghio et al. (2015, pp. 11, 14) acknowledges that it does influence venture performance, but is it an influential factor of open innovation? Those with a science-based academic background "are aware of the commercial value of new knowledge when market related knowledge is embedded in their research context, as well as when they cultivate external contacts with those with market knowledge," potentially for open innovation to occur. Ghio et al. went on to question if there is a difference for enterprise performance, between the academic knowledge domains of natural (life) sciences versus the social sciences (for instance, business management), which raises the ongoing and unanswered question if they are influential for the

UK Life Science entrepreneurs to openly innovate. It is important to note, that Life Science entrepreneurs may have no Life Science academic knowledge and are therefore considered ‘agents’ rather than ‘creators,’ “transforming knowledge into marketable products into new markets.”

Of course, not all entrepreneurial knowledge is sourced from academia, but from industry too, which was raised by Gray and Jones (2016, p. 476), who highlighted that entrepreneurs of micro Welsh enterprises lead a solitary working life, and so through coaching to pursue collaboration (for open innovation activities, for example), they found a positive impact on the resilience of their ventures through achieving access to a “supportive peer learning community,” to detect potential failures and develop entrepreneurial skills.

Meso: Enterprise

This chapter will examine the characteristics of an enterprise, as influential factors for open innovation in the UK Life Sciences.

Firstly, the size of enterprise is considered by Ries (2011, p. 254), who states that there is a commonly held belief that larger enterprises lose their capacity for innovation with growth. Yet Ries is quick to quash this, suggesting that entrepreneurs can build up an organisation from scratch, and with intent to explore new (and potentially open) business models for innovation; even adding that larger enterprises could learn and change their management philosophies to reflect their “portfolio thinking”.

In a co-authored paper with the founder of open innovation, Weiblen and Chesbrough (2015) found that UK pharmaceutical SMEs are in a confident position, as due to the wider industry opening up their assay libraries, big-pharma can now out-licence their otherwise abandoned programs to their SME counterparts to commercialise for the benefit of economic and health outcomes. This was reemphasised by Henderson (2015, p. 30) who, not only discussed that there are strategies to anchor such Life Science SMEs in Scotland to “increase the number of more resilient companies,” but also highlighted that, on a more regional level, found that larger Life Science businesses “struggle to maintain their product [innovation] pipelines …to meet the increasing demands of shareholders to maintain growth margins” and so used the solution of partnering with, and licencing to, SMEs.

Questioning if size of an enterprise affects their innovation, Forés and Camisón (2016) asserted that larger organisations also have more capability to create knowledge in-house, which is encouraging for medium-sized enterprises and upwards, but not so good for micro and small enterprises. Specifically in the Life Sciences, Marangos and Warren (2017, p. 212) demonstrate a similar point, that larger organisations have had to re-evaluate their business models to seek access to better ideas (knowledge) and technologies from outside, whilst still having a focus on their in-house capabilities. There has even been a trend to "draw more extensively on discoveries, tools and target compounds which have been licensed-in from smaller firms… Big life science firms have been looking to small companies for new [Intellectual Property], seeking partners to evaluate, utilise and acquire knowledge."

Whilst examining the unique relationship between big-pharma and small-biotech, Tidd and Bessant (2018, p. 407) commented that it is a popular dynamic for industry and academic research, as the mutually beneficial alliance gains them access to complementary assets: (a) big-pharma can seek expansion of their technological capabilities from smaller specialist biotech enterprises, and (b) the small biotech enterprises seek access to "funding, development, marketing and distribution" for their innovation activities. Tidd and Bessant claim that the market leaders in pharmaceuticals each have about 200 active collaborations, with half being drug-discovery, yet they question the motives of smaller biotech enterprises: "For the pharmaceutical firms, there is a strong positive correlation between the number of alliances and market sales. For the biotechnology firms, the benefits of such relationships are less clear."

In an American study, investigating the link between size, innovativeness, and risk, Marom et al. (2019, p. 40) stressed that there is a lack of homogeneity within the SME bracket, as there are even differences in innovation activities per size, with entrepreneurs from larger SMEs (assumedly, in this case, medium-sized) pursuing "a strategy that tends to be higher in innovation but with reduced risk, while in smaller firms the owners pursue a strategy that is higher in risk but lower in innovation." This is inverted when considering risk, with the smaller SMEs (assumedly, micro-, and small-sized) taking on more risk, than larger SMEs.

Providing the UK legal definitions of the different enterprise sizes, the Department for Business Energy and Industrial Strategy (2019) requests that SMEs must fulfil two out of the three following ceiling limits, as defined in the Companies Act 2006:

Size Type	Section of Act	Maximum Turnover	Maximum Balance Sheet Total	Maximum Number of Employees
Micro	384a	£632,000	£316,000	10
Small	382	£10.2 million	£5.1 million	50
Medium	465	£36 million	£18 million	250

Referring again to the study of the 'UK Innovation Survey', Achur (2020) states that large enterprises are innovating more than SMEs, with 50% of larger businesses, compared to only 37% of SMEs being categorised as 'innovation active.' Achur used an arguably wide defining criteria from the Organisation for Economic Co-operation and Development, which did not include any mention of keywords associated with open innovation (external sources, collaboration, etc.).

Secondly, age is considered as an influential factor of open innovation. It could be argued that all SMEs are young, as they have not yet had the success to yet grow, and so it is a likely (but not exclusive) scenario that medium-sized enterprises are more well-established than micro enterprises. Describing the last 50 years of Life Sciences, Malerba and Orsenigo (2015, p. 674) suggest that newer biotech SMEs are just trying to commercialise their drug discoveries, becoming suppliers of knowledge to big pharma, which is encouraging for open innovation as it is "giving rise to a dense network of alliances and collaborative relationships and to the development of vibrant markets for technology and knowledge." However, due to their young age, they lack the capital to conduct vital elements of the downstream value chain to extract profits, citing such examples as: (a) drug development, (b) regulatory product approval, (c) manufacturing, and (d) marketing. Instead, they recommend that young SMEs make their money from selling their knowledge to larger and/or well-established enterprises.

Although a lack of capital is indeed a concern, Ries (2017, p. 122) argued that start-ups (new SMEs) are at an advantage as their innovation is not restricted by the "archaic, inflexible structures and protocols in place" for larger and/or well-established enterprises. Below, shows their conceptual model of how the shared values of entrepreneurial and general management

of start-ups result in continuous innovation. In agreement, Marangos and Warren (2017) found it was the case that new Life Science SMEs to bring new science (cited as drugs, devices, and clinical processes) to market.

In a study of young Finnish companies, Tornikoski et al. (2017) agreed that due to the heterogeneous nature of young enterprises who each have diverse specialisms, it is not a guarantee that the entrepreneur would focus on building competitive advantage through creating unique technologies or obtaining them across their enterprise borders. Using a national technology funding agency's database, they sampled 100 SMEs that were created after a certain date to ensure their immaturity – the paper emphasised that the agency had no bias upon the research. Tornikoski et al. found that the entrepreneurs were especially hesitant to transfer technology due to it being a high-risk and resource-heavy activity, which both were barriers for SMEs to confidently take on. This brings the conversation back around to the micro-level factors, and if the entrepreneur has the experience and knowledge to circumnavigate uncertainty, risk, and resource-allocation.

Although previously cited as discussing SME size as an influential factor of open innovation, Marom et al. (2019, p. 41) also considered SME age, and agreed with Tornikoski et al. that younger SMEs have to be higher risk-takers, which is "one of the many reasons for the low survivability of firms within the SME sector." As start-ups, innovation was found to be low whilst the enterprises were establishing themselves and gaining resources. Yet, in favour of open innovation, Marom et al. suggested that to overcome this, SMEs should build networks with other smaller enterprises and actors within their ecosystem, and therefore 'harnessing' resources through teams, partnerships, and stakeholders, all beyond the enterprise boundaries.

Critiquing the academic research on SME age and performance, Nikolić et al. (2019) found there to be a positive correlation between the two, as larger enterprises have more access to resources and a better knowledge of their 'business environment,' providing them with more readiness to handle uncertainty. Alternatively, Nikolić et al. identified research which promotes a negative correlation, with older, larger enterprises being less flexible to adaptation within their environment. So, this academic uncertainty justifies the need for further research into if age is an influential factor for open innovation within UK Life Science SMEs.

Finally, location is considered as a competitive and influential factor of open innovation. Porter (1998) observed that its importance is changing due to enterprises now operating on a global,

open economy, since enhanced by the internet too. According to Ghio et al. (2015) location matters, as the local context is an influential factor for enterprise creation and growth, particularly in relation to local human and financial capital. In agreement, and as per 'classic' business management academic literature, Conz et al. (2017) identified that geographic location is heavily linked to the entrepreneurial performance.

Location is particularly important for technology acquisition, as Tidd and Bessant (2018, p. 416) suggest that it is what binds the link between local enterprises (intra-regional), with domestic alliances increasing faster than international alliances, despite globalisation. They highlight that understanding and communicating with other national cultures is a barrier for cross-border alliances and acquisitions to take place, preferring instead to collaborate with those enterprises in locations familiar to the entrepreneur. Tidd and Bessant suggested that UK enterprises have a stereotype to focus more on the short-term financial and legal control over an alliance, rather than the longer-term learning from it, resulting in a lack of "organisational memory" being developed.

Macro: Ecosystem

This chapter asks if the types of alliances that the UK Life Science SMEs have within their ecosystem, influences their open innovation. To provide structure to the following chapter, Porter (1998, pp. 200, 202) identified the following categories of actors within the UK Life Science ecosystem:

Vertical	"Identifying the constituent parts of a cluster involves starting with a large firm or concentration of like firms and then looking upstream and downstream in the vertical chain of firms and institutions"
Horizontal	"The next set is to look horizontally to identify industries that pass through common channels or that produce complementary products and services. Additional horizontal chains of industries are identified based on the use of similar specialized inputs or technologies or with supply-side linkages"
Multiple	"Cluster boundaries should encompass all firms, industries, and institutions with strong linkages, whether vertical, horizontal, or institutional; those with weak or non-existent linkages can safely be left out. …labelling a single industry as a cluster overlooks crucial cross-industry and institutional interconnections that strongly affect competitiveness"

To be explicit, this subchapter will consider factors at ecosystem-, rather than sectoral-level, as it is then exclusive of actors that are located inside and outside the Life Sciences, which SMEs openly innovate with. Especially as Porter (2004a, p. 175) believed that technology can alter

sector boundaries anyway, stating that "distinctions between an industry's product and substitutes, incumbents and potential entrants and incumbents and suppliers or buyers are often arbitrary."

Chesbrough and Euchner (2011, p. 18) described ecosystems as a "voluntary community that comes together" to innovate. They continued their idealistic description, with the presumption that participation means that everybody (all stakeholders) wins, by utilising other actor's skills to collectively build. Making a similar point, Escoffier et al. (2016, p. 59) suggests that there should be no negative impact on any stakeholder of the SME involved, and then went on to define the main parties:

> *Companies in the supply chain servicing the ultimate customers (end users) are obvious, as are regulators and funding agencies. Often overlooked are opinion leaders (experts, trade publications and other traditional and social media gurus, key people in advocacy groups, etc.), industry and professional association and society officers and committee chairs or members, and key people in relevant nongovernmental organizations.*

Taking this further, but specifically for UK Life Science SMES, Marangos and Warren (2017) define the ecosystem as a network for R&D collaborations with such actors as (a) start-ups, (b) established Life Science firms, (c) universities, (d) research centres, and (e) science parks; all contributing to the open innovation process. From their research, Marangos and Warren devised a Polar Plot Analysis according to their interview responses (see Figure 9, below), revealing that: (a) Inter-SME partnering very popular, favouring collaboration with other smaller enterprises rather than with big-pharma; (b) Government intervention is significant due to their sponsorship of SME partnerships, especially through such agencies as Innovate UK (gov.uk/.../innovate-uk), the Medical Research Council (mrc.ukri.org), and the obvious, National Health Service (nhs.uk); (c) Academia, including alumni that have since moved into the Life Science industry jobs; and (d) Large Life Science enterprises (big-pharma, for example), although with a caveat that SMEs are wary of such collaboration with them due to a feeling of inferiority due to inexperience. Marangos and Warren therefore recommend that SMEs find a specific, approachable contact within the large enterprise to innovate with.

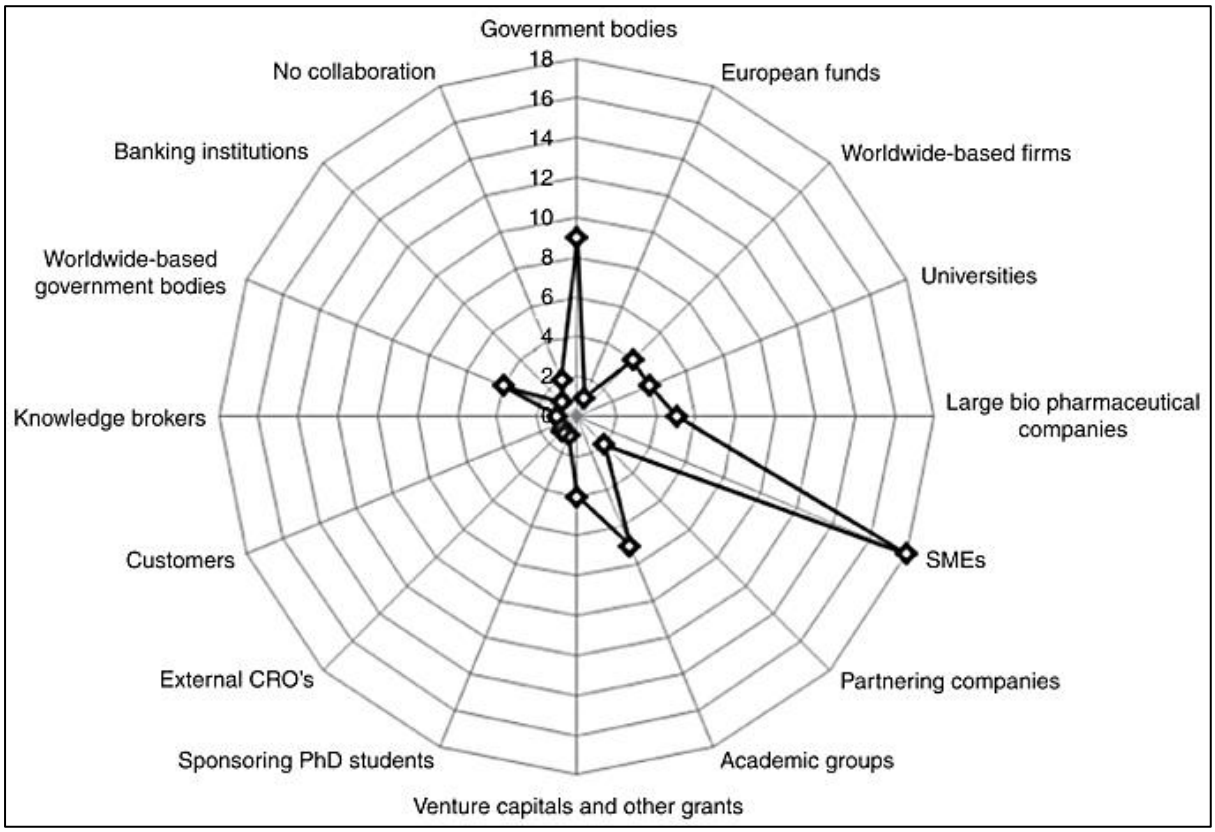


Figure 9: UK Life Science SME Collaboration Behaviour (Marangos and Warren, 2017, p. 217)

Conclusion

As evidenced, there are two main reasons (failure and fragmentation) into why UK Life Science SMEs require an investigation into enhancing their resilience, with the combined consideration of openness and innovation (combined as 'open innovation') as a solution, and what factors facilitate or hinder the adoption of openly innovative entrepreneurship, policy, and practice, to create public value in social health. Based on their conclusions, a recommendation can be made for SMEs to adopt a trial of even a partial level of openness in their innovation activities, as Tidd and Bessant don't believe that the rigid open versus closed approach is helpful anyway. A recommendation to provide a significant and original contribution to academic knowledge would be to investigate the influential factors of open innovation more widely, for SMEs to make an informed choice towards an openly innovative resilience strategy. This paper forms the basis of the literature review of a wider piece of research for a doctoral thesis, whereby organisational resilience and open innovation theories and models are explored in greater detail.

References

Achur, J. 2020. UK Innovation Survey. In: Department for Business Energy and Industrial Strategy (ed.) 2019 ed.: Crown.

Acs, Z. J., Audretsch, D. B. & Lehmann, E. E. 2013. The Knowledge Spillover Theory of Entrepreneurship. Small Business Economics, 41, 757-774.

Annarelli, A. & Nonino, F. 2016. Strategic and Operational Management of Organizational Resilience: Current State of Research and Future Directions. Omega, 62, 1-18.

Beynon, M. J., Jones, P. & Pickernell, D. 2020a. SME Development Strategy and Product/Service Innovation Intention: A NCaRBS Analysis of the Role of Uncertainty. International Journal of Entrepreneurship and Innovation, 21, 3-16.

Beynon, M. J., Jones, P., Pickernell, D. & Huang, S. 2020b. Growth and Innovation of SMEs in Local Enterprise Partnerships Regions: A Configurational Analysis using fsQCA. International Journal of Entrepreneurship and Innovation, 21, 83-100.

Bogers, M., Chesbrough, H. W. & Moedas, C. 2018. Open Innovation: Research, Practices, and Policies. California Management Review, 60, 5-16.

Caliendo, M., Fossen, F. M. & Kritikos, A. S. 2009. Risk Attitudes of Nascent Entrepreneurs: New Evidence from an Experimentally Validated Survey. Small Business Economics, 32, 153-167.

Chesbrough, H. W. 2003. Open Innovation: The New Imperative for Creating and Profiting from Technology, Boston, USA, Harvard Business School Press.

Chesbrough, H. W. 2019. Open Innovation Results: Going Beyond the Hype and Getting Down to Business, Oxford, Oxford University Press.

Chesbrough, H. W. & Euchner, J. 2011. The Evolution of Open Innovation: An Interview with Henry Chesbrough. Research Technology Management, 54, 13-18.

Conz, E., Denicolai, S. & Zucchella, A. 2017. The Resilience Strategies of SMEs in Mature Clusters. Journal of Enterprising Communities, 11, 186-210.

Cormican, K. & O'Sullivan, D. 2004. Auditing Best Practice for Effective Product Innovation Management. Technovation, 24, 819-829.

Department for Business Energy and Industrial Strategy. 2019. Small and Medium Enterprises (SME) Action Plan. Crown.

Doz, Y. L. & Kosonen, M. 2008. Fast Strategy: How Strategic Agility Will Help You Stay Ahead of the Game, Pearson/Longman.

Escoffier, L., La Vopa, A., Speser, P. L. & Satinsky, D. 2016. Open Innovation Essentials for Small and Medium Enterprises, New York, Business Expert Press.

European Commission. 2014. Bankruptcy and Second Chance for Honest Bankrupt Entrepreneurs. Internal Market, Industry, Entrepreneurship and SMEs [Online]. Available: https://ec.europa.eu/growth/content/study-bankruptcy-and-second-chance-honest-bankrupt-entrepreneurs-0_en.

Forés, B. & Camisón, C. 2016. Does Incremental and Radical Innovation Performance Depend on Different Types of Knowledge Accumulation Capabilities and Organizational Size? Journal of Business Research, 69, 831-848.

Ghio, N., Guerini, M., Lehmann, E. E. & Rossi-Lamastra, C. 2015. The Emergence of the Knowledge Spillover Theory of Entrepreneurship. Small Business Economics, 44, 1-18.

Goldberg, A. 2020. How Collaboration will Strengthen the Future of Cell and Gene Therapies. In: Licking, E. (ed.) Health Sciences and Wellness. Ernst & Young Global Limited.

Gough, J. 2021. Business Insights and Impact on the UK Economy: 25 February. Office for National Statistics: Crown.

Gray, D. & Jones, K. F. 2016. Using Organisational Development and Learning Methods to Develop Resilience for Sustainable Futures with SMEs and Micro Businesses: The Case of the 'Business Alliance'. Journal of Small Business and Enterprise Development, 23, 474-494.

Henderson, A. 2015. Investment in Life Sciences in Scotland: Challenges and Opportunities. Journal of Commercial Biotechnology, 21, 29-34.

Herbane, B. 2019. Rethinking Organizational Resilience and Strategic Renewal in SMEs. Entrepreneurship & Regional Development, 31, 476-495.

HM Government 2021. Life Sciences Vision. 06 July ed. Department for Business Energy and Industrial Strategy: Crown.

Howson, T. 2019. A Tool to Support Life Science and Health Innovation Management. PhD, Swansea University.

Iborra, M., Safón, V. & Dolz, C. 2020. What Explains Resilience of SMEs? Ambidexterity Capability and Strategic Consistency. Long Range Planning, 1-15.

Jarvis, P. 2019. Company of One, UK, Penguin Business.

Korber, S. & McNaughton, R. B. 2018. Resilience and Entrepreneurship: A Systematic Literature Review. International Journal of Entrepreneurial Behaviour & Research, 24, 1129-1154.

Lai, Y., Saridakis, G., Blackburn, R. & Johnstone, S. 2016. Are the HR Responses of Small Firms Different from Large Firms in Times of Recession? Journal of Business Venturing, 31, 113-131.

Lengnick-Hall, C. A., Beck, T. E. & Lengnick-Hall, M. L. 2011. Developing a Capacity for Organizational Resilience through Strategic Human Resource Management. Human Resource Management Review, 21, 243-255.

Lettieri, E., Bartoli, L. & Masella, C. 2013. Coordinating Intra-Sector Services in Healthcare: Requirements and Elements That Managers Should Take Into Account. European Management Journal, 31, 591-601.

Lopes, A. P. V. B. V. & de Carvalho, M. M. 2018. Evolution of the Open Innovation Paradigm: Towards a Contingent Conceptual Model. Technological Forecasting and Social Change, 132, 284-298.

Malerba, F. & Orsenigo, L. 2015. The Evolution of the Pharmaceutical Industry. Business History, 57, 664-687.

Marangos, S. & Warren, L. 2017. A Mapping for Managers: Open Innovation for R&D Intensive SMEs in the Life Sciences Sector. European Journal of Innovation Management, 20, 210-229.

Marom, S., Lussier, R. N. & Sonfield, M. 2019. Entrepreneurial Strategy: The Relationship Between Firm Size and Levels of Innovation and Risk in Small Businesses. Journal of Small Business Strategy, 29, 33-45.

Meyer, A. D. 1982. Adapting to Environmental Jolts. Administrative Science Quarterly, 27, 515-537.

Morrison, M. 2021. The Promises and Challenges of Biomodifying Technologies for the UK. Oxford University Research Archive [Online]. Available: https://www.openaccessgovernment.org/biomodifying-technologies/68041/

Nikolić, N., Jovanović, I., Nikolić, Đ., Mihajlović, I. & Schulte, P. 2019. Investigation of the Factors Influencing SME Failure as a Function of Its Prevention and Fast Recovery after Failure. Entrepreneurship Research Journal, 9.

Nilsson, N. & Minssen, T. 2018. Unlocking the Full Potential of Open Innovation in the Life Sciences through a Classification System. Drug Discovery Today, 23, 771-775.

Office for Life Sciences 2011. Strategy for UK Life Sciences. Department for Business Innovation and Skills: Crown.

Office for Life Sciences 2017. Life Sciences Industrial Strategy. Crown.

Office for Life Sciences 2020. Bioscience and Health Technology Sector Statistics. 2019 ed. Department for Business Energy and Industrial Strategy: Crown.

Oliver, D. 2017. When 'Resilience' Becomes a Dirty Word. British Medical Journal, 1-2.

Porter, M. E. 1998. On Competition, Boston, Harvard Business School Publishing.

Porter, M. E. 2004a. Competitive Advantage: Creating and Sustaining Superior Performance, New York, Free Press.

Porter, M. E. 2004b. Competitive Strategy: Techniques for Analyzing Industries and Competitors, New York, Free Press.

Richter, S., Yeh, R., Weinreb, R., Chen, Z., Patel, K. & Astor, A. 2018. The Genome Revolution. Profiles in Innovation. Redacted ed.

Ries, E. 2011. The Lean Startup, London, Penguin.

Ries, E. 2017. The Startup Way, New York, USA, Currency.

Salge, T. O., Farchi, T., Barrett, M. I. & Dopson, S. 2013. When Does Search Openness Really Matter? A Contingency Study of Health-Care Innovation Projects. The Journal of Product Innovation Management, 30, 659-676.

Sasson, A. 2005. Medical Biotechnology: Achievements, Prospects and Perceptions, Tokyo, United Nations University Press.

Schabacker, D. S., Levy, L.-A., Evans, N. J., Fowler, J. M. & Dickey, E. A. 2019. Assessing Cyberbiosecurity Vulnerabilities and Infrastructure Resilience. Frontiers in Bioengineering and Biotechnology, 7.

Stam, E., Audretsch, D. & Meijaard, J. 2008. Renascent Entrepreneurship. Journal of Evolutionary Economics, 18, 493-507.

Syed, M. 2015. Black Box Thinking: The Surprising Truth About Success, London, John Murray.

Syed, M. 2019. Rebel Ideas: The Power of Diverse Thinking, London, John Murray.

The Lancet 2018. UK Life Science Research: Time to Burst the Biomedical Bubble. 392, 187.

Tidd, J. & Bessant, J. R. 2018. Managing Innovation: Integrating Technological, Market and Organizational Change, New Jersey, Wiley.

Toni, A. D. & Nassimbeni, G. 2003. Small and Medium District Enterprises and The New Product Development Challenge: Evidence from Italian Eyewear District. International Journal of Operations & Production Management, 23, 678-697.

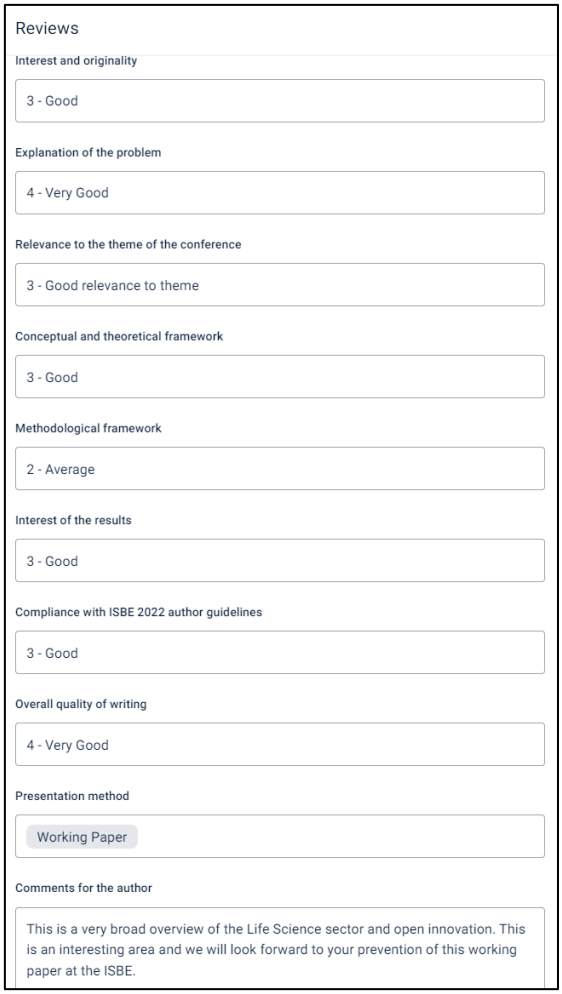
Tornikoski, E. T., Rannikko, H. & Heimonen, T. P. 2017. Technology-Based Competitive Advantages of Young Entrepreneurial Firms: Conceptual Development and Empirical Exploration. Journal of Small Business Management, 55, 200-215.

Veer, T., Lorenz, A. & Knut, B. How Open is too Open? The 'Dark Side' of Openness along the Innovation Value Chain. In: Danish Research Unit for Industrial Dynamics, ed. 35th Celebration Conference, 17-19 June 2013 Barcelona, Spain. 1-31.

Weiblin, T. & Chesbrough, H. W. 2015. Engaging with Startups to Enhance Corporate Innovation. California Management Review, 57, 66-90.

Williams, T., Gruber, D., Sutcliffe, K., Shepherd, D. & Zhao, E. Y. 2017. Organizational Response to Adversity: Fusing Crisis Management and Resilience Research Streams. The Academy of Management Annals, 11.

Peer-Review Results by the Institute of Small Business and Entrepreneurship



Reviews

Interest and originality

3 - Good

Explanation of the problem

4 - Very Good

Relevance to the theme of the conference

3 - Good relevance to theme

Conceptual and theoretical framework

3 - Good

Methodological framework

2 - Average

Interest of the results

3 - Good

Compliance with ISBE 2022 author guidelines

3 - Good

Overall quality of writing

4 - Very Good

Presentation method

Working Paper

Comments for the author

This is a very broad overview of the Life Science sector and open innovation. This is an interesting area and we will look forward to your prevention of this working paper at the ISBE.

European Conference on Innovation and Entrepreneurship (September 2022)

This abstract was accepted by the conference for publication and presentation (May 2022), but later withdrawn by the researcher (June 2022).

Despite the recent, substantial impacts of BREXIT and COVID, it has been imperative for UK life science enterprises to be resilient and continue to innovate through the threats, for wider public, animal, plant, and aquaculture health. SMEs in the sector face a 39% failure rate within their first three years of operating (Office for Life Sciences, 2011), yet the life sciences are becoming progressively fragmented, due to such enterprises specialising to tackle an ever-increasing diversity of demographics and medical conditions, rather than collaborating and unifying for wider public health (Lettieri et al., 2013). Such fragmented and closed innovation by life science SMEs is argued to lead to a higher risk of market failure (Marangos & Warren, 2017).

Early competition literature cited such isolated enterprises, unconnected within ecosystems, face higher costs for acquiring ideas, as resources must be internally allocated to generate them; proposing innovation could instead come from "outsider" enterprises and industries (Porter, 1998). The use of external ideas was later conceptualised as 'open innovation' (Chesbrough, 2003), which since expanded to include the exchange of technology, money, people, and intellectual property (Escoffier et al., 2016).

Multi-layer analysis (Marangos & Warren, 2017; Asthana et al., 2019) is used to consider the various factors within the literature, each with an ever-more specific context: (a) macro: enterprise, (b) meso: innovation; and (c) micro: management. Online surveys are used to collect quantitative data to understand the perceptions of SME owner-managers regarding their factors of open innovation and their resilience. Pilot study feedback improved usability. A stratified and opportunity sample frame of 2000+ UK Life Science enterprises is used to achieve the desired response rate, as calculated by a power analysis. Statistical analysis will be applied, using principal component analysis and regression techniques (Evans, 2016; Albright & Winston, 2020), to provide a significant and original contribution to knowledge.

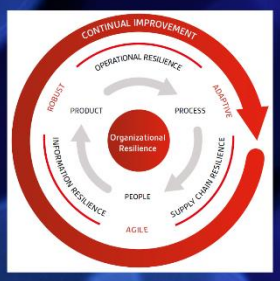
Non-Traditional Research Outputs

Industry Reports

Celtic Advanced Life Science Innovation Network (CALIN)

RESEARCH THEME ONE:
ORGANISATIONAL RESILIENCE

"The ability of an organization to anticipate, prepare for, respond and adapt to incremental change and sudden disruptions in order to survive and prosper" (British Standards Institute; see figure below sourced from their blog by Mehmi).

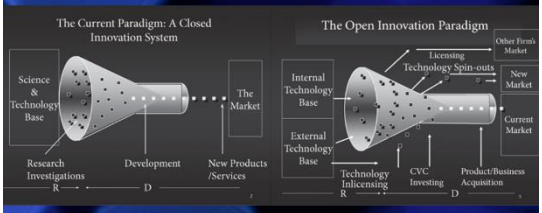


Pescaroli et al. (2020) proposed a four-tier resilience framework to measure this theme, from no to high resilience. Using this, the sampled enterprises from Republic of Ireland and Wales perceived themselves to have a medium level of organisational resilience, which matches the UK average.

Page 3

RESEARCH THEME TWO:
LIFE SCIENCE ENTERPRISE OPEN INNOVATION

"A distributed innovation process based on purposively managed knowledge flows across organizational boundaries" (Chesbrough, 2019; see figures below).



Nilsson & Minssen (2018) proposed a framework of six tiers of openness, specific to the life science enterprises. The scale ranged from completely closed (internal only resources) to completely open (internal and external resources). Using this, the sampled enterprises from Republic of Ireland and Wales perceived themselves to practice a partially open model of innovation, which again, matches the UK average.

Page 4

Following a review of current business management research, gaps in academic knowledge were identified to form the two following research questions. A structured, online survey was designed and shared by CALIN and other agencies for life science small-to-medium enterprises to answer those questions. The quantitative data was then statistically analysed using regressions.

WHAT IS THE *RELATIONSHIP* BETWEEN ORGANISATIONAL RESILIENCE AND LIFE SCIENCE OPEN INNOVATION?

A positive linear relationship was calculated between the two themes, meaning that they increase together: the more resilient your enterprise, the more open your innovation processes. However, there was a low statistical association connecting them. Due to the nuance and complexity of enterprises, a second phase of research was required, in the form of qualitative interviews. These have been conducted and currently being analysed. Please contact the researcher (2024671@swansea.ac.uk) for more information

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WHAT ARE THE *INFLUENCES* OF ORGANISATIONAL RESILIENCE AND LIFE SCIENCE OPEN INNOVATION?

This research offers an original contirbution to knowledge by unqiuely combining the two research themes. for statistical testing. Variables found in the current peer-reviewed literature were tested in the survey for their influence against the two themes. The results may influence new-to-firm policies and procedures that enhance your enterprise along the two themes of this research.

The most influential factors of both research themes are:

1. ENVIRONMENTAL CONTEXT (PROXIMITY TO RESOURCES)
2. PORTFOLIO DIVERSITY
3. MANAGEMENT'S INDUSTRY EXPERIENCE
4. DEDICATED INNOVATION STAFF
5. AQUACULTURE SUBSECTOR

Whereas the least influential factors were:

1. ENTERPRISE AGE
2. AGRITECH SUBSECTOR
3. MANAGEMENT'S ENTREPRENEURIAL EXPERIENCE OF CONCURRENT ENTERPRISES
4. OUTREACH (INTERNATIONALISATION)
5. ANIMAL HEALTH SUBSECTOR

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THANK YOU FOR YOUR PARTICIPATION AND INTEREST IN THIS RESEARCH.

This Irish and Welsh sample forms part of a wider UK sample, for the original doctoral research by Michael Winn, School of Management, Swansea University. The results are more comprehensively explained in upcoming publications.
Email: **2024671@SWANSEA.AC.UK**
Please cite this research as: **WINN (DUE 2023)**

Special thanks to everyone at CALIN for their help and support of this research collaboration.

REFERENCES

British Standards Institute (No Date) *Organizational Resilience*. Our Services. Available at: bsigroup.com/en-GB/our-services/Organizational-Resilience/

Chesbrough, H. (2019) *Open Innovation Results* (1st ed.). Oxford University Press.

Mehmi, J. (No Date) *How does Organizational Resilience link with Lean Six Sigma?* British Standards Institute. Available at: bsigroup.com/en-GB/blog/Lean-Six-Sigma-Blog/How-does-Organisational-Resilience-link-with-Lean-Six-Sigma/

Nilsson, N., & Minssen, T. (2018) Unlocking the Full Potential of Open Innovation in the Life Sciences through a Classification System. Drug Discovery Today, 23(4), 771-775. doi.org/10.1016/j.drudis.2018.01.002

Pescaroli, G., Velazquez, O., Alcántara-Ayala, I., Galasso, C., Kostkova, P., & Alexander , D. (2020) A Likert Scale-Based Model for Benchmarking Operational Capacity, Organizational Resilience, and Disaster Risk Reduction. *International Journal of Disaster Risk Science*, 11, 404-409. doi.org/10.1007/s13753-020-00276-9

Life Sciences Hub Wales

ENGLISH LANGUAGE (WELSH LANGUAGE, BELOW)

Swansea University
Prifysgol Abertawe

ORGANISATIONAL RESILIENCE & LIFE SCIENCE ENTERPRISE OPEN INNOVATION

This handbook summarises the results of the research collaboration between the Life Sciences Hub Wales (government) and Swansea University (academia), to influence further projects, policies, and procedures at the Hub and their partner enterprises (industry).

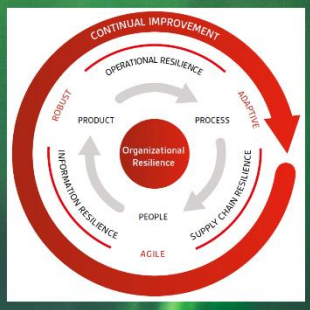
With your help, 71 Welsh life science small-to-medium enterprises were sampled, mainly (but not exclusively) in the medical technology subsector. These formed part of a wider UK sample, for the original doctoral research conducted by Michael Winn at the School of Management, Swansea University. Therefore, please cite this research as:
WINN (DUE 2023).

Special thanks to Dr Gareth Healey (Programme Lead for Precision Medicine and Head of Accelerate at the Life Sciences Hub Wales) for his supervision and survey promotion.

RESEARCH THEME 1: ORGANISATIONAL RESILIENCE

"The ability of an organization to anticipate, prepare for, respond and adapt to incremental change and sudden disruptions in order to survive and prosper" (British Standards Institute; see figure below sourced from their blog by Mehmi).

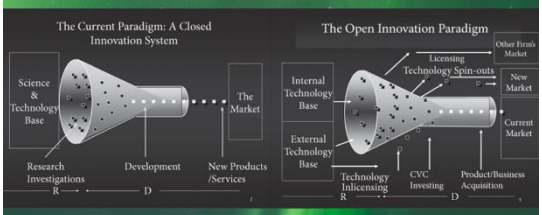
Pescaroli et al. (2020) proposed a four-tier resilience framework to measure this theme, from no to high resilience. On average, Welsh enterprises perceived themselves to have a *medium* level of organisational resilience, which matches the UK average.



RESEARCH THEME 2: LIFE SCIENCE ENTERPRISE OPEN INNOVATION

"A distributed innovation process based on purposively managed knowledge flows across organizational boundaries" (Chesbrough, 2019; see figures below).

Nilsson & Minssen (2018) proposed a six-tier openness framework, specific to life science enterprises. The scale ranged from completely closed (internal only resources) to completely open (internal and external resources). On average, Welsh enterprises perceived themselves to practice a *partially open* model of innovation, which, again, matches the UK average.



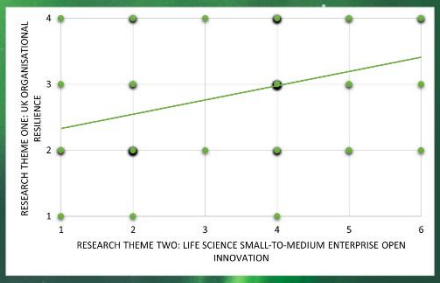
Following a review of current business management research, gaps in academic knowledge were identified to form the two following research questions. A structured, online survey was designed to answer those overarching research questions.

This survey was then shared by the Life Sciences Hub Wales and other agencies to capture, and then statistically analyse, quantitative data upon the research themes, by life science small-to-medium enterprises.

Page 5

RESEARCH QUESTION 1: WHAT IS THE *ASSOCIATION* BETWEEN THE RESEARCH THEMES?

A positive linear relationship was calculated between the two themes, meaning that they increase together: the more resilient your enterprise, the more open your innovation processes. However, their association had lesser significance when applied to the wider population. Due to the nuance and complexity of enterprises, this requires further research in the form of qualitative online interviews.



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RESEARCH QUESTION 2: WHAT *INFLUENCES* THE RESEARCH THEMES?

Factors found in the current peer-reviewed literature were allocated to the following components:

Macro: Exogenous (external) factors of the enterprise
Meso: Demographic factors of the enterprise
Micro: Endogenous (internal) factors of the enterprise

A multivariate linear regression calculated the following top three influences of each theme (as listed below), and can therefore be recommended to be prioritised to enhance your enterprise.

RESEARCH THEME 1: ORGANISATIONAL RESILIENCE	RESEARCH THEME 2: LIFE SCIENCE ENTERPRISE OPEN INNOVATION
MOST INFLUENTIAL: Life science qualifications represented in your management team	MOST INFLUENTIAL: Size of your management team
Speed in which you can get your innovation to market	Life science qualifications represented in your management team
Dedicated innovation staff	Concurrent enterprises run by your management team

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The top three influences of both themes feature at the *micro* level, meaning that enterprises should look to developing their endogenous (internal) factors to achieve organisational resilience and/or open innovation. Technical life science knowledge, rather than business management or engineering qualifications also score highly for both themes.

THANK YOU FOR YOUR PARTICIPATION AND INTEREST IN THIS RESEARCH.

REFERENCES

British Standards Institute (No Date) *Organizational Resilience*. Our Services. Available at: bsigroup.com/en-GB/our-services/Organizational-Resilience/

Chesbrough, H. (2019) *Open Innovation Results* (1st ed.). Oxford University Press.

Mehm, J. (No Date) *How does Organizational Resilience link with Lean Six Sigma?* British Standards Institute. Available at: bsigroup.com/en-GB/blog/Lean-Six-Sigma-Blog/How-does-Organisational-Resilience-link-with-Lean-Six-Sigma/

Nilsson, N., & Minssen, T. (2018) Unlocking the Full Potential of Open Innovation in the Life Sciences through a Classification System. Drug Discovery Today, 23(4), 771-775. doi.org/10.1016/j.drudis.2018.01.002

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Presentations at Swansea University

- Medical School Research Groups (April 2022)
- Research Excellence Scholarship Snapshots, Postgraduate Festivals (May 2022 and 2023)

Appendix M: Quantitative Data Cleaning and Substitution Audit

Firstly, when asked for their enterprise age in years, some enterprises (e27s, e56s, e118s) cited their establishing year as a date, and so these were converted into the correct format.

Secondly, the dataset was then reviewed for any incomplete responses to be disregarded for other reasons (see table below). Note that enterprises too large or outside of the UK were automatically exited from the survey due to the Qualtrics branching/logic feature, leaving an incomplete response.

Reasons for Incompletion	Frequency	List of Enterprises
Too Large of an Enterprise	12	e21s, e58s, e67s, e69s, e72s, e78s, e83s, e97s, e104s, e105s, e150s, e151s
Consented but then did not Proceed	10	e109s, e113s, e116s, e124s, e128s, e132s, e143s, e155s, e156s, e158s
Did not Consent to Proceed	9	e7s, e10s, e11s, e15s, e17s, e36s, e88s, e93s, e142s
Enterprise Outside the UK	7	e33s, e76s, e82s, e91s, e106s, e127s, e139s

Thirdly, by checking the internet protocol (IP) addresses of each enterprise, which are automatically collected by Qualtrics, the duplicate pairings were reviewed to keep or be disregarded:

Duplications		Decision
e14s ✓	e48s ✓	Compared and sufficiently different responses to assume they are different enterprises, perhaps using shared work/lab space with the same router.
e22s ✓	e96s ✓	
e28s ✓	e110s ✗	e28s will be kept as a unique case, as e110s was only partially completed.
e67s ✗	e122s ✓	e67s was already disregarded due to the enterprise being too large, so only e122s will be kept as a unique case.
e78s ✗	e128s ✗	Both were already disregarded for other reasons: e78s for being too large of an enterprise, e128s for not proceeding with the survey after giving consent.
e129s ✓	e152s ✗	e129s will be kept as a unique case, as e152s was only partially completed.

Finally, the dataset was then reviewed to substitute any missing data. This is commonly known as ‘imputation’, with the median calculated values of the variable being the substitute. In research regarding SME resilience, an IBM SPSS ‘expectation maximisation’ algorithm was

used (Auzzir, 2019). Yet, real-world data is never perfect, and so it is the business researchers' responsibility to correct any such problems before analysis can begin, to prevent any misleading results later on. It was warned that this task requires tedious, but necessary, detective work to uncover and rectify any issues (Albright & Winston, 2020). A lack of substitution "indiscriminately could result in misleading information and conclusions about the data" (Evans, 2016, p. 335).

Regressions require complete datasets, and so there is debate within quantitative business researchers as to what is the most effective placeholder value to substitute missing data. Although critical of all replacement methods of missing data, Hoffman (2016) immediately disregarded the mean average, as it leads to a biased slope of coefficients and standard errors, with the higher values missing. This effects the later regression, and leaves mode (most frequent value) and median (middle value when sorted) measures of central tendency to be considered. They are both compatible with numerical and categorical variables - useful for this mixed-scale research. Mode was attempted by the researcher, but was disregarded due to significantly skewed results, leaving median to calculate the substituted missing data. The benefit of median is that it is unaffected by any potential outliers in the data (Evans, 2016). Yet, all methods of substituting data are subjective and can lead to researcher bias (Camm et al., 2021). It is recommended to preserve auditability "by tracking which fields were original and which fields were statistically populated" (Stubbs, 2014, p. 123). For transparency, this is displayed, next:

Influence	Enterprises with Missing Values	Median Substitute
Enterprise Size	0 enterprises	-
Enterprise Type	1 enterprise (e145s)	2 = Private limited company (Ltd.)
Subsector	3 enterprises (e108s, e135s, e145s)	"Unknown"
Enterprise Age	8 enterprises (e107s, e108s, e114s, e123s, e135s, e137s, e145s, e146s)	11 (years)
Supply Chain	30 enterprises[29] (e3, e9, e13, e32, e34, e55, e60, e63, e68, e80, e84, e85, e87, e89, e98, e100, e107, e108, e112, e114, e123, e135, e136, e137, e141, e145, e146, e147, e148, e154)	-19
Organisational Resilience	13 enterprises (e107s, e108s, e114s, e123s, e135s, e137s, e138s, e145s, e146s, e147s, e148s, e154s, e157s)	3 = Medium
COVID	18 enterprises (e57s, e87s, e107s, e108s, e114s, e121s, e123s, e125s, e135s, e136s, e137s, e138s, e145s, e146s, e147s, e148s, e154s, e157s)	-8
Open Innovation	20 enterprises (e107s, e108s, e111s, e114s, e121s, e123s, e125s, e126s, e130s, e135s, e136s, e137s, e138s, e145s, e146s, e147s, e148s, e153s, e154s, e157s)	4 = Partially open
Innovation Diversity	21 enterprises (e107s, e108s, e111s, e112s, e114s, e121s, e123s, e125s, e126s, e130s, e135s, e136s, e137s, e138s, e145s, e146s, e147s, e148s, e153s, e154s, e157s)	2 = Multiple of single theme
Innovation In-House Staff	21 enterprises (e107s, e108s, e111s, e112s, e114s, e121s, e123s, e125s, e126s, e130s, e135s, e136s, e137s, e138s, e145s, e146s, e147s, e148s, e153s, e154s, e157s)	1 = Yes
Innovation Speed to Market	23 enterprises (e107s, e108s, e111s, e112s, e114s, e115s, e121s, e123s, e125s, e126s, e129s, e130s, e135s, e136s, e137s, e138s, e145s, e146s, e147s, e148s, e153s, e154s, e157s)	2 (years)
UK Country of Operation	23 enterprises (e107s, e108s, e111s, e112s, e114s, e115s, e121s, e123s, e125s, e126s, e129s, e130s, e135s, e136s, e137s, e138s, e145s, e146s, e147s, e148s, e153s, e154s, e157s)	4 = Wales
Internationalisation	23 enterprises (e107s, e108s, e111s, e112s, e114s, e115s, e121s, e123s, e125s, e126s, e129s, e130s, e135s, e136s, e137s, e138s, e145s, e146s, e147s, e148s, e153s, e154s, e157s)	5 = International

[29] Missing data was indistinguishable from 'unknown' values to be substituted, hence the increase in frequency of enterprise responses for this influence.

Locational Setting	23 enterprises (e107s, e108s, e111s, e112s, e114s, e115s, e121s, e123s, e125s, e126s, e129s, e130s, e135s, e136s, e137s, e138s, e145s, e146s, e147s, e148s, e153s, e154s, e157s)	4 = Suburban
MGMT Team Size	24 enterprises (e107, e108, e111, e112, e114, e115, e121, e123, e125, e126, e129, e130, e131, e135, e136, e137, e138, e145, e146, e147, e148, e153, e154, e157)	2
MGMT: Family	24 enterprises (e107s, e108s, e111s, e112s, e114s, e115s, e121s, e123s, e125s, e126s, e129s, e130s, e131s, e135s, e136s, e137s, e138s, e145s, e146s, e147s, e148s, e153s, e154s, e157s)	4 = No
MGMT Diversity: Sexes	24 enterprises (e107s, e108s, e111s, e112s, e114s, e115s, e121s, e123s, e125s, e126s, e129s, e130s, e131s, e135s, e136s, e137s, e138s, e145s, e146s, e147s, e148s, e153s, e154s, e157s)	“Unknown”
MGMT Diversity: Ages	24 enterprises (e107s, e108s, e111s, e112s, e114s, e115s, e121s, e123s, e125s, e126s, e129s, e130s, e131s, e135s, e136s, e137s, e138s, e145s, e146s, e147s, e148s, e153s, e154s, e157s)	“Unknown”
MGMT Industry Experience	27 enterprises (e53s, e62s, e107s, e108s, e111s, e112s, e114s, e115s, e121s, e123s, e125s, e126s, e129s, e130s, e131s, e134s, e135s, e136s, e137s, e138s, e145s, e146s, e147s, e148s, e153s, e154s, e157s)	25 (years)
MGMT Entrepreneurial Experience	27 enterprises (e53s, e62s, e107s, e108s, e111s, e112s, e114s, e115s, e121s, e123s, e125s, e126s, e129s, e130s, e131s, e134s, e135s, e136s, e137s, e138s, e145s, e146s, e147s, e148s, e153s, e154s, e157s)	“Unknown”
MGMT Academic Knowledge	27 enterprises (e41s, e62s, e107s, e108s, e111s, e112s, e114s, e115s, e121s, e123s, e125s, e126s, e129s, e130s, e131s, e134s, e135s, e136s, e137s, e138s, e145s, e146s, e147s, e148s, e153s, e154s, e157s)	“Unknown”
BREXIT	31 enterprises (e53s, e56s, e62s, e74s, e80s, e87s, e107s, e108s, e111s, e112s, e114s, e115s, e121s, e123s, e125s, e126s, e129s, e130s, e131s, e134s, e135s, e136s, e137s, e138s, e145s, e146s, e147s, e148s, e153s, e154s, e157s)	-100

Appendix N: Raw Quantitative Data

This appendix displays the raw quantitative data collected for:

- C1: Organisational Resilience
- C2: Open Innovation
- F1-3: Each of the influences

Each abbreviated enterprise is indicated as being from the survey sample (e1s, e2s, e3s, etc.). For ease of reference, the labels of the values are cited, rather than the ordinal or categorical data.

C1: Organisational Resilience

Enterprise	Rating	Enterprise	Rating	Enterprise	Rating	Enterprise	Rating
e1s	Medium	e39s	Medium	e73s	Medium	e118s	Medium
e2s	Low	e40s	High	e74s	Low	e119s	Low
e3s	Medium	e41s	Low	e75s	Medium	e120s	High
e4s	High	e42s	Low	e77s	High	e121s	Low
e5s	High	e43s	Medium	e79s	Medium	e122s	Low
e6s	No	e44s	High	e80s	Low	e123s	Medium
e8s	Low	e45s	Low	e81s	High	e125s	Medium
e9s	No	e46s	Medium	e84s	Low	e126s	Medium
e12s	Medium	e47s	High	e85s	Low	e129s	Medium
e13s	High	e48s	Low	e86s	Medium	e130s	High
e14s	Low	e49s	Low	e87s	High	e131s	Low
e16s	Medium	e50s	High	e89s	Low	e133s	High
e18s	Low	e51s	Low	e90s	Low	e134s	Low
e19s	Medium	e52s	High	e92s	High	e135s	Medium
e20s	High	e53s	Medium	e94s	High	e136s	No
e22s	Low	e54s	High	e95s	High	e137s	Medium
e23s	Low	e55s	No	e96s	Low	e138s	Medium
e24s	Medium	e56s	High	e98s	Medium	e140s	Low
e25s	Medium	e57s	Low	e99s	Low	e141s	Medium
e26s	High	e59s	Low	e100s	Medium	e144s	High
e27s	High	e60s	Low	e101s	Low	e145s	Medium
e28s	High	e61s	Low	e102s	Low	e146s	Medium
e29s	Medium	e62s	Low	e103s	High	e147s	Medium
e30s	Medium	e63s	Low	e107s	Medium	e148s	Medium
e31s	Medium	e64s	Medium	e108s	Medium	e149s	Low
e32s	Low	e65s	Low	e111s	High	e153s	High
e34s	High	e66s	High	e112s	Low	e154s	Medium
e35s	Medium	e68s	High	e114s	Medium	e157s	Medium
e37s	Low	e70s	High	e115s	Low	-	-
e38s	Medium	e71s	Medium	e117s	High	-	-

C2: Open Innovation

Enterprise	Rating	Enterprise	Rating	Enterprise	Rating	Enterprise	Rating
e1s	Partially open	e39s	Mainly open	e73s	Partially open	e118s	Mainly open
e2s	Completely closed	e40s	Completely open	e74s	Partially open	e119s	Mainly closed
e3s	Mainly closed	e41s	Partially open	e75s	Mainly open	e120s	Partially closed
e4s	Mainly closed	e42s	Partially open	e77s	Completely open	e121s	Partially open
e5s	Mainly open	e43s	Mainly closed	e79s	Mainly closed	e122s	Partially closed
e6s	Completely closed	e44s	Mainly closed	e80s	Mainly closed	e123s	Partially open
e8s	Completely closed	e45s	Partially open	e81s	Partially open	e125s	Partially open
e9s	Mainly closed	e46s	Partially closed	e84s	Partially open	e126s	Partially open
e12s	Completely open	e47s	Partially open	e85s	Mainly closed	e129s	Partially open
e13s	Partially open	e48s	Mainly closed	e86s	Partially open	e130s	Partially open
e14s	Mainly closed	e49s	Partially open	e87s	Mainly open	e131s	Mainly closed
e16s	Partially open	e50s	Mainly closed	e89s	Completely closed	e133s	Completely open
e18s	Partially closed	e51s	Mainly closed	e90s	Completely closed	e134s	Completely closed
e19s	Mainly open	e52s	Partially open	e92s	Completely open	e135s	Partially open
e20s	Partially open	e53s	Partially open	e94s	Completely closed	e136s	Partially open
e22s	Mainly closed	e54s	Completely closed	e95s	Mainly closed	e137s	Partially open
e23s	Partially open	e55s	Mainly closed	e96s	Mainly closed	e138s	Partially open
e24s	Completely closed	e56s	Partially open	e98s	Completely open	e140s	Mainly closed
e25s	Mainly open	e57s	Completely closed	e99s	Partially open	e141s	Mainly closed
e26s	Mainly closed	e59s	Partially open	e100s	Mainly closed	e144s	Partially open
e27s	Mainly closed	e60s	Completely open	e101s	Mainly closed	e145s	Partially open
e28s	Partially open	e61s	Mainly closed	e102s	Mainly closed	e146s	Partially open
e29s	Completely open	e62s	Mainly open	e103s	Mainly open	e147s	Partially open
e30s	Mainly open	e63s	Mainly open	e107s	Partially open	e148s	Partially open
e31s	Partially closed	e64s	Completely closed	e108s	Partially open	e149s	Partially open
e32s	Mainly closed	e65s	Mainly closed	e111s	Partially open	e153s	Partially open
e34s	Mainly closed	e66s	Partially closed	e112s	Mainly closed	e154s	Partially open
e35s	Mainly open	e68s	Partially open	e114s	Partially open	e157s	Partially open
e37s	Completely closed	e70s	Mainly open	e115s	Mainly closed	-	-
e38s	Partially open	e71s	Partially open	e117s	Mainly closed	-	-

F1: Internal Influences

Enterprise	Inn. Portfolio Div.	Inn. Speed to Market (Years)	Inn. In-house Staff?	MGMT Family	MGMT Team Size	MGMT Diversity: Ages (Median Range)	MGMT Diversity: Sexes	MGMT Ind. Service (Median Years)	MGMT Present Ent. Exp.	MGMT Past Ent. Exp.	MGMT Prev. Emp.	MGMT Know.: Business	MGMT Know.: Eng.	MGMT Know.: Sci.
e1s	Multi of single	10	Yes	Yes	2	41-60	Diverse	20	Just this ent.	Success	Yes	No	No	Yes
e2s	Multi of multi	-1	Yes	No	1	41-60	Single sex	45	Un-known	Success	Yes	No	No	Yes
e3s	Multi of single	-2	Not inn.	Some-what	1	21-40	Single sex	6	Con-current	Un-known	Yes	Yes	No	No
e4s	Multi of single	2	Yes	No	10	21-40	Diverse	35	Con-current	Un-known	Yes	Yes	Yes	Yes
e5s	Multi of multi	3	Yes	No	2	21-40	Single sex	23	Un-known	Success	No	Yes	No	Yes
e6s	Multi of single	12	Yes	No	3	81≥	Single sex	5	Con-current	Success	No	No	No	Yes
e8s	Multi of single	-2	Not inn.	Yes	2	21-40	Diverse	30	Con-current	Success	No	No	No	No
e9s	Single	10	No	No	3	81≥	Diverse	25	Con-current	Both	No	Yes	No	Yes
e12s	Multi of single	2	No	No	6	21-40	Diverse	20	Just this ent.	Success	No	Yes	Yes	No
e13s	Multi of multi	6	Yes	No	9	81≥	Diverse	22	Un-known	Success	No	Yes	Yes	Yes
e14s	Single	2	Yes	No	2	21-40	Single sex	0	Un-known	Success	No	No	No	No
e16s	Multi of single	2	No	Some-what	1	41-60	Single sex	40	Con-current	Un-known	No	No	Yes	Yes
e18s	Multi of single	10	Yes	Yes	2	41-60	Diverse	40	Un-known	Both	No	Yes	Yes	No
e19s	Multi of multi	6	Yes	No	2	81≥	Single sex	33	Un-known	Success	No	Yes	Yes	No
e20s	Single	8	Yes	No	5	21-40	Diverse	31	Con-current	Both	Yes	Yes	Yes	Yes
e22s	Multi of single	-1	Yes	Some-what	3	21-40	Diverse	38	Just this ent.	Both	Yes	Yes	Yes	No

e23s	Multi of multi	8	Yes	No	1	21-40	Single sex	25	Con-current	Un-known	No	Yes	No	Yes
e24s	Multi of single	-1	Yes	Some-what	4	61-80	Single sex	33	Con-current	Un-known	Yes	Yes	Yes	Yes
e25s	Multi of single	3	No	Yes	2	21-40	Single sex	23	Con-current	Un-known	No	No	No	Yes
e26s	Multi of multi	10	Yes	Yes	2	21-40	Single sex	24	Un-known	Success	No	Yes	No	Yes
e27s	Multi of multi	3	No	No	1	41-60	Single sex	35	Un-known	Success	No	No	No	No
e28s	Multi of single	2	No	No	6	81≥	Diverse	25	Just this ent.	Un-known	No	Yes	Yes	Yes
e29s	Multi of single	4	Yes	No	3	21-40	Single sex	20	Just this ent.	Un-known	No	Yes	No	Yes
e30s	Multi of single	1	Yes	Yes	3	41-60	Single sex	2	Con-current	Un-known	No	Yes	Yes	Yes
e31s	Multi of single	4	No	No	3	21-40	Diverse	5	Un-known	Success	Yes	Yes	No	Yes
e32s	Multi of single	-1	Yes	No	8	21-40	Single sex	20	Just this ent.	Un-known	No	No	No	No
e34s	Multi of multi	-2	Not inn.	Yes	1	21-40	Single sex	38	Un-known	Success	No	No	No	Yes
e35s	Multi of multi	-1	Yes	Yes	2	81≥	Diverse	40	Con-current	Un-known	Yes	Yes	No	Yes
e37s	Multi of single	-1	Yes	No	3	81≥	Single sex	25	Con-current	Both	No	No	No	Yes
e38s	Multi of single	4	Yes	No	2	21-40	Single sex	25	Un-known	Success	No	Yes	Yes	Yes
e39s	Multi of single	2	No	No	3	81≥	Single sex	10	Just this ent.	Fail	Yes	Yes	Yes	Yes
e40s	Multi of single	2	Yes	Yes	2	21-40	Single sex	25	Con-current	Un-known	No	No	Yes	Yes
e41s	Multi of single	1	Yes	No	2	21-40	Single sex	4	Un-known	Success	No	No	No	No
e42s	Multi of single	-1	Yes	No	1	41-60	Single sex	6	Just this ent.	Success	No	No	No	Yes
e43s	Multi of multi	1	Yes	Yes	1	41-60	Single sex	40	Concurre nt enter-prises	Un-known	No	No	No	Yes
e44s	Multi of single	3	Yes	No	10	81≥	Diverse	30	Con-current	Success	Yes	Yes	Yes	Yes

e45s	Multi of single	3	No	No	6	≤20	Single sex	10	Just this ent.	Un-known	No	Yes	Yes	Yes
e46s	Multi of single	2	Yes	No	5	41-60	Diverse	20	Un-known	Both	Yes	No	No	Yes
e47s	Single	1	Yes	Yes	2	21-40	Single sex	12	Just this ent.	Un-known	No	No	No	Yes
e48s	Single	2	Yes	No	2	21-40	Single sex	3	Con-current	Un-known	No	No	No	No
e49s	Multi of single	2	No	No	3	81≥	Diverse	30	Both	Both	No	Yes	No	Yes
e50s	Multi of multi	3	Yes	Yes	2	41-60	Diverse	27	Un-known	Success	No	No	No	No
e51s	Multi of multi	2	Yes	No	7	21-40	Single sex	45	Con-current	Un-known	No	No	Yes	No
e52s	Multi of multi	5	No	Yes	1	81≥	Diverse	22	Con-current	Success	No	Yes	No	No
e53s	Multi of multi	10	No	No	0	41-60	Single sex	25	Con-current	Success	No	Yes	Yes	Yes
e54s	Multi of single	2	Yes	No	4	21-40	Single sex	30	Just this ent.	Un-known	No	Yes	Yes	Yes
e55s	Single	-1	Yes	Some-what	1	21-40	Single sex	25	Just this ent.	Un-known	No	No	Yes	No
e56s	Multi of single	-2	Yes	No	1	61-80	Single sex	50	Just this ent.	Un-known	No	Yes	Yes	Yes
e57s	Multi of multi	1	No	No	3	81≥	Diverse	17	Con-current	Un-known	No	No	Yes	No
e59s	Multi of multi	10	No	No	1	41-60	Single sex	23	Con-current	Un-known	No	Yes	No	Yes
e60s	Multi of single	1	No	Some-what	2	21-40	Single sex	20	Un-known	Success	Yes	No	No	Yes
e61s	Multi of single	-2	Yes	No	1	41-60	Single sex	40	Just this ent.	Un-known	No	Yes	Yes	No
e62s	Multi of multi	5	No	No	0	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No
e63s	Multi of multi	-1	No	No	1	≤20	Single sex	3	Just this ent.	Un-known	No	No	No	Yes
e64s	Multi of multi	-2	Yes	No	4	41-60	Single sex	20	Just this ent.	Success	No	Yes	No	Yes
e65s	Multi of multi	2	No	No	1	21-40	Single sex	30	Con-current	Un-known	No	No	No	No

e66s	Multi of multi	7	Yes	No	1	41-60	Single sex	50	Con-current	Success	Yes	No	Yes	Yes
e68s	Single	-1	Yes	Yes	4	21-40	Single sex	20	Con-current	Both	Yes	Yes	No	Yes
e70s	Multi of multi	2	Yes	No	2	21-40	Single sex	26	Con-current	Success	Yes	No	Yes	Yes
e71s	Multi of single	1	Yes	No	6	21-40	Single sex	15	Un-known	Both	No	Yes	Yes	Yes
e73s	Multi of single	1	No	No	1	21-40	Single sex	25	Just this ent.	Un-known	Yes	Yes	No	No
e74s	Multi of multi	10	Yes	Yes	1	41-60	Single sex	55	Un-known	Success	No	No	No	No
e75s	Multi of multi	-2	Not inn.	Yes	2	41-60	Single sex	36	Un-known	Un-known	Yes	Yes	No	Yes
e77s	Multi of multi	7	Yes	Yes	2	81≥	Diverse	13	Un-known	Success	No	No	No	Yes
e79s	Multi of single	4	No	No	10	81≥	Diverse	25	Both	Success	No	Yes	Yes	Yes
e80s	Multi of single	1	No	No	1	21-40	Single sex	21	Un-known	Fail	No	Yes	No	Yes
e81s	Multi of multi	2	Yes	Yes	2	21-40	Single sex	23	Un-known	Success	No	Yes	Yes	Yes
e84s	Multi of single	7	Yes	Yes	1	Un-known	Single sex	30	Un-known	Success	No	No	No	No
e85s	Multi of single	-2	Not inn.	Yes	1	21-40	Single sex	25	Con-current	Un-known	No	Yes	No	No
e86s	Multi of multi	5	No	Some-what	5	81≥	Diverse	3	Un-known	Success	No	Yes	No	Yes
e87s	Multi of multi	1	Yes	No	1	21-40	Single sex	10	Un-known	Un-known	No	No	No	No
e89s	Multi of single	-2	Not inn.	No	1	21-40	Single sex	12	Un-known	Un-known	No	No	No	No
e90s	Multi of single	-2	Not inn.	No	2	41-60	Diverse	40	Just this ent.	Success	No	Yes	No	No
e92s	Multi of multi	3	Yes	No	1	21-40	Single sex	22	Con-current	Both	Yes	Yes	No	No
e94s	Multi of multi	10	Yes	Yes	2	21-40	Single sex	30	Un-known	Success	No	Yes	Yes	No
e95s	Multi of single	5	Yes	No	1	21-40	Single sex	10	Just this ent.	Both	No	Yes	No	No

e96s	Multi of single	-2	Yes	Some-what	3	21-40	Diverse	25	Just this ent.	Both	Yes	Yes	Yes	No
e98s	Multi of multi	2	Yes	No	1	21-40	Single sex	20	Un-known	Success	No	Yes	Yes	Yes
e99s	Multi of single	-1	No	No	2	81≥	Single sex	38	Just this ent.	Both	Yes	No	No	Yes
e100s	Multi of single	5	Yes	No	6	81≥	Diverse	30	Con-current	Un-known	No	Yes	Yes	Yes
e101s	Multi of single	10	Yes	No	2	41-60	Single sex	50	Con-current	Un-known	No	No	No	Yes
e102s	Multi of single	-1	No	Yes	2	21-40	Diverse	14	Just this ent.	Un-known	No	Yes	No	Yes
e103s	Multi of single	1	No	No	1	41-60	Single sex	25	Con-current	Success	Yes	Yes	No	Yes
e107s	Multi of single	2	Yes	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No
e108s	Multi of single	2	Yes	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No
e111s	Multi of single	2	Yes	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No
e112s	Multi of single	2	Yes	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No
e114s	Multi of single	2	Yes	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No
e115s	Multi of multi	2	No	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No
e117s	Multi of multi	1	Yes	Yes	2	21-40	Diverse	30	Con-current	Success	No	Yes	No	Yes
e118s	Multi of single	2	Yes	No	7	81≥	Diverse	20	Un-known	Success	Yes	Yes	Yes	Yes
e119s	Single	1	Not inn.	No	5	81≥	Diverse	25	Con-current	Success	No	Yes	Yes	Yes
e120s	Multi of multi	2	Yes	No	2	21-40	Diverse	27	Just this ent.	Un-known	Yes	Yes	Yes	No
e121s	Multi of single	2	Yes	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No
e122s	Multi of multi	6	Yes	Yes	6	21-40	Diverse	30	Just this ent.	Un-known	No	Yes	No	No
e123s	Multi of single	2	Yes	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No

e125s	Multi of single	2	Yes	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No
e126s	Multi of single	2	Yes	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No
e129s	Multi of single	2	No	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No
e130s	Multi of single	2	Yes	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No
e131s	Single	5	Yes	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No
e133s	Multi of multi	6	No	No	1	21-40	Single sex	10	Just this ent.	Un-known	No	Yes	Yes	Yes
e134s	Multi of single	6	Yes	No	4	21-40	Single sex	25	Un-known	Un-known	No	No	No	No
e135s	Multi of single	2	Yes	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No
e136s	Multi of single	2	Yes	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No
e137s	Multi of single	2	Yes	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No
e138s	Multi of single	2	Yes	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No
e140s	Multi of single	2	Not inn.	Some-what	1	21-40	Single sex	35	Just this ent.	Un-known	Yes	Yes	Yes	Yes
e141s	Multi of single	5	Yes	No	4	41-60	Single sex	13	Un-known	Both	Yes	Yes	Yes	Yes
e144s	Multi of multi	2	No	Some-what	0	21-40	Single sex	12	Con-current	Un-known	No	Yes	Yes	Yes
e145s	Multi of single	2	Yes	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No
e146s	Multi of single	2	Yes	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No
e147s	Multi of single	2	Yes	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No
e148s	Multi of single	2	Yes	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No
e149s	Multi of single	3	No	No	2	21-40	Single sex	10	Both	Un-known	Yes	No	No	Yes
e153s	Multi of single	2	Yes	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No

e154s	Multi of single	2	Yes	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No
e157s	Multi of single	2	Yes	No	2	Un-known	Single sex	25	Un-known	Un-known	No	No	No	No

F2: Demographic Influences

Enterprise	Enterprise Size	Enterprise Type	Enterprise Age (Years)	Subsector: Agritech	Subsector: Anihealth	Subsector: Aquaculture	Subsector: Biotech	Subsector: Medtech	Subsector: Pharma	Subsector: Bus. Supp.
e1s	Micro	Ltd.	7	No	No	No	Yes	No	No	No
e2s	Micro	Ltd.	10	Yes	No	No	No	No	No	No
e3s	Micro	Ltd.	5	No	No	No	No	No	Yes	Yes
e4s	Small	Ltd.	33	No	No	No	Yes	No	No	No
e5s	Medium	PLC	30	No	Yes	No	No	Yes	No	No
e6s	Micro	Ltd.	2	No	No	No	No	No	Yes	No
e8s	Micro	Ltd.	30	No	No	No	No	No	Yes	No
e9s	Micro	Ltd.	4	No	No	No	No	No	Yes	No
e12s	Small	Ltd.	9	No	No	No	No	Yes	No	No
e13s	Micro	Ltd.	26	No	No	No	Yes	Yes	Yes	No
e14s	Micro	Ltd.	5	No	No	No	No	No	Yes	No
e16s	Micro	Ltd.	11	No	No	No	Yes	No	Yes	No
e18s	Small	Ltd.	20	No	No	No	No	Yes	No	No
e19s	Micro	Ltd.	5	No	No	No	Yes	Yes	No	No
e20s	Micro	Ltd.	11	No	No	No	No	Yes	No	No
e22s	Micro	Ltd.	2	No	No	No	No	Yes	No	No
e23s	Micro	Ltd.	15	No	No	No	No	No	No	Yes
e24s	Micro	Ltd.	16	No	No	No	No	Yes	No	No
e25s	Micro	Ltd.	4	No	No	No	Yes	No	No	No
e26s	Micro	Ltd.	13	No	No	No	Yes	No	No	No
e27s	Small	Ltd.	14	No	No	No	No	Yes	No	No
e28s	Small	Ltd.	41	No	Yes	Yes	No	No	No	No
e29s	Micro	Ltd.	8	No	No	No	No	Yes	No	No
e30s	Micro	Ltd.	2	No	No	No	No	Yes	No	No

e31s	Micro	Ltd.	16	No	No	No	Yes	No	No	No
e32s	Small	Ltd.	11	No	No	No	No	Yes	No	No
e34s	Small	Ltd.	15	No	No	No	No	No	No	Yes
e35s	Small	Ltd.	14	No	No	No	Yes	Yes	Yes	Yes
e37s	Micro	Ltd.	3	No	No	No	No	Yes	No	No
e38s	Small	Ltd.	12	No	No	No	Yes	Yes	No	No
e39s	Micro	Ltd.	3	No	No	No	No	Yes	No	No
e40s	Small	Ltd.	13	No	No	No	No	Yes	Yes	No
e41s	Micro	Ltd.	3	No	No	No	No	Yes	No	No
e42s	Micro	Ltd.	6	No	No	No	No	Yes	No	No
e43s	Micro	Ltd.	7	No	No	No	No	Yes	No	No
e44s	Small	Ltd.	34	No	No	No	Yes	Yes	No	No
e45s	Small	Ltd.	8	No	No	No	Yes	No	No	No
e46s	Small	Ltd.	11	No	No	No	No	Yes	No	No
e47s	Small	Ltd.	7	No	No	No	No	Yes	No	No
e48s	Micro	Ltd.	4	No	No	No	Yes	No	Yes	No
e49s	Micro	Ltd.	7	No	No	No	Yes	No	No	No
e50s	Micro	Ltd.	33	No	No	No	No	Yes	No	No
e51s	Small	Ltd.	37	Yes	No	No	Yes	Yes	No	No
e52s	Medium	Ltd.	54	No	No	No	No	Yes	Yes	No
e53s	Medium	Ltd.	40	No	No	No	No	Yes	No	No
e54s	Small	Ltd.	23	No	No	No	No	Yes	No	No
e55s	Micro	Ltd.	4	No	No	No	No	Yes	No	No
e56s	Small	Ltd.	53	No	No	No	No	Yes	No	No
e57s	Micro	Ltd.	20	No	No	No	No	Yes	No	No
e59s	Micro	Ltd.	13	No	No	No	No	No	Yes	No
e60s	Small	Non-Profit	16	No	Yes	No	No	No	No	No
e61s	Small	Ltd.	13	No	No	No	No	Yes	No	No

e62s	Small	Non-Profit	17	No	No	No	Yes	No	No	No
e63s	Micro	Non-Profit	28	No	Yes	Yes	Yes	Yes	No	No
e64s	Micro	Ltd.	14	Yes	Yes	Yes	Yes	Yes	Yes	Yes
e65s	Small	PLC	15	No	No	No	No	No	Yes	No
e66s	Micro	Ltd.	18	No	Yes	No	Yes	Yes	Yes	No
e68s	Micro	Ltd.	5	No	No	No	No	No	Yes	No
e70s	Medium	Ltd.	8	Yes	Yes	Yes	Yes	Yes	No	No
e71s	Small	Ltd.	8	No	No	No	Yes	Yes	No	No
e73s	Medium	Ltd.	22	Yes	Yes	No	Yes	No	No	No
e74s	Micro	Ltd.	12	No	No	No	Yes	No	No	No
e75s	Micro	Non-Profit	36	No	No	No	Yes	Yes	No	No
e77s	Micro	Ltd.	7	Yes	No	No	Yes	No	No	No
e79s	Medium	Ltd.	34	No	No	No	Yes	Yes	No	No
e80s	Micro	Ltd.	12	No	No	No	No	No	No	Yes
e81s	Micro	Ltd.	15	No	Yes	No	No	No	No	No
e84s	Micro	Ltd.	4	No	No	No	No	Yes	No	No
e85s	Micro	Ltd.	7	No	No	No	No	No	No	Yes
e86s	Small	Ltd.	14	No	No	No	Yes	Yes	No	No
e87s	Small	Ltd.	2	Yes	No	No	Yes	No	No	Yes
e89s	Micro	Ltd.	12	No	No	No	No	No	No	Yes
e90s	Micro	Ltd.	16	No	No	No	No	No	No	Yes
e92s	Micro	Ltd.	6	No	No	No	No	Yes	No	No
e94s	Micro	Ltd.	7	Yes	Yes	No	Yes	Yes	No	No
e95s	Small	Ltd.	25	No	No	No	No	Yes	No	No
e96s	Micro	Ltd.	2	No	No	No	No	Yes	No	No
e98s	Micro	Ltd.	20	No	No	No	No	Yes	No	No
e99s	Micro	Ltd.	10	No	No	No	No	No	Yes	No
e100s	Micro	Ltd.	3	No	No	No	No	Yes	No	No

e101s	Micro	Ltd.	8	No	No	No	No	Yes	No	No
e102s	Micro	Ltd.	4	No	No	No	Yes	No	No	No
e103s	Small	Ltd.	15	Yes	Yes	No	No	No	Yes	No
e107s	Micro	Non-Profit	11	Yes	No	No	No	No	No	No
e108s	Micro	Non-Profit	11	No	No	No	No	No	No	No
e111s	Medium	Ltd.	100	No	No	No	No	Yes	No	No
e112s	Micro	Ltd.	7	No	Yes	No	No	Yes	No	No
e114s	Small	Ltd.	11	No	No	No	No	Yes	No	No
e115s	Micro	Ltd.	5	No	No	No	No	Yes	No	No
e117s	Small	Ltd.	16	No	No	No	No	Yes	No	No
e118s	Medium	Ltd.	12	No	No	No	No	Yes	No	Yes
e119s	Micro	Ltd.	5	No	No	No	No	No	No	Yes
e120s	Medium	Ltd.	30	No	No	No	No	No	Yes	No
e121s	Micro	Ltd.	7	No	No	No	No	No	No	Yes
e122s	Medium	Ltd.	70	No	No	No	No	Yes	No	No
e123s	Medium	Ltd.	11	No	No	No	No	Yes	Yes	No
e125s	Small	Ltd.	4	No	No	No	No	Yes	No	No
e126s	Medium	PLC	80	No	No	No	No	No	Yes	No
e129s	Micro	Ltd.	10	No	No	No	Yes	No	No	No
e130s	Small	Ltd.	23	No	No	No	No	No	Yes	No
e131s	Small	Ltd.	15	No	No	No	No	Yes	No	No
e133s	Micro	Ltd.	6	No	No	No	No	Yes	No	No
e134s	Small	Ltd.	10	No	No	No	Yes	No	No	No
e135s	Micro	PLC	11	No	No	No	No	No	No	No
e136s	Micro	Ltd.	2	No	No	No	Yes	No	No	No
e137s	Small	Ltd.	11	No	No	No	No	Yes	No	No
e138s	Micro	Ltd.	12	No	No	No	No	Yes	No	No
e140s	Micro	Ltd.	9	Yes	No	Yes	No	Yes	No	Yes

e141s	Micro	Ltd.	16	No	No	No	No	Yes	No	No
e144s	Micro	Ltd.	6	No	No	No	No	Yes	No	No
e145s	Micro	Ltd.	11	No	No	No	No	No	No	No
e146s	Small	Ltd.	11	No	No	No	No	Yes	No	No
e147s	Small	Non-Profit	10	No	No	No	Yes	No	No	No
e148s	Small	Ltd.	10	No	No	No	No	No	Yes	No
e149s	Micro	Ltd.	8	No	No	No	No	Yes	No	No
e153s	Small	Ltd.	16	No	No	No	No	Yes	No	No
e154s	Micro	Ltd.	21	No	No	No	Yes	Yes	No	No
e157s	Small	Ltd.	7	No	No	No	No	No	No	No

F3: External Influences

Enterprise	UK Country of Operation	Internationalisation	Locational Setting	Supply Chain	BREXIT	COVID
e1s	England	International (UK)	Rural	Supplier	-80	-16
e2s	England	International (UK)	Rural	Supplier	-100	-9
e3s	Wales	National (UK)	Urban	Manufacturer	-100	-50
e4s	Wales	International (UK)	Suburban	Manufacturer	-100	100
e5s	Wales	International (UK)	Urban	Manufacturer	-100	100
e6s	Wales	International (UK)	Urban	Supplier	-100	-100
e8s	Wales	National (UK)	Urban	Manufacturer	-100	0
e9s	England	Not yet/currently trading	Urban	Manufacturer	-61	0
e12s	Scotland	International (UK)	Urban	Manufacturer	-100	70
e13s	Scotland	International (UK)	Isolated, remote	Manufacturer	-100	11
e14s	Wales	International (UK)	Suburban	Manufacturer	-100	-37
e16s	England	International (UK)	Suburban	Supplier	-100	-38
e18s	Wales	International (UK)	Suburban	Manufacturer	31	32
e19s	Wales	International (UK)	Suburban	Manufacturer	-64	39
e20s	Scotland	National (UK)	Operate online-only	Manufacturer	-70	-68
e22s	England	Not yet/currently trading	Urban	Manufacturer	-100	-6
e23s	Scotland	Continental (Europe)	Rural	Supplier	-100	22
e24s	Wales	Not yet/currently trading	Urban	Manufacturer	25	-75
e25s	England	International (UK)	Rural	Supplier	-100	-15
e26s	England	International (UK)	Operate online-only	Supplier	-100	-84
e27s	England	International (UK)	Suburban	Manufacturer	-100	61
e28s	Scotland	Continental (Europe)	Rural	Supplier	-100	2
e29s	Wales	National (UK)	Urban	Distributor	-85	-75
e30s	Wales	National (UK)	Urban	Manufacturer	0	0

e31s	Scotland	International (UK)	Operate online-only	Supplier	-100	-10
e32s	England	Not yet/currently trading	Suburban	Manufacturer	-50	50
e34s	England	International (UK)	Suburban	Manufacturer	-100	100
e35s	Scotland	International (UK)	Urban	Supplier	-100	22
e37s	England	Not yet/currently trading	Suburban	Manufacturer	-83	2
e38s	England	International (UK)	Suburban	Supplier	-100	-30
e39s	England	National (UK)	Operate online-only	Manufacturer	-100	34
e40s	Wales	Continental (Europe)	Operate online-only	Manufacturer	-100	50
e41s	Wales	International (UK)	Urban	Supplier	-100	-72
e42s	England	International (UK)	Urban	Supplier	-100	30
e43s	Northern Ireland	International (UK)	Urban	Distributor	100	-21
e44s	Wales	International (UK)	Suburban	Supplier	-100	100
e45s	Wales	International (UK)	Urban	Manufacturer	-100	-10
e46s	Wales	International (UK)	Suburban	Manufacturer	-100	51
e47s	Wales	International (UK)	Operate online-only	Supplier	-100	72
e48s	Wales	International (UK)	Suburban	Manufacturer	-100	-11
e49s	England	National (UK)	Operate online-only	Supplier	-52	-85
e50s	Wales	International (UK)	Rural	Manufacturer	-100	0
e51s	Wales	International (UK)	Rural	Supplier	-100	-18
e52s	Wales	International (UK)	Suburban	Manufacturer	-100	-100
e53s	Wales	International (UK)	Urban	Manufacturer	-100	50
e54s	Wales	International (UK)	Suburban	Manufacturer	-100	-5
e55s	Wales	Local or regional	Urban	Manufacturer	-100	-100
e56s	Wales	International (UK)	Operate online-only	Supplier	-100	45
e57s	Wales	International (UK)	Urban	Supplier	1	-8
e59s	Wales	International (UK)	Suburban	Manufacturer	100	-80
e60s	Wales	International (UK)	Operate online-only	Manufacturer	-100	0
e61s	Wales	International (UK)	Urban	Supplier	-51	-90

e62s	Wales	Local or regional	Urban	Distributor	-100	-27
e63s	Wales	Local or regional	Suburban	Manufacturer	-100	-30
e64s	England	International (UK)	Suburban	Supplier	-99	10
e65s	England	International (UK)	Rural	Supplier	-100	100
e66s	Wales	International (UK)	Suburban	Manufacturer	-49	45
e68s	England	Not yet/currently trading	Urban	Manufacturer	-100	-26
e70s	England	International (UK)	Operate online-only	Manufacturer	-100	100
e71s	Wales	International (UK)	Urban	Manufacturer	-100	0
e73s	England	International (UK)	Rural	Supplier	-43	70
e74s	Wales	National (UK)	Suburban	Manufacturer	-100	100
e75s	Scotland	International (UK)	Suburban	Distributor	-100	-100
e77s	Wales	International (UK)	Operate online-only	Manufacturer	-100	-100
e79s	Wales	International (UK)	Suburban	Manufacturer	-100	100
e80s	Wales	National (UK)	Suburban	Manufacturer	-100	-25
e81s	Wales	International (UK)	Suburban	Manufacturer	100	-11
e84s	England	Not yet/currently trading	Urban	Manufacturer	14	-60
e85s	Wales	National (UK)	Operate online-only	Manufacturer	100	-29
e86s	England	International (UK)	Rural	Manufacturer	1	46
e87s	Wales	International (UK)	Rural	Manufacturer	-100	-8
e89s	England	National (UK)	Urban	Manufacturer	51	-96
e90s	Wales	National (UK)	Urban	Supplier	-100	0
e92s	England	International (UK)	Suburban	Manufacturer	-100	-72
e94s	England	Continental (Europe)	Operate online-only	Manufacturer	100	-39
e95s	Scotland	International (UK)	Suburban	Manufacturer	-4	-36
e96s	England	Not yet/currently trading	Urban	Manufacturer	-100	-5
e98s	Scotland	International (UK)	Isolated, remote	Manufacturer	100	2
e99s	England	Not yet/currently trading	Urban	Supplier	-100	0
e100s	England	Not yet/currently trading	Urban	Manufacturer	-100	-30

e101s	Wales	Not yet/currently trading	Rural	Supplier	-100	-20
e102s	England	International (UK)	Operate online-only	Supplier	-100	-40
e103s	England	International (UK)	Rural	Supplier	-100	-10
e107s	Wales	International (UK)	Suburban	Manufacturer	-100	-8
e108s	Wales	International (UK)	Suburban	Manufacturer	-100	-8
e111s	Wales	International (UK)	Suburban	Manufacturer	-100	-40
e112s	Wales	International (UK)	Suburban	Manufacturer	-100	2
e114s	Wales	International (UK)	Suburban	Manufacturer	-100	-8
e115s	Wales	International (UK)	Suburban	Supplier	-100	42
e117s	Wales	National (UK)	Rural	Distributor	-100	0
e118s	Northern Ireland	International (UK)	Urban	Manufacturer	-100	25
e119s	Wales	National (UK)	Urban	Supplier	-100	-90
e120s	Northern Ireland	International (UK)	Rural	Manufacturer	-50	3
e121s	Wales	International (UK)	Suburban	Supplier	-100	-8
e122s	England	International (UK)	Suburban	Manufacturer	-80	37
e123s	Wales	International (UK)	Suburban	Manufacturer	-100	-8
e125s	Wales	International (UK)	Suburban	Supplier	-100	-8
e126s	Wales	International (UK)	Suburban	Manufacturer	-100	-69
e129s	Wales	International (UK)	Suburban	Manufacturer	-100	-80
e130s	Wales	International (UK)	Suburban	Supplier	-100	50
e131s	Wales	Not yet/currently trading	Urban	Manufacturer	-100	-70
e133s	Wales	International (UK)	Urban	Manufacturer	100	-91
e134s	England	Not yet/currently trading	Suburban	Supplier	-100	-24
e135s	Wales	International (UK)	Suburban	Manufacturer	-100	-8
e136s	Wales	International (UK)	Suburban	Manufacturer	-100	-8
e137s	Wales	International (UK)	Suburban	Manufacturer	-100	-8
e138s	Wales	International (UK)	Suburban	Supplier	-100	-8
e140s	Wales	Continental (Europe)	Operate online-only	Supplier	-1	-70

e141s	Wales	Not yet/currently trading	Urban	Manufacturer	45	-74
e144s	Wales	International (UK)	Urban	Manufacturer	100	-91
e145s	Wales	International (UK)	Suburban	Manufacturer	-100	-8
e146s	Wales	International (UK)	Suburban	Manufacturer	-100	-8
e147s	Wales	International (UK)	Suburban	Manufacturer	-100	-8
e148s	Wales	International (UK)	Suburban	Manufacturer	-100	-8
e149s	England	Not yet/currently trading	Urban	Supplier	-100	-67
e153s	Wales	International (UK)	Suburban	Distributor	-100	80
e154s	Wales	International (UK)	Suburban	Manufacturer	-100	-8
e157s	Wales	International (UK)	Suburban	Supplier	-100	-8

Appendix O: Regression Coefficients

*C1*C2*

The results of the 28th model of the multivariate regression, with backwards elimination of variables, sorted by ascending significance (sixth column) to reveal the nine influences of the interaction of the dual concepts (C1*C2) within the final model.

Influences	Unstandardised Coefficients		Standard-ised Co-efficients (β)	t	Signifi-cance (p)	95% Confidence Interval for b		Correlation			Collinearity Statistics	
	b	Standard Error				Lower Bound	Upper Bound	Zero-Order	Partial	Part	Tolerance	VIF
Internationalisation	1.220	0.334	0.309	3.658	0.000	0.559	1.882	0.365	0.333	0.284	0.845	1.183
Management Qualifications: Science	3.152	0.953	0.279	3.307	0.001	1.263	5.041	0.178	0.305	0.256	0.843	1.186
Supply Chain: Manufacturer	2.849	1.008	0.245	2.825	0.006	0.849	4.848	0.117	0.263	0.219	0.801	1.248
Management Team Size	-0.604	0.236	-0.219	-2.556	0.012	-1.073	-0.136	-0.094	-0.240	-0.198	0.820	1.220
UK Country of Operation: Scotland	4.074	1.639	0.201	2.486	0.014	0.825	7.323	0.212	0.234	0.193	0.918	1.090
Enterprise Size: Medium	3.449	1.611	0.185	2.140	0.035	0.255	6.643	0.196	0.203	0.166	0.806	1.241
Supply Chain: Distributor	3.561	1.901	0.159	1.873	0.064	-0.207	7.329	0.145	0.178	0.145	0.837	1.195
Subsector: Business Support	-2.527	1.388	-0.145	-1.820	0.072	-5.279	0.225	-0.170	-0.173	-0.141	0.948	1.054
Enterprise Size: Small	1.870	1.044	0.155	1.791	0.076	-0.200	3.940	0.120	0.171	0.139	0.803	1.245

C1: Organisational Resilience

Influences	Unstandardised Coefficients		Standard-ised Co-efficients (β)	t	Signifi-cance (p)	95% Confidence Interval for b		Correlations			Collinearity Statistics	
	b	Standard Error				Lower Bound	Upper Bound	Zero-Order	Partial	Part	Tolerance	VIF
Internationalisation	0.202	0.048	0.337	4.184	0.000	0.106	0.297	0.371	0.377	0.309	0.841	1.189
Supply Chain: Manufacturer	0.540	0.147	0.307	3.679	0.000	0.249	0.831	0.132	0.337	0.272	0.786	1.273
Supply Chain: Distributor	0.717	0.281	0.211	2.555	0.012	0.161	1.273	0.122	0.241	0.189	0.799	1.252
Management Qualifications: Science	0.346	0.138	0.203	2.502	0.014	0.072	0.619	0.184	0.236	0.185	0.834	1.199
Enterprise Age	0.010	0.004	0.174	2.262	0.026	0.001	0.018	0.276	0.215	0.167	0.919	1.088
Management Experience: Previous Employment	0.361	0.160	0.178	2.255	0.026	0.044	0.678	0.134	0.214	0.167	0.879	1.138
Enterprise Size: Small	0.317	0.140	0.174	2.255	0.026	0.038	0.595	0.216	0.214	0.167	0.922	1.085
Enterprise Type: Non-Profit	-0.599	0.283	-0.166	-2.117	0.037	-1.160	-0.038	-0.086	-0.201	-0.157	0.890	1.124
Locational Setting	-0.102	0.050	-0.158	-2.023	0.046	-0.202	-0.002	-0.271	-0.193	-0.150	0.894	1.119
Innovation In-House Staff	-0.178	0.104	-0.131	-1.710	0.090	-0.384	0.028	-0.198	-0.164	-0.126	0.931	1.074

C2: Open Innovation

Influences	Unstandardised Coefficients		Standard-ised Co-efficients (β)	t	Signifi-cance(p)	95% Confidence Interval for b		Correlations			Collinearity	
	b	Standard Error				Lower Bound	Upper Bound	Zero-Order	Partial	Part	Tolerance	VIF
UK Country of Operation: Scotland	1.659	0.447	0.326	3.709	0.000	0.772	2.546	0.205	0.343	0.291	0.796	1.257
Supply Chain: Distributor	5.280	1.734	0.937	3.046	0.003	1.842	8.718	0.148	0.287	0.239	0.065	15.385
Internationalisation	0.251	0.084	0.253	3.005	0.003	0.086	0.417	0.279	0.284	0.236	0.867	1.153
Enterprise Size: Medium	1.448	0.494	0.309	2.930	0.004	0.468	2.427	0.135	0.277	0.230	0.554	1.806
Supply Chain: Manufacturer	5.455	1.961	1.866	2.782	0.006	1.566	9.345	0.083	0.264	0.218	0.014	73.116
Enterprise Age	-0.028	0.010	-0.297	-2.649	0.009	-0.048	-0.007	0.016	-0.253	-0.208	0.489	2.043
Supply Chain: Supplier	5.014	1.946	1.654	2.576	0.011	1.155	8.874	-0.143	0.246	0.202	0.015	66.989
Management Diversity: Sexes	-0.701	0.282	-0.215	-2.489	0.014	-1.259	-0.142	-0.143	-0.238	-0.195	0.821	1.217
Management Diversity: Ages	0.170	0.075	0.202	2.286	0.024	0.023	0.318	0.118	0.220	0.179	0.791	1.264
Management: Length of Industry Experience	-0.024	0.011	-0.184	-2.150	0.034	-0.047	-0.002	-0.187	-0.207	-0.169	0.841	1.189
Management Qualifications: Science	0.500	0.247	0.177	2.025	0.045	0.010	0.991	0.129	0.196	0.159	0.809	1.236
Subsector: Business Support	-0.668	0.355	-0.152	-1.882	0.063	-1.371	0.036	-0.164	-0.182	-0.148	0.938	1.066
Management: Family	-0.280	0.155	-0.160	-1.802	0.074	-0.588	0.028	0.009	-0.175	-0.141	0.780	1.281

Ent. Size: Med.	Ent. Size: Small	Ent. Size: Mic.	C1*C2	-
0.196	0.120	-0.233	1.000	**C1*C2**
-0.392	-0.804	1.000	-0.233	**Enterprise Size: Micro**
-0.232	1.000	-0.804	0.120	**Enterprise Size: Small**
1.000	-0.232	-0.392	0.196	**Enterprise Size: Medium**
0.177	0.088	-0.192	0.029	**Enterprise Type: Public Limited Company**
-0.061	-0.105	0.136	-0.084	**Enterprise Type: Private Limited Company**
-0.084	0.057	-0.002	0.084	**Enterprise Type: Non-Profit**
0.085	-0.034	-0.020	0.079	**Subsector: Agricultural Technology**
0.165	-0.052	-0.052	0.146	**Subsector: Animal Health**
0.068	-0.055	0.010	0.024	**Subsector: Aquaculture**
-0.034	0.029	-0.006	0.063	**Subsector: Biological Technology**
0.118	0.077	-0.145	0.113	**Subsector: Medical Technology**
0.118	-0.064	-0.011	0.030	**Subsector: Pharmaceuticals**
-0.037	-0.085	0.102	-0.170	**Subsector: Business Support**
0.566	0.048	-0.391	0.125	**Enterprise Age**
-0.172	0.068	0.040	-0.179	**Supply Chain: Supplier**
0.204	-0.079	-0.051	0.117	**Supply Chain: Manufacturer**
-0.091	0.103	-0.042	0.145	**Supply Chain: Distributor**
0.200	0.340	-0.444	0.101	**COVID**
0.153	-0.063	-0.034	0.205	**Innovation Portfolio Diversity**
-0.039	-0.129	0.146	-0.166	**Innovation In-house Staff**
0.083	-0.103	0.047	0.069	**Innovation: Speed to Market**
-0.028	-0.078	0.091	-0.155	**UK Country of Operation: England**
0.302	-0.111	-0.079	0.030	**UK Country of Operation: Northern Ireland**
-0.102	0.051	0.015	0.212	**UK Country of Operation: Scotland**
-0.013	0.079	-0.067	0.014	**UK Country of Operation: Wales**
0.204	0.176	-0.291	0.365	**Internationalisation**
0.007	-0.063	0.055	-0.228	**Locational Setting**
0.079	0.179	-0.218	-0.094	**MGMT Team Size**
0.066	0.105	-0.139	-0.046	**MGMT: Family**
0.126	-0.028	-0.051	-0.072	**MGMT Diversity: Sexes**
0.055	0.030	-0.062	0.060	**MGMT Diversity: Ages**
0.015	0.097	-0.101	-0.142	**MGMT Length of Industry Experience**
-0.019	0.072	-0.057	0.100	**MGMT Entrepreneurial Experience: Present**
-0.102	0.142	-0.072	-0.043	**MGMT Entrepreneurial Experience: Past**
0.084	-0.116	0.059	0.093	**MGMT: Previous Employment**
0.124	-0.086	0.005	0.093	**MGMT Know.: Business**
0.062	0.017	-0.054	0.097	**MGMT Know.: Engineering**
-0.068	-0.096	0.132	0.178	**MGMT Know.: Science**
-0.099	-0.195	0.245	-0.036	**BREXIT**

Subsector: Anihealth	Subsector: Agritech	Ent. Type: Non-Prof.	Ent. Type: Ltd.	Enterprise Type: PLC
0.146	0.079	0.084	-0.084	0.029
-0.052	-0.020	-0.002	0.136	-0.192
-0.052	-0.034	0.057	-0.105	0.088
0.165	0.085	-0.084	-0.061	0.177
0.050	-0.074	-0.058	-0.658	1.000
-0.150	0.020	-0.714	1.000	-0.658
0.153	0.043	1.000	-0.714	-0.058
0.374	1.000	0.043	0.020	-0.074
1.000	0.374	0.153	-0.150	0.050
0.486	0.367	0.125	-0.060	-0.049
0.150	0.238	0.151	-0.009	-0.150
0.005	-0.079	-0.148	0.136	-0.036
0.047	-0.011	-0.124	0.036	0.081
-0.037	0.153	-0.092	0.129	-0.085
0.067	-0.052	0.051	-0.189	0.215
0.008	0.153	-0.173	0.185	-0.077
0.030	-0.113	0.101	-0.088	0.021
-0.091	-0.086	0.218	-0.228	0.091
0.185	0.007	-0.083	-0.009	0.103
0.202	0.222	0.083	-0.137	0.105
0.005	-0.022	0.123	-0.031	-0.089
-0.030	-0.034	-0.103	0.084	-0.008
0.095	0.182	-0.160	0.164	-0.062
-0.054	-0.052	-0.041	0.057	-0.037
-0.002	-0.098	0.052	-0.087	0.068
-0.070	-0.096	0.131	-0.120	0.031
0.106	0.154	0.001	-0.061	0.086
-0.184	-0.327	-0.017	0.010	0.005
-0.072	-0.066	-0.127	0.170	-0.106
0.031	0.015	0.020	-0.046	0.045
-0.132	-0.120	-0.147	0.143	-0.047
-0.163	-0.124	0.109	-0.060	-0.031
0.007	0.084	-0.039	0.037	-0.011
-0.064	-0.026	0.167	-0.139	0.018
-0.227	-0.129	0.124	-0.085	-0.013
0.150	0.172	0.034	0.063	-0.126
0.068	-0.018	-0.171	0.123	0.008
0.062	0.023	-0.176	0.247	-0.163
0.157	0.018	-0.044	0.093	-0.085
0.087	0.028	-0.120	0.123	-0.046

Subsector: Bus. Supp.	Subsector: Pharma	Subsector: Medtech	Subsector: Biotech	Subsector: Aqua.
-0.170	0.030	0.113	0.063	0.024
0.102	-0.011	-0.145	-0.006	0.010
-0.085	-0.064	0.077	0.029	-0.055
-0.037	0.118	0.118	-0.034	0.068
-0.085	0.081	-0.036	-0.150	-0.049
0.129	0.036	0.136	-0.009	-0.060
-0.092	-0.124	-0.148	0.151	0.125
0.153	-0.011	-0.079	0.238	0.367
-0.037	0.047	0.005	0.150	0.486
0.183	0.003	0.095	0.140	1.000
-0.066	-0.039	-0.157	1.000	0.140
-0.216	-0.271	1.000	-0.157	0.095
0.018	1.000	-0.271	-0.039	0.003
1.000	0.018	-0.216	-0.066	0.183
-0.121	0.082	0.114	-0.028	0.064
0.140	0.027	-0.180	0.108	0.125
-0.094	0.029	0.092	-0.086	-0.098
-0.099	-0.133	0.163	-0.028	-0.057
-0.039	-0.020	0.091	0.091	0.045
0.031	-0.054	0.144	0.215	0.132
0.389	0.056	-0.291	-0.007	0.132
-0.264	0.012	0.005	0.156	-0.131
-0.060	0.018	-0.060	0.119	0.052
0.107	0.056	0.030	-0.105	-0.034
0.077	0.004	0.076	0.069	0.087
-0.023	-0.037	0.003	-0.116	-0.087
-0.035	0.043	-0.051	0.199	-0.020
0.014	0.153	0.055	-0.213	-0.192
-0.082	-0.082	0.160	0.217	0.020
-0.036	-0.018	0.009	-0.064	0.076
0.027	0.007	0.028	0.090	-0.026
-0.107	0.040	-0.011	-0.073	-0.120
0.002	-0.019	0.053	0.013	-0.050
-0.028	-0.136	-0.111	0.092	-0.258
-0.033	-0.029	-0.047	-0.120	-0.017
0.050	0.088	0.018	0.044	0.086
0.170	-0.048	0.143	0.041	0.049
-0.091	-0.118	0.347	0.056	0.121
0.040	0.005	0.063	0.145	0.203
0.030	-0.109	0.122	-0.145	-0.027

Inn. Portfolio Div.	COVID	Supply Chain: Dist.	Supply Chain: Manu.	Supply Chain: Supp.	Ent. Age
0.205	0.101	0.145	0.117	-0.179	0.125
-0.034	-0.444	-0.042	-0.051	0.040	-0.391
-0.063	0.340	0.103	-0.079	0.068	0.048
0.153	0.200	-0.091	0.204	-0.172	0.566
0.105	0.103	0.091	0.021	-0.077	0.215
-0.137	-0.009	-0.228	-0.088	0.185	-0.189
0.083	-0.083	0.218	0.101	-0.173	0.051
0.222	0.007	-0.086	-0.113	0.153	-0.052
0.202	0.185	-0.091	0.030	0.008	0.067
0.132	0.045	-0.057	-0.098	0.125	0.064
0.215	0.091	-0.028	-0.086	0.108	-0.028
0.144	0.091	0.163	0.092	-0.180	0.114
-0.054	-0.020	-0.133	0.029	0.027	0.082
0.031	-0.039	-0.099	-0.094	0.140	-0.121
0.201	0.113	0.073	0.082	-0.078	1.000
-0.063	-0.012	-0.114	-0.893	1.000	-0.078
0.005	0.025	-0.325	1.000	-0.893	0.082
0.123	0.003	1.000	-0.325	-0.114	0.073
0.161	1.000	0.003	0.025	-0.012	0.113
1.000	0.161	0.123	0.005	-0.063	0.201
0.038	-0.127	0.040	-0.122	0.102	-0.002
0.152	-0.055	-0.103	0.089	-0.053	0.014
0.030	0.083	-0.097	-0.164	0.202	-0.198
0.120	0.034	0.171	0.014	-0.111	0.010
0.086	0.001	0.039	-0.078	0.051	0.119
-0.115	-0.088	0.013	0.192	-0.180	0.112
0.321	0.230	-0.049	-0.078	0.100	0.226
-0.150	-0.118	-0.062	0.146	-0.145	-0.057
-0.171	0.275	-0.112	0.073	-0.043	0.155
-0.167	0.070	-0.086	-0.039	0.105	0.002
-0.004	0.112	-0.080	0.011	0.014	0.159
-0.137	-0.011	0.051	-0.003	-0.003	0.080
0.186	0.222	0.129	-0.143	0.122	0.202
0.098	-0.007	-0.078	0.225	-0.203	-0.009
-0.233	-0.182	0.094	-0.033	0.007	0.013
-0.049	0.048	0.014	-0.077	0.056	-0.053
0.102	-0.064	0.077	0.015	-0.049	0.099
0.023	0.067	-0.046	0.137	-0.099	0.042
0.074	0.016	0.126	-0.214	0.158	-0.075
0.235	-0.251	-0.003	0.193	-0.211	-0.097

UK Country of Op.: N. Ire.	UK Country of Op.: Eng.	Inn.: Speed to Market	Inn. In-house Staff
0.030	-0.155	0.069	-0.166
-0.079	0.091	0.047	0.146
-0.111	-0.078	-0.103	-0.129
0.302	-0.028	0.083	-0.039
-0.037	-0.062	-0.008	-0.089
0.057	0.164	0.084	-0.031
-0.041	-0.160	-0.103	0.123
-0.052	0.182	-0.034	-0.022
-0.054	0.095	-0.030	0.005
-0.034	0.052	-0.131	0.132
-0.105	0.119	0.156	-0.007
0.030	-0.060	0.005	-0.291
0.056	0.018	0.012	0.056
0.107	-0.060	-0.264	0.389
0.010	-0.198	0.014	-0.002
-0.111	0.202	-0.053	0.102
0.014	-0.164	0.089	-0.122
0.171	-0.097	-0.103	0.040
0.034	0.083	-0.055	-0.127
0.120	0.030	0.152	0.038
-0.105	0.095	-0.236	1.000
-0.047	-0.035	1.000	-0.236
-0.103	1.000	-0.035	0.095
1.000	-0.103	-0.047	-0.105
-0.049	-0.194	0.073	0.045
-0.199	-0.782	0.006	-0.079
0.098	-0.284	0.040	-0.090
0.064	-0.076	-0.120	-0.007
0.058	0.005	0.027	-0.138
-0.035	-0.122	-0.029	-0.107
0.153	0.058	0.093	0.118
-0.022	-0.224	0.074	-0.184
0.070	0.019	0.036	-0.069
-0.052	-0.180	0.159	-0.188
0.011	-0.178	-0.225	-0.055
0.168	0.233	-0.141	0.065
0.059	0.022	0.072	0.184
0.115	-0.129	0.055	-0.054
0.048	0.166	0.106	0.113
0.157	-0.038	0.143	0.123

MGMT: Family	MGMT Team Size	Prox. to Res.	Intern.	UK Country of Op.: Wales	UK Country of Op.: Scot.
-0.046	-0.094	-0.228	0.365	0.014	0.212
-0.139	-0.218	0.055	-0.291	-0.067	0.015
0.105	0.179	-0.063	0.176	0.079	0.051
0.066	0.079	0.007	0.204	-0.013	-0.102
0.045	-0.106	0.005	0.086	0.031	0.068
-0.046	0.170	0.010	-0.061	-0.120	-0.087
0.020	-0.127	-0.017	0.001	0.131	0.052
0.015	-0.066	-0.327	0.154	-0.096	-0.098
0.031	-0.072	-0.184	0.106	-0.070	-0.002
0.076	0.020	-0.192	-0.020	-0.087	0.087
-0.064	0.217	-0.213	0.199	-0.116	0.069
0.009	0.160	0.055	-0.051	0.003	0.076
-0.018	-0.082	0.153	0.043	-0.037	0.004
-0.036	-0.082	0.014	-0.035	-0.023	0.077
0.002	0.155	-0.057	0.226	0.112	0.119
0.105	-0.043	-0.145	0.100	-0.180	0.051
-0.039	0.073	0.146	-0.078	0.192	-0.078
-0.086	-0.112	-0.062	-0.049	0.013	0.039
0.070	0.275	-0.118	0.230	-0.088	0.001
-0.167	-0.171	-0.150	0.321	-0.115	0.086
-0.107	-0.138	-0.007	-0.090	-0.079	0.045
-0.029	0.027	-0.120	0.040	0.006	0.073
-0.122	0.005	-0.076	-0.284	-0.782	-0.194
-0.035	0.058	0.064	0.098	-0.199	-0.049
0.034	0.149	-0.185	0.099	-0.374	1.000
0.105	-0.108	0.155	0.175	1.000	-0.374
0.058	-0.066	-0.193	1.000	0.175	0.099
0.195	0.021	1.000	-0.193	0.155	-0.185
0.163	1.000	0.021	-0.066	-0.108	0.149
1.000	0.163	0.195	0.058	0.105	0.034
-0.198	0.485	-0.091	-0.042	-0.241	0.242
0.277	0.033	0.126	0.096	0.272	-0.102
-0.119	-0.028	-0.063	-0.064	-0.024	-0.027
0.090	-0.107	0.005	0.224	0.216	-0.058
0.160	-0.091	0.104	-0.117	0.201	-0.069
-0.018	0.136	-0.118	-0.165	-0.340	0.124
-0.104	0.280	-0.101	-0.056	-0.218	0.315
0.048	0.375	-0.005	-0.016	0.020	0.110
-0.126	0.218	-0.207	-0.075	-0.267	0.172
-0.236	-0.168	-0.032	-0.056	-0.030	0.027

MGMT Entr. Exp.: Past	MGMT Ent. Exp.: Present	MGMT Ind. Exp.	MGMT Div.: Ages	MGMT Div.: Sexes
-0.043	0.100	-0.142	0.060	-0.072
-0.072	-0.057	-0.101	-0.062	-0.051
0.142	0.072	0.097	0.030	-0.028
-0.102	-0.019	0.015	0.055	0.126
-0.013	0.018	-0.011	-0.031	-0.047
-0.085	-0.139	0.037	-0.060	0.143
0.124	0.167	-0.039	0.109	-0.147
-0.129	-0.026	0.084	-0.124	-0.120
-0.227	-0.064	0.007	-0.163	-0.132
-0.017	-0.258	-0.050	-0.120	-0.026
-0.120	0.092	0.013	-0.073	0.090
-0.047	-0.111	0.053	-0.011	0.028
-0.029	-0.136	-0.019	0.040	0.007
-0.033	-0.028	0.002	-0.107	0.027
0.013	-0.009	0.202	0.080	0.159
0.007	-0.203	0.122	-0.003	0.014
-0.033	0.225	-0.143	-0.003	0.011
0.094	-0.078	0.129	0.051	-0.080
-0.182	-0.007	0.222	-0.011	0.112
-0.233	0.098	0.186	-0.137	-0.004
-0.055	-0.188	-0.069	-0.184	0.118
-0.225	0.159	0.036	0.074	0.093
-0.178	-0.180	0.019	-0.224	0.058
0.011	-0.052	0.070	-0.022	0.153
-0.069	-0.058	-0.027	-0.102	0.242
0.201	0.216	-0.024	0.272	-0.241
-0.117	0.224	-0.064	0.096	-0.042
0.104	0.005	-0.063	0.126	-0.091
-0.091	-0.107	-0.028	0.033	0.485
0.160	0.090	-0.119	0.277	-0.198
-0.278	-0.204	0.051	0.003	1.000
0.170	0.446	0.121	1.000	0.003
0.028	-0.021	1.000	0.121	0.051
-0.130	1.000	-0.021	0.446	-0.204
1.000	-0.130	0.028	0.170	-0.278
-0.112	-0.208	0.089	-0.218	0.192
-0.198	-0.366	-0.025	-0.343	0.370
-0.099	-0.299	0.146	-0.224	0.210
-0.268	-0.284	-0.059	-0.305	0.136
0.030	-0.053	-0.066	-0.214	-0.097

BREXIT	MGMT Know.: Sci.	MGMT Know.: Eng.	MGMT Know.: Bus.	MGMT: Prev. Emp.
-0.036	0.178	0.097	0.093	0.093
0.245	0.132	-0.054	0.005	0.059
-0.195	-0.096	0.017	-0.086	-0.116
-0.099	-0.068	0.062	0.124	0.084
-0.046	-0.085	-0.163	0.008	-0.126
0.123	0.093	0.247	0.123	0.063
-0.120	-0.044	-0.176	-0.171	0.034
0.028	0.018	0.023	-0.018	0.172
0.087	0.157	0.062	0.068	0.150
-0.027	0.203	0.121	0.049	0.086
-0.145	0.145	0.056	0.041	0.044
0.122	0.063	0.347	0.143	0.018
-0.109	0.005	-0.118	-0.048	0.088
0.030	0.040	-0.091	0.170	0.050
-0.097	-0.075	0.042	0.099	-0.053
-0.211	0.158	-0.099	-0.049	0.056
0.193	-0.214	0.137	0.015	-0.077
-0.003	0.126	-0.046	0.077	0.014
-0.251	0.016	0.067	-0.064	0.048
0.235	0.074	0.023	0.102	-0.049
0.123	0.113	-0.054	0.184	0.065
0.143	0.106	0.055	0.072	-0.141
-0.038	0.166	-0.129	0.022	0.233
0.157	0.048	0.115	0.059	0.168
0.027	0.172	0.110	0.315	0.124
-0.030	-0.267	0.020	-0.218	-0.340
-0.056	-0.075	-0.016	-0.056	-0.165
-0.032	-0.207	-0.005	-0.101	-0.118
-0.168	0.218	0.375	0.280	0.136
-0.236	-0.126	0.048	-0.104	-0.018
-0.097	0.136	0.210	0.370	0.192
-0.214	-0.305	-0.224	-0.343	-0.218
-0.066	-0.059	0.146	-0.025	0.089
-0.053	-0.284	-0.299	-0.366	-0.208
0.030	-0.268	-0.099	-0.198	-0.112
-0.058	0.284	0.175	0.241	1.000
0.287	0.391	0.474	1.000	0.241
0.264	0.283	1.000	0.474	0.175
0.092	1.000	0.283	0.391	0.284
1.000	0.092	0.264	0.287	-0.058

Appendix Q: Raw Qualitative Data

Emergent Influences from Survey

An optional question at the end of the quantitative survey to garner some emergent influences. Here are the results:

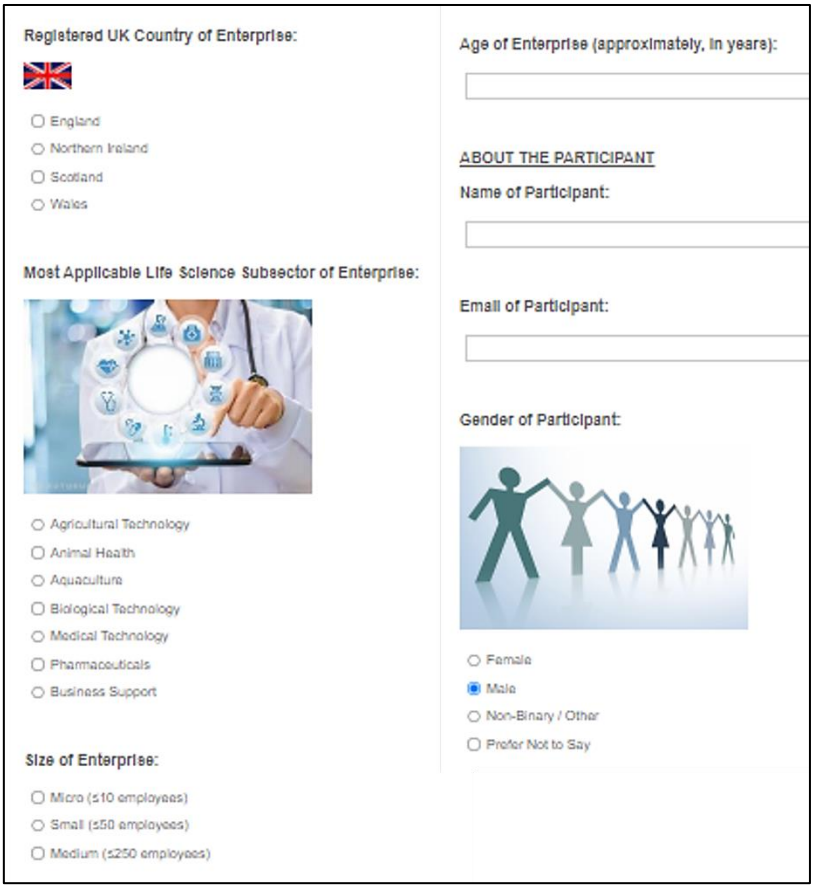
Enterprise	Combined Citations
e1s	During; ideas and IP; Industry; mutual; Legal, technological; Openness of potential licensee companies to open innovation (most big pharma and biotech companies wouldn't touch it with a bargepole - you need to know this it is a more important answer than any of your questions are able to solicit).
e2s	protect IP; money; multiple; regulatory
e3s	Money and IP are key influences - without these to start with innovation is either hard (without money) and pointless (if no IP).
e4s	We continually watch the behaviour of partners/competitors to maintain our resilience; If we need any resources we will find and fund them. Funding internally is not usually an issue; We are an employee owned company and only have internal stakeholders. We are very self reliant; If we want to approach an external resource we will but I would not count these as stakeholders at the current time; We have a robust diversity policy but this will not influence or innovation process.; Our innovation will not be swayed by these factors, though we may collect ideas from any of these sources
e9s	During; People - it is all about links and who you trust to actually do a job; Investors dominate any significant decisions; It is who can do the job. I have founded companies with straight and gay men and women, why should I care? I am not planning to have sex with them! I slightly prefer atheists, as they do not think God will sort it all out.
e12s	Key factor is motivation of the senior management/leadership team to support such innovations.
e13s	OPENNESS; PEOPLE; INDUSTRY; MULTIPLE; WE ARE EMPLOYEE OWNED; LEGAL, ECONOMIC; REGULATORY
e16s	not really sure I understand this question, openness is based on trust
e18s	continual improvement; people; NHS; mutual; technological
e20s	Continual improvement, we take this seriously; Data protection officer, CTO, we own our IP, We're funded by angel investors; Government investment and grants, Working with industry.; mutual, partnership; Parity in gender. We work with gay partners.; NHS (potential customer) is very political. COVID has paralysed many of our customers making decisions on taking on new services. It's difficult to recruit technical staff.
e23s	Time; people centric; diversity of stakeholders; Multiple and networking; Growing diversity; political and social - pandemic has reshaped life science
e26s	Intellectual Property are our assets. Give them away and we have nothing to license, sell, acquire. Stop pushing "open" anything until you understand what it is like to be an innovator in this mercenary environment.

e28s	Documentation, argumentation and fact comparison; Contacts and network; Shared values; Export opportunities and documentation. Currency differences. Language barriers.
e29s	Continual improvement; People; Academia; Mutual
e31s	Improving services and quality; Technology, People; Scientific Community, Industry; Economic
e35s	Our products and services have a mix of stakeholders including academia patients regulators commercial pharmaceutical and medical device companies and to the NHS; We have multiple engagements with various stakeholders and members of multi and cross industry consortia
e38s	Adaptable; People; Industry, Investors; Mutual; Becoming more diverse.; Technological; COVID, Economic sanctions
e40s	continual improvement; people; academia; mutual; Sexual Orientation; technological
e42s	Ideas and IP
e43s	Resilient; people; govt; multiple; diverse
e44s	Employee owned company
e46s	flexibility and proper preparedness; Tech, IP and money; regulatory boundaries; multiple - as many people with different context as possible; legal and regulatory; being close to science / scientists / universities
e47s	Resilient; Open but under [Confidential Disclosure Agreement]; Open-minded
e50s	Vital; Essential; Valuable; Essential; Not important; High negative effect; Too much red tape
e52s	Strong Leadership; All have an influence; Multiple; Not at all; Very few
e54s	Continual Improvement; Technology; Industry; Mutual; Technological
e55s	Find as many ways as possible to get support and feedback that does not involve borrowing money; Intellectual property and experience; Potentially academia and industry. Hopefully society.; Still trying to engage.; Only myself at the moment; Pandemics are tough, but survivable. There are usually ways to get things done.; An uphill struggle - very hard to gain significant backing until IP protection is in place and the product is proven to be profitable. Also at the mercy of others who may take the idea. Openness in business is really questionable until the idea is already fully developed and protected from predators.
e59s	Versatile; technology; Academia; irrelevant; economic
e60s	YES; In the non-profit sector, openness is influenced by common non-financial goals and establishing trust with partners/competitors
e61s	Planning; Technology; Industry; Inbound; All diversity encouraged; Technological
e64s	Possibly Agree; STRATEGY
e66s	collaboration and academic partnership; ideas and technology; Industry, Academia, investors; mutual and multiple; diverse we are completely open; political and economic [with reference to] international collaboration. There was an immediate impact from BREXIT but this is now changing for the better; expectations especially from academia of IP ownership and value-do not value sufficiently the contribution form the commercial partner
e68s	Continual improvement; Technology and people; Patients; multiple; diversity; health needs
e70s	We are ISO13485 so continuous improvement is built into the business; We have intelligence and profits, both important; management, employees, clients; its a two way conversation with all stakeholders; we make a point of having as many people from different backgrounds to

	maximise creativity in the organisations; markets; to have true innovation in an organisation you need a person at the top of the business that understands the capabilities of the business and the markets around the business. So many businesses have un-powered Innovation Managers who can't really implement change
e73s	The culture of continual improvement as the complexity of the customer requirements from us increases
e74s	IP; Industry and academia
e77s	Innovation; Ideas; Industry; Multiple; Wider; Environmental
e80s	Adaptability; Support
e84s	During; technology; industry; none; open; medical regulations
e86s	Good; OK
e89s	We had policies in place that did not factor the economic impact of COVID, but had processes in place to have the entire workforce work remotely; Technology and people, funds seemed to be lacking; The management is one person, having the ability to discuss matters and bounce ideas around may have helped; Economical
e90s	No; Don’t know; Possibly
e98s	Don't understand the question
e99s	Before; People; Outbound; Financial
e100s	IP protects the invention, cant be open until patents applied for
e102s	Continual Improvement; Funds; Industry; Mutual; Economic
e103s	Very important Technology, ideas, Money; Industry, Employees; Mutual; Female majority in management, generous maternity leave, absolutely non-discriminatory re race, religion, sexual orientation; Manily technological and political (key supplier in Russia)
e118s	STRATEGY REVIEWS - seeking continual approval; Positive IDEAS: Negative Money; CUSTOMERS, Patients and Clinicians; MUTUAL; UPSTREAM & DOWNSTREAM; diversity; Technological
e119s	Swift response; Ideas; Society; Open; Wide; Social
e120s	Speed of consumer change; Ideas & market; Industry; Mutual
e140s	Low Debt; Engineering Experience from many types of Industry; Mostly Industry; Currently N/A as 1 owner - White Male; Cronyism is rife within most establishments including Acadamia & Local Goverment
e144s	Intuition and logic; Availability; Mixture; Minimal; Challenging; Institutions not willing to share foreground IP even though they say they do not want to Commercialise

Transcripts

Each qualitative interview transcript is separated into the semantic coded dialogue for C1, C2, and RQ1. Whereas latent coding is used across the whole interview to identify, extract, and analyse the combined influences of the concepts to test RQ2. For consistency with the in-text citations, each abbreviated enterprise is indicated as being from the interview sample (e1i, e2i, e3i, etc.). Due to the anonymous nature of this research, any identifying information has been redacted from the transcripts. The following figure is the abridged screenshot of the interview baseline data collection from the registration form:



Enterprise One (e1i)

UK Country of Operation	England
Life Science Subsector	Aquaculture
Enterprise Size	Medium
Enterprise Age	11
Enterprise Respondent	Male

Prompt: Their UK Life Science Enterprise

The organisation itself is a not-for-profit. It's registered in the UK and in The Netherlands as charities. We have a number of trading companies that allow us to operate in various parts of the rest of the world. And we are a certification and labelling programme, so that means we operate a number of standards that are focused on improving the environmental and social footprint of aquaculture. The program works by both setting standards, that determines the level of performance that producers have to meet globally. And the products from their farms can then enter the market using our logo, which grades market incentives, and consumer interest in in the products. So that it's a sort of a market-led initiative if you like. But the principles of it are embedded in improving both the environmental performance, and the social responsibility of fish farms as a quality standard. It's a private scheme, so it's not a government-sponsored quality-standard. So, it's not like the lion on the egg, if you like, or the British safety logos, but it serves the same purpose. I mean, [marketing] is the underlying intention, definitely. I'm the CEO, and so I've been with the with the [redacted] since inception. I've laid the development, … You know, when we started, we essentially had next to nothing that would count as an operational organisation, including not enough money. So, it was a classic startup scenario. Umm, one that I'd actually undertaken previously, with a similar organisation that focused on the certification of wild capture fisheries, and so I have a background in natural resources, you know, fisheries management in particular. And worked both in the private sector, and for the UK Government in overseas development aid and previously so sort of broad background that was relevant for the work ahead of us basically.

Prompt: Their Organisational Resilience (C1)

Resilience operates at different levels within the organisation. I mean, fundamentally, our financial viability will return us a lot of the resilience of the organisation, and at some levels you could say it's bedded within our reserves policy, that provide financial reserves that can

buffer unexpected events. But resilience is also for us, measured in terms of our human capital, in terms of the people that we employ. Resilience can be measured, both in terms of their own health, but also in terms of their capacity to do the work that we need them to do, so resilience covers a broad range of topics. I think, at its basis, and as a clear metric, then certainly financial stability, and/or the ability to weather unforeseen events, fundamentally allows us to operate within some boundaries of comfort. And I guess its being wrapped up within the general strategic direction that we've defined. We've certainly been able to maintain and grow our financial resilience, in the sense that obviously, in moving from three employees to 120 employees, then the sort of financial resources you need increase, but we've managed to maintain reserves policies that have kept in step with that. So the reserves pot is increased. In terms of human capital, then as we've grown, matured and professionalised, then certainly we've invested more in our people development, if you like. There's not just recruiting people, it's recruiting, retaining and developing those people, as they're on a journey as well, right? But it doesn't mean that each and every employee that you start with will stay with you forever. But nonetheless, you want to do your best to ensure that they leave the organisation for the right reasons. We had some sticky moments in the early parts of the development where our cash position was fairly fragile, so finding financial supporters that were willing to invest in us and move us into a position where our commercial income could sustain us, was really important. A key part of our early struggles was to ensure that we had enough money to pay all the bills, and I suppose the experience I had previously in the networks that I had with potential funders was, of course, pretty helpful. So, having a clear plan of where you want to go and find that money, was important for us. It was the niche that we operated within the market then there was quite a steady demand and growth. Last year was not as good for us, but we still grew the organisation at a rate of 10%, which many businesses would bite your arm off for that rate of growth. So yeah, but that also creates a challenge, and as well in the sense that there's this latent demand with our income that comes in, somewhat after we supplied the goods and services, just because of the way the business operates. Then there's quite a lag between people using their logo, and actually paying us money for the logo, and so there's if you like, there's always this sort of larger demand in the market, than for which we're currently staffed for. So it's always a stretch of our human resource to keep servicing, as we're always playing catch up. It's a vulnerability particularly for human resources. I mean, after we sort of got through the first sort of three years, then from a cash perspective, we were secure. So, cash flow was always fine, but the stress that it puts on your human resources is quite considerable, because you know

this is a mission-led business, in the sense that everybody that works for us, wants to do good things to save the planet, and they're quite keen to just keep on doing work, and taking on more work. So, the issues around prioritization of human resource, their ability to make the right decisions, were aligned with strategy, is something that has been both a key concern, and the key focal point as we've grown, basically. I don't think you could have a plan for each, and every threat that occurs, right? I mean we've invested over that course of time, in periodic reviews of strategy. Looking at where we are, so that we can set a course, defining what we want to do. But we also identify the risks that could be associated with that could stop us doing it. So, there's an element of risk planning and risk mitigation that we undertake, but nobody could really scenario plan for COVID or the Russian invasion of Ukraine, for instance. Would most businesses actually invest the time for such events, with such a low likelihood of occurring really? You can under or overplay it, but at the same time, I think you just need to have the right balance, so that you can plan for what you can foresee, right? But beyond that, you just hope you have an organisation with resilience, to be able to respond. Financial resources are certainly important, right? Because if your sales decrease, because of whatever it is in front of you, then, of course, there's a problem that you didn't, or couldn't foresee. But you have got provision for it to be able to, perhaps weather it. We were really fortunate in COVID because people didn't eat in restaurants then. They were more likely to go and buy seafood from the from the supermarkets and consume it at home. So COVID, for us, was a period of good growth. That was fortuitous though, we didn't foresee it. We maintain a risk register, and that is periodically reviewed, as a statutory requirement for the board that the auditors check against. So the threats that we've identified are recalibrated or rescored and so there is some element of that. The financial resilience is quite a narrow piece of it, in the sense that having some financial reserves, to allow you to weather a poor period, is just good financial planning for any business.

Prompt: Their Open Innovation (C2)

Yeah, I'd say [innovation] is something drives a lot of the work within the organisation, particularly around technology, and the incorporation of technology into our work. It'll feature even more strongly in this next strategic period for us, because we see it as both an opportunity to present us as a leader in what we do, and it also gives us competitive advantage in the marketplace, as well. So I'd say this is absolutely a priority for us in the sense that when the world of certification was evolving early on, it was a reaction of many about the failure to move

policy (national or international) forward at a significant pace to meet the challenges in front of it. Hence this idea of programmes like ours that engaged the market to try and drive and scale the changes that you wanted to see around you. In much of that early thinking, it was thought that certification was the panacea for all problems, and it was painstakingly analogue, and there was lots of rigorous scrutiny. All of these good things, but nonetheless, they're extremely costly. Innovating so that you can both reduce costs, is an important part of that innovation journey for us, but also the adoption of it too, outside and beyond that certification space so that we can actually shape impacts in a different way, not just based on the use of the standards. It's both fundamental to what's happened already for us, and it's something that we want to continue with into the into the future. I don't really understand the difference between open and closed innovation though. I mean, is it proprietary? I think it's both [closed and open] actually. If you look at what we do, then we're fundamentally a service organisation. We provide skills and a range of services to not just producers [redacted, specialism], but also through the supply chain and into retail. Particularly for retail, a lot of those services are desired. It helps them. It means that they have to do less, so it creates efficiency for them, that they outsource to us. You have to be credible, you have to have integrity in all of these things. If you get that right then you are a service provider. Everybody we employ are postgraduates, often with a range of skills that are technical-related to fish, fish farming, environmental impacts, through to marketing skills. And of course, within that we have the ability to produce products that are innovative and useful in their own right. But most of the use of technology has involved external resources. We're not going out and exploring how we can use science to improve the digital traceability, or the determination of provenance of a product through the use of the monitoring of trace elements in in seafood. We use external people with those skills, sometimes in early partnerships, because seafood presents an opportunity to them. We're working with one big multinational … but all the technology lies with them, with the testing for the application. So that means we don't have to invest in either gaining that knowledge, or the capital investments you need to pursue it. For us to work in the marketplace, then we have to engage consumers through marketing, so I think that will be a societal benefit, but let's not forget the benefits of ensuring that the production is actually in line with conventions such as health and safety issues on the production sites, and that supply chains are free of modern-day slavery, or child labour. So I think the social aspects of the work we do are quite significant actually. All stakeholder groups feature in the work that we do, that the balance of them differs depending on which country you're in. Modern Western democracies, the role in the

engagement of governments is relatively modest. But as we move into more developing countries, the role of government is much more pervasive, to be able to work in the ways that you want. There are often collaborations with central ministries, but if you want to engage with small scale producers then you have to work with their local government agencies as well. With academia, we have a supervisory board that gives overall direction, but we also run a technical advisory group that is full of academics, because they lead on many of the issues related to fish health and environmental impacts and antibiotic uses and chemical treatments to improve fish health. The breadth of the scientists and academics that we engage with is pretty significant, and not just the UK, but from the [United States of America], from China and many other parts of the world. We do [openly transfer resources] and some of the collaborations we have are covered formally with non-disclosure agreements or other contractual arrangements where these sorts of things are covered. In other cases, we're often working with like-minded organisations where the arrangements are … less formal, and we had to agree that there's a project that we could do collectively. We might look for investment to support those projects, we might have shared resources across them, too. We work closely where we share resources, and one organisation would lead on particular areas of interest, where we're best suited, but for the collective good of the both of us … We're not big tech innovators ourselves; we don't go off and make things. … We certainly make use of [technology], via the companies that have invested. So, you know often the information from that innovation would flow into us, as part of the process of certification and monitoring. It's all of those things [transfer in, out, mutual], right? I mean, it just depends on the circumstance.

Prompt: Their Relationship (C1*C2)

Well, they're fundamentally linked, aren't they? In the sense that if you think that if you did everything from within, the intellectual and capital expenditures that you need to be able to do would be just astronomical. And making best use of what somebody else has done, and maybe improving it because of what we do and how we use it. It's common sense surely. I think what drives the rest of it, comes back to having a clear vision for the organisation and is aspirational. The mission is what you can achieve, you recognise [that] you can't do everything yourself, right? That has to drive collaboration to create the improvements that you want to see in our sphere. I think all of those things … flow from having a clear understanding of what you want to, and what you would like to achieve aspirationally, understanding what you know that you

can achieve, and then working out how you scale through collaboration to achieve those impacts, basically.

Enterprise Two (e2i)

UK Country of Operation	Scotland
Life Science Subsector	Business Support
Enterprise Size	Micro
Enterprise Age	15
Enterprise Respondent	Female

Prompt: Their UK Life Science Enterprise

I'm a lawyer, my law firm purely acts for scientists. We're about 80% life science and the rest in other [intellectual property] rich sectors. … I teach entrepreneurship and have over the years taught at a number of universities, in particular, [at] the moment I'm teaching at [redacted] university, in biotechnology and entrepreneurship.

Prompt: Their Organisational Resilience (C1)

Resilience, I would say, is the ability, when something goes wrong, to either keep going or to adapt to the new circumstance. Within life science startups, … the biggest problem they have is running out of money, and there's really very limited things that you can do there, you can put projects on ice, but if you're a one-project company, that's a bit of a struggle. Umm, they are normally low on overheads, but anyway, they don't hire staff, they have a lot of consultants and things. They'll apply for grants if the technology doesn't work, or if the market becomes crowded in one area, they tend to be pretty good at pivoting the technology to something else. But money is the crucial thing. It's very difficult to get your way around not having any money. We have the normal policies on, you know, computers going down and that sort of thing. But for actual threats to the business, we don't have policies, but we've had to cope. BREXIT was enormously disruptive to our business. We lost about one third of our business overnight. At that time, I was doing a lot of work for Central European universities. I was setting at Tech Transfer Offices and helping them develop new programs that was paid for by [European Union] grants, and that vanished overnight. So we had to pivot a bit, and see what else I knew how to do … I've worked with high-tech engineering before our medical devices, so I thought that was something I could do … BREXIT also had us in other ways, in that it hit a lot of our clients [businesses] badly, and if they haven't got any money, they can't pay me … COVID is also being problematic in fundraising. So, during COVID, most people managed to keep going in some form. The hit came last year, when they run out of money because they hadn't been

able to raise money during COVID. And also because of problems in the [National Health Service], haven't been able to run clinical trials. So, the big hit was last year, and we took a big hit too because there's no point in invoicing someone who hasn't got any money. So last year was financially extremely difficult. However, things are picking up now, but there's still is an issue with getting clinical trials run. I'm not sure there's an easy answer to that, and BREXIT hasn't helped. I think we're reasonably proactive. We knew that BREXIT was going to be a problem. And so started looking for stuff, new work to do before that. COVID, [I] hadn't really anticipated what a big hit last year would be, and we really were scrabbling around. LinkedIn is your friend. We've picked up a lot of work through LinkedIn, so I did a course on how to do that and got on with it. And it has paid off. I mean, you wouldn't believe how much work you can get from LinkedIn. Well, especially if you can't travel, like during COVID. I mean, you couldn't go to any scientific meetings, you had to do online ones, and then try and follow up somehow. Yeah, and conferences as well. They were all gone, yeah. We are a very small firm. There's only two of us. External factors influence resilience, and people only change if they have to. Most people have gotten an idea which they're really passionate about. In academia, I mean, you'll have seen people become positively manic about their big idea. They can spend 20 years doing it. You've got to really care. With SMEs, people have often given up a steady job to take this forward. They really care passionately about making it work. So they won't change unless external forces, such as the technology not working, or being told that the market doesn't want their product, which happens more often than you would think. It takes an external force to make people change direction, they don't want to do it. I mean, you may get people who are constantly on the lookout for new applications for their technology. Unless people tend to do very well, but again, they're looking at what's happening in the outside world. It's very rare that they internally are saying let's change the direction of the world, and go and do this instead, because it's very difficult to persuade doctors, say, to do something different, so you really want to find a product that allows them to carry on practicing medicine the way they always have, but gets better results. So a new pill, rather than a whole way of managing a patient. So if you have something very radical, it's quite difficult to get the market to accept it because they become used to doing something a particular way, and you're asking a whole industry to change how it works. That's not something that's easy … This is a difficult area to get disruptive technologies into. So disruptive is better to be a new class of drugs rather than a new way of treating people. The doctors are used to giving people pills. That's fine … Market research [is] influential … I'm not sure it links really to open innovation, but certainly links

into resilience. Investor intervention may want you to have better risk management, but most investors idea of risk management is what sort of backup have you got for the computers? It's unlikely that they've jumped much further than that.

Prompt: Their Open Innovation (C2)

We support the innovation of others. We try to be creative in how we do it, but at the end of the day, it's what others do. It's more interesting than what we did. Open innovation is where ideas are shared, usually at a pre-competition level in the hope that everyone can then build on it and then go off and do things. Some people take that further. I did take a part in a university collaboration on this, where we were looking at our 'patents necessary' … Mainly Canadian academics were of the view that open innovation, if everybody's shared their ideas, and didn't patent them, we'd all be better off. Their argument being that there is very little patenting in … aquaculture. That's not actually true. I don't think we had looked into it properly and their argument being … [in] aquaculture, you're looking at an 18-month turnaround now. It's true if you've got something literally be on the market for a short time, a boom and bust … There's actually huge numbers of patients in our aquaculture. My argument is without patents, how can I raise investment? … If we take life science, as many people mean it as simply pharmaceuticals and medical devices, it is impossible to raise money on a project without patents. Now open innovation is interesting. At the university level, and where you get groups of companies together, it used to be terribly popular. We forgot what these things were called, but they were sponsored by the government and you got like a dozen companies together and they sponsor universities to do competitions in basic science, understanding mechanisms and things, and then all the companies would be able to share that and go out and invent bigger and better things, based on this precompetitive style, those have rather died out. I will say there used to be quite popular back in, say, the late 80s, early 90s, there were a whole lot of them. The most recent thing I worked on was one European-funded thing during COVID, which was meant to come up with new drugs for COVID. Most of the discussion was how people could remove things from the collaboration to work on themselves, because big companies are now looking at technologies earlier in the system, they're no longer just screening compounds. If we get a good compound, then we'll go and develop it. They're actually looking at designing compounds, so they want to control the means of discovery, so it's earlier up the stream. And that makes it harder to do pre-competitive science, unless you're looking at areas that nobody's interested in. Now, until COVID, that would have included anti-infectives. Now people have

actually grasped that this is important and are getting involved … Innovation comes from the animal health industry and that is adapted for children. And they're mainly used in the third world, so there's no money in it. And according to one of my colleagues who works for [World Health Organisation] in this area, there are no new anthelmintics under development anywhere in the world. And we're beginning to see resistance in Africa. Umm, this is a huge health problem for children under five. So that's probably where you could get open innovation, and it would actually make a difference because no-one is going to make any money out of it anyway. So, it would be a case of getting people together who wanted to work in a philanthropic way, like The Gates Foundation. Some of the big charities, to make that happen. Yeah, we've worked with all of them. First three [industry, government, academia] are probably the most common. Companies get together to develop something together. They bring their technologies together. Those are the most effective. Government is useful for grants, but the grants are rarely big enough. To do anything late-stage, they tend to be useful for early work. They're very useful for 'blue sky thinking', really. Exciting new thinking where you don't really know if at all work, and that's very important. A lot of that government money has to be spent within academia. In order to get the grant, you and a company often have to work with at least one academic institution to get it. There's also schemes whereby you have to work with a company in another country, but post-BREXIT, the government said it would sign up to the [European Union] science thing, but that's not going through because the [European Union] won't sign it until the Northern Ireland border is sorted. This is a huge, huge problem and the UK's been frozen out of, not just the money, but also the potential to collaborate on a lot of big projects. This is very depressing academia. Yes, that work is ongoing - we're probably doing two contracts every week with collaborations between companies and academia. Society in the sense of patient groups and health charities and things that's done in a much lesser scale. When you do one, it's considered quite exotic. It tends to be for underrepresented diseases, the more popular ones such as cancer, they'll work directly with academia themselves. They might license something to companies later, but on the whole, most of them don't have enough money to make huge differences. When you're working with them as a company, it's usually because you want access to their patients, either for feedback on their conditions … Rather than actually developing anything new, unless it's something at a very low technical level … There's less engagement with patient groups on that. I mean, there's ethical questions apart from everything else, though, that can be an issue. We're looking at the natural environment and that's a regulatory requirement for animal health products, the fourth hurdle. So for example, if you're

putting something into cattle. You know, if I give a child a medicine, I want the child to recover if I give the same medicine to a cow, I also have to think that people are going to drink that milk or eat the cow. So residues from things become important. You also have to think what goes into the cattle, comes out the other end and does that get into water? … There's a whole environmental issue, but that's part of the regulatory process. That's not a 'nice to have', that's a 'you are required to have', if you're dealing with farm animals. I mean, obviously it's less of a problem with, say, a dog because, no-one is eating that, but you still have to think what's coming out the other end. People travel around, they take ideas with them. We are losing out because of BREXIT. Sorry to harp on about that, but you cannot underestimate the damage BREXIT is doing to the British science space. You can't bring in postdocs, generally, because you're not paying them enough to get over the hurdle. And yet by the time the scientist is older, and is making enough money that you can bring them in, they're married. They've got kids, they're less mobile, you know. You got to think the spouses probably got a job now. The fear she wants to mess up their career with coming to the UK to an environment, where they can't settle. They're on short term contracts and where they're made to feel unwelcome. What happens when their children are 18? You cannot ask people to disrupt their lives like that. Whereas if they come as post-docs, the chances are they're single. They'll get married here and it's less of a hassle. So moving people around is a big issue. There's also on the opposite side, there can be a fear of senior people moving around. They'll all have signed up to contracts with non-competes [clauses] when they leave, which lasts for a year, or if they were a big shareholder, two years. But at the same time, you can't stop someone earning a living. How much do they leak when they travel? So that can be as concern. One of the things that we've sometimes done when I've been with bigger companies … And we would write, say, to the head of HR at the company that the person is moving to and say, we're delighted that Doctor X is moving to work with you. Please be aware, here's a copy of his confidentiality terms with us. These are the areas he's been working on. Please do not put him in an embarrassing situation. And then you've put them on notice. Some companies take these things more seriously than others. Japanese companies have a reputation for not respecting confidentiality. Maybe it's an attitude, but it is something that people talk about in the industry. Again, one never knows, because there's no proper data on where the leaks are. So it's gossip. I've never seen a study that says company X leaks more than company Y, but there are suspicions. And there are suspicions about certain companies; European, Israeli, you know, other non-Japanese ones, individual companies that have a reputation for being less careful than others. I think it's very

well understood within academia that if you publish, you can't get a patent. People do seem to have grasped, they may not know a lot of other stuff, but that's one thing that they cling to. So when you have a startup, they usually understand that they may not know much else, but that people had rammed that into them. So that's usually fairly safe. So you tend nowadays not to get the disclosures that you used to. I mean you used to find people were leaking all over the place, but that is less common now … Clearly, you know, with money you can license things. Everyone has their price. The lack of money in the UK for later-stage development means that we're seeing a lot of companies, still too early, so we're not seeing the new Glaxo[SmithKline] … What we're seeing is great technology that's taken to certain level, then it's sold out to [a] foreign company, or the technology is simply licensed-out to someone else, and the UK company closes down. We're also seeing listings that are taking place more on, say, NASDAQ, than in the UK … It's mainly licensing-in from universities into companies. By a long, long way, and then when SMEs get to a certain stage, they license out to bigger companies because they can't afford to go the whole way themselves … The biggest thing [influence] is people read the literature and think "ohh, he's got a good idea, let's go and work with him". So, it's the old fashioned where, I'm afraid, publish articles, publish your tech, don't publish the patentable bit though. And I'm going to conferences and hearing people give papers. It's the old-fashioned way. Like you may get people saying "That's a small market, so can we use this technology in bigger markets, that may lead to more open innovation?" That may be a concern. Human resource structure in very large companies, that can be an issue … [as] people may not have the agency to ask inquiring questions. In an SME, which is mainly where we work, there isn't usually much of a structure. You've only got a small number of people in the company. They're sharing ideas all the time. But it can be a barrier in a big company. Especially if there isn't a very good relationship between management and the workforce. I worked in one company like that. Data protection is not much of an issue really. I mean people have got their knickers in a twist about that, but actually it's not really a problem. Clinical trial data is the only area where I can think that it's been a barrier, is in DNA research. You know, things like ancestry, … where you find out whether your granddad was a neanderthal or something. That can be an issue because you are providing basically your genome to assist them, that may be covered by [General Data Protection Regulation], but it is not managed by doctors, so it's not covered by the privacy around medical records, and this means the police can get access to it, and that Is an area of some concern. But I'm not sure it really goes to open innovation. [I] just don't really see that the people worrying about GDPR, probably don't understand it very well because I

don't think it's really the bogeyman that has been talked about. None of our clients have had a problem. I don't see it and I don't think it particularly encourages innovation either. It's just it exists, you know. Quite [a] curious system where people are seeing it as an issue. It's interesting.

Prompt: Their Relationship (C1*C2)

Resilience is important for open innovation, but in the sense of collaboration, it is critical to all companies in the field, [especially] If we're looking at open innovation as sharing. So, there's two different ways of looking at open innovation. If it's sharing, it's become less and less important for the life sciences. So, it depends how you're defining it. But collaboration, protected by patents, is absolutely crucial. Very few people can manage on their own. And most small companies don't hire people, they don't even try to do it in-house. Their whole business model is on the basis of collaboration, and increasingly we're seeing that large companies are doing less. They're more open to bringing in compounds than they were in the past. They used to say ‘not invented here, can't be worth anything’, now they are much more open to it. And that's been over the last eight or nine years, I would say.

Enterprise Three (e3i)

UK Country of Operation	Scotland
Life Science Subsector	Medical Technology
Enterprise Size	Micro
Enterprise Age	25
Enterprise Respondent	Male

Prompt: Their UK Life Science Enterprise

I'm general manager at small medical device company called [redacted] … We think we're probably one of the longest running startups in the existence ... This will be our 25th year. And predominantly we are an IP house, with multiple patent families, around about 20 patent families, all relating to products which [redacted specialism] … So, we have our own products, uh, just about to relaunch in the market. We've been working with a larger US manufacturer, and the products are due pending FDA [Food and Drugs Administration] approval, to be back in the market … We have a small consultancy to the business, where we support other SMEs, and we've just set up a small ... manufacturing capabilities. So we have targeted the area in the market, which is probably the lumpiest. It's when companies are probably pre-revenue, but they need products built to the standard which it will be, ultimately, in full scale manufacturers … That's not particularly attractive business, to big companies, because it's very lumpy. You can get very small volumes, high demand, low expectation on price, you know all the negatives, but it's an interesting space to be in.

Prompt: Their Organisational Resilience (C1)

I mean the company has been small, medium, tiny, nearly non-existent at several times, and it's 25 years [old]. We've had to trial multiple different businesses, so to summarise here, we are resilient. I think we're adaptive, in that we adjust and realign, as the business needs change. So, we've gone from being a completely virtual manufacturer, to having a subcontract manufacturing model. We've taken on parts of the manufacturing ourselves. We've had the product in the market, off our own back. We set up a US operation, and we had probably 10-15 staff at one point, we raised multiple millions of investment. But [have] failed to take a hold of the market, before the investors decided to pull the plugs, so we scaled right back, looked to where we could continue to bring revenue into the business, and that's when we set up the consultancy side of the business, and then we sought to out-license our product to another

company. So just kept at it. I think we're determined not to fail. We are lucky that we have a relatively patient investor. We have as lower possible cash burn, as we as we can. We're very, very frugal with what small revenue we have. And we're always just looking for other ways to bring revenue into the company to sort of ease the pain at the investment front. I mean, we don't have any [resilience] policies or procedures. I mean our strategy is, ultimately, to add value to the business, by owning as much of the supply chain as possible. And we've made several moves over the past three years to try and line that up. What is probably holding that back is funding. And then we're in an interesting position because we have an investor who sees that his returning investment isn't necessarily improved by the strategy, but not enough for him to be willing to dilute his shareholding in the business. From that perspective, it's quite hard to manage, because we are holding back from trying to develop the business. If we could bring in investment, then we could probably be further down the path, but with an investor who's keen to not lose his equity in the business. The effect of that is that we're getting there. It's just taking longer. If you were to have a blank chequebook, you could definitely accelerate things, and improve the potential outcomes. I think our biggest barrier [to resilience] at the moment is the changing dynamic of regulatory platforms, in that BREXIT hasn't helped, because that's now meant that CE [Conformity with European standards] markings, no longer cover the UK, so we don't have a product recognised in the UK. We have to go through UKCA [UK Conformity Assessed], so we're CE marking before, meant that you had all of Europe, including the UK. So there's a changing regulations in Europe for [the] medical device industry, and [the] FDA [Food and Drug Administration] in the [United States of America] have really, really tightened up the their policies. For a long time, they were seen as the easy route to market, that you could get product through FDA quite, quite easily. Then you would use that to help you get into other parts of the world, and that's just not the case anymore. So what was good five years ago, or even three years ago, is just not fit for purpose in many cases. It's good because it's catching companies that are maybe not as compliant, and as structured, and rigorous, with how they go about things. But it's made it hard for the people that are still trying to do things properly. And everything's got more expensive. And supply chain issues are definitely, definitely real. Simple things like the plastic packaging that our products come in. There's been supply issues at source, of the raw material, and that has meant that you're looking at six to eight monthly times, on something simple like packaging. So that's forcing us to have to buy large inventory of materials, to make sure that we don't run out. So that's just some of the challenges. I think unfortunately we're reactive and agile, at the moment, I would love to

be more proactive and anticipate. I could see the lessons learned through the current process, and we will definitely try, and become more, you know, proactive in preparing for what we see as threats. I mean we put in a whole-set project-management office, a couple of years ago, but then the person that put it in was a student, and left, took with them the enthusiasm for following the process. But a big part of that was lessons learned, and we do. We're not going to have a weekly project review, and we do definitely try. This may be not as formal as been through a lessons learned process, but we're definitely looking to see how we can improve, based on what we've done in the past, for the next time. So each time we run a project, we try and make sure it's a bit better than the last one. Being small does mean that it's quite easy to make changes. You don't have an awful lot of bureaucracy to go through to change a procedure, or a policy, or a way you do things so. No, we're trying keep our enemies as close as possible. So we probably have one or two sort of direct competitors, and we definitely keep fairly close contact with them, so it's friendly fire, and that's healthy to have more than just one company, more than one product, because it generally improves the awareness and uptake of that device. If you're the only one, then it can be a hard battle to convince people that that's the right one, whereas if there are other products in the market, doing the same thing, it validates your technology. I mean, I think for us, what influences resilience is survival. As a small company, everybody having the same feeling, that we're pulling in the same direction, for the future of the company, and then the future of the team, because they're all acutely aware of the journey that business goes on.

Prompt: Their Open Innovation (C2)

[We are] definitely open to partnerships, collaborations, usually through academia. We tend to use funding portals that academics, or universities, try and access, and we sort of join in there, as maybe industrial partners, so [we are] not closed. I suppose I have quite a bit of a narrow line of sight, because we are about one single technology, and it does have applications across multiple platforms, but nonetheless it's still the same concept. We maybe [have] a wee bit of narrow vision, as far as that goes. I think it is just not having any rigorous boundaries. This is what we seem to have fairly stiff boundaries. I think open innovation is really where you're just looking to see what's new, what's exciting, what's next, where the business, where the industry is moving, where treatments [are] moving. I suppose we are trying to adapt … Creating products and devices that can be accessed or used by the patients themselves, it's quite on-trend, at the moment. So certainly, one of one of our products is targeted at that. That's the next

one of our next innovations is to have a device that supports home use. We've looked for opportunities to collaborate and partner with other similar companies who have got products, so that [you] have a synergy. So yeah, we do definitely collaborate with industry. And government, I would say national [government] and the fact that we actively seek government funding, through grants like Innovate UK. Locally, we're an active member of the our local Chamber of Commerce. There's a bio-cluster within [redacted, Scottish city], which we are part of. We have a three-way agreement in place with the University of [redacted] and [National Health Service] [redacted], so we definitely expand our capability by using the network that we have. So it becomes a bit a bigger, feels like a bigger organisation, than the sum of its parts. We are realising that we can't do everything ourselves, so we are looking to provide some of our service offerings, through contracting out to other companies. So again, still being effective with the point of contact, or front of house, but actually subcontracting parts of projects, [so] that otherwise, we would have to turn away the business … Our ideas and knowledge probably were quite closed, and that we feel that we are potentially experts in our own field. Technology would definitely, always looking at other ways of doing things and other technologies. People, we actively have programmes for students. So we've generally always got somebody on the team that isn't part of the team, has come from somewhere else, as student (summer) placements are pretty typical … We've got two PhD students with us just now, who are just finishing up. Sadly, no, not enough [money and finance] from outside. Other than you know, what we generate as part of our consultancy business. We've occasionally been opportunistic, and tried to acquire IP that we thought might fit in our portfolio, not successfully. We do use IP consultants, to try and help guide us with their own IP. We had two patents, granted a couple of years ago. Most of the rest of our patent family is aging. Umm. And we need to just constantly keep recalibrating, and making sure that we're not paying for patents that are just not really any value to the business anymore. I think it's probably equal [transferring]. It seems to be, yeah, as much coming in, as going out probably.

Prompt: Their Relationship (C1*C2)

I think that they [are] definitely directly linked. If you turned back to before, [we] have been able to be adaptive as a business, you need to constantly be looking to see where the business needs to move. You know, where the industry's going, where patient care is going. It's a very cyclical process … There are trends. There are periods where certain treatments have [been] seen as the gold standard, and other ones are very out of favour … It's the early adopters of

technologies, seems to have paved the way for everybody else to follow. And then it's the stronger, the resilient, that survives so. We're probably almost at a point where our technology is becoming outdated slightly, but it's probably the one of the only ways you can treat that type of that type of [medical] procedure, but it feels like an outdated concept … But it's the way it gets done so. … I think that's where the industry is partly refining and improving on. Before it was just "let's put something in that we know works, in that set" and there was no real understanding of what that necessarily meant upstream or downstream of the device, or what the what the actual human factor impacts were on the patient with this device. And I think as time progressed, as [there is a] better understanding of what products and devices and treatments need to do, and what would make them better, and what would be the best version of that device and needs of aspiring to repeat keep trying to improve it. Innovation comes as part of that desire to succeed. We can't be complacent and just sit back, and when only have one product, or feel that the products that we have are good enough anyway, why try and improve them?

Enterprise Four (e4i)

UK Country of Operation	Wales
Life Science Subsector	Medical Technology
Enterprise Size	Micro
Enterprise Age	6
Enterprise Respondent	Male

Prompt: Their UK Life Science Enterprise

OK, [redacted] has been in operation since 2003. We are essentially a leadership and management development program organisation, plus we have, for the past 15 years, been undertaking evaluations of European-funded projects, ESF [European Social Fund] and ERDF [European Regional Development Fund] programmes and projects. And we currently have in the region of six or seven to complete before the final one runs through to August 2023; they've just been given us a six-month extension from March. I'm the Managing Director of [redacted], so I tend to take a lead role in the evaluations, and also, we get involved in developing leadership and development programmes. I co-deliver on those with a colleague.

Prompt: Their Organisational Resilience (C1)

Resilience, as far as I'm concerned, is the ability to adapt and change to suit developing circumstances. Financial resilience means that we have a situation where we did not have income for a period of time, then we would not be putting the company or the business in jeopardy. So, building up a reserve, almost. We've always had a reserve. We've never had overdrafts. So financial resilience, we've always been very strong. Operational resilience is really just having to adapt. The example I can give is that is that BREXIT and COVID gave, in the region of, a year's extension to all the evaluation projects [that] we were doing. Now, it's great for them, [but] we don't get any extra if they extend for year, it just means we get paid a year later. Office overheads continue. Our employment continues. But, at the same time, we've seen it's been good for the project, and we've actively encouraged, and indeed supported some of them through their mid-term evaluations, to go for and gain an extension. We've always got modest overheads. We are very adaptable and situations have always arisen. We've never not been busy. We don't have specific [resilience] policies or strategies. What we have done is always been very adaptable to different circumstances. We've always explored and developed opportunities, as they've arisen. For example, when the all the face-to-face workshops dried up

because of COVID, we were very quick to adapt, to saying “we can deliver online”. I think it during that period I used seven different online platforms for delivery, and again part of the programs we were working on, such as the ‘Superfast Business Wales’ programme. They were adaptable, and coming back, and saying “can you deliver online?”, and the response was “yes, I can. I'll develop new online materials”. It also created whole new opportunities on some of the business support programs in Wales, where organisations were saying “OK, actually, this is good news for us. We don't need to travel to have a meeting with you. We can have a two-hour meeting, we can do it online”. And we're still doing that on one of the programmes. It has not gone back at all, to face-to-face, OK. It's less travel, it's more efficient … I thought that COVID was going to a have a dramatic impact. For the first time in many years, I had an empty diary for a week, but that was partly down to the fact that I was due to go on holiday and that was cancelled. So, I thought I've got an empty diary. I've got so many things I can catch up with, carry on with and I'm busy after that. Everything else went down like a pack of dominoes. Meetings would be cancelled. I had days in North Wales, mid-Wales, West Wales, Cardiff. All cancelled. We had a 10-day program with the university, all cancelled. It all just stopped, and I thought I've got nothing going forward, other than the evaluations, and of course, they were then being delayed and postponed and extended. But within two weeks my diary was full again, with programs coming back, and saying “We can't meet face-to-face, can you operate online?” And on one of the programs, the Welsh government said you need to support any sized organisation, not just growth organisations. And therefore, suddenly they had twice, and sometimes three times, as many clients as they'd had previously, so during lockdown, I was flat out. I think I'd say it's the latter [reactive, agile approach], because if we were to try and predict everything that might happen and come up with all sorts of events and strategies for a small organisation, [its] very time consuming. So what we do is we say, “OK, if we're facing a threat, what tactics are we going to take? What actions are we going to take to address that?” And because we have a lot of financial security, if I had not had income for six months, it would just be a nuisance, it would not have killed the business. So [we’re] quite resilient and that's good, yeah. So we are very resilient and I would say we are reactive rather than proactive. And that's very common, actually. What we found so far is that, uh, yeah, it's more reactive. I don't know if we've had any threats that would have created any sort of issue or problem … This week we heard that a project that was due to end in March, has now been extended for six months. It's like, OK. And that's not a problem, but my time in the business will be filled. We will do other things. We tend to turn up the heat on our marketing, if we feel that we are getting

to a stage where we're going to be short of work. And we're prepared for it and ready for it. Truthfully, it's not happening for a long time. Lately we have been very selective with the tenders we've bid for. And of the last four we did for; we have been successful with all four. Umm, so we're not looking for any more business between now and September. Yeah, it is a great situation to be in. I mean, it's partly caused by BREXIT, ERDF and ESF funding ending, and all the evaluations needing to be completed by a specific date. And we've scheduled for those … One of the things we've always been good at is planning. [Resilience] is adaptability and … flexibility to change quickly, and I know there's a there's a word, adaptability and there's not so much flexibility. Adaptability and agility. Those are the two in terms of in ensuring resilience, if they're adaptable and they're agile, they can change direction very quickly. If you have an investor coming into your organisation, they should be able to contribute more than money. They should know something about your business, and in truth, is one of the reasons they want to, should be that they're able to contribute something to help. And that would increase their knowledge and expertise, that would increase resilience. Yeah, I think [market research] provides additional knowledge, if the market research provides, you know, valuable information that can increase resilience because it can change its strategy. I know [the Russia-Ukraine War] has impacted certain organisations we've spoken to in the life sciences sector through having supply from Eastern Europe that has been more challenging … I think one of the things, probably, that has impacted on resilience more is BREXIT. If BREXIT hadn't happened, the Ukraine-Russian War would have been far, far more significant. But because of those channels of supply from Europe were already challenged and strained, I think it's had less impact than it would have had had we still been in the [European Union].

Prompt: Their Open Innovation (C2)

I would describe open innovation as a sharing process with mutual benefit. And in reality, we don't see a lot of it. What we've tended to find is that if organisations have things that they consider to be unique, that has intellectual property, they're very protective of it. They don't see that it's anything they would share, until such a time it was well protected. In the academic environment, we have seen the desire to protect intellectual property, but not the desire to commercialise it. They're very good at saying “we must put a patent on this”, and there's not enough people at a high level saying “why?”. If an eminent professor says “this is going to be patented, it's totally unique. It's completely new. We have got to put a patent on it worldwide”. The response tends to be “yes, of course”. Whereas the response ought to be “Why? What are

we going to do with it? Are we going to License it? Are you going to develop it? How are we going to sell it?" Because I did a project in number of years ago on innovation and intellectual property in academic institutions, and what we saw was that they described their Intellectual property portfolio as an asset. Now the definition of asset is something that has a value. The definition of a liability is something that costs you something. And their intellectual property portfolio was costing in the region of £100,000 a year, just to keep. And I said "I can save you £100,000 a year, give it all away". [They replied] "We can't do that. It's an asset". It's like, "No". So, we agreed, it is a potential asset, but it is a current liability. Because they are not geared up to commercialising the intellectual property, that they've developed. They're very good at creating it. But once they've created it, they'll sit on it, and move on to the next thing. And that's their skill. But what needs to be behind them is somebody who's saying "Right, we've got to decide, do we license it? Do we develop it? Do we sell it? But there's no point in us sitting on it. We sitting at a cost us money and eventually somebody will come up with an alternative." Not so much [industry stakeholder] clients, but I've worked in close collaboration with … a life sciences company that is going through very rapid change. So, what we do is provide the external guidance of how to manage change, how to address crucial conversations, how they, certainly from their point of view, need to understand situational leadership. So, we address a lot of, what might be called, 'traditional' but some of the leading-edge techniques and processes we did a workshop day with them on recruitment and selection. And other days have been focused on retention, because one of their biggest issues is people moving. People using them as a stepping stone for two years and moving on to the next job. And we've seen a big difference in the different generations. The 'generation Z' (the selfie generation, if I'm allowed to call them that) do not expect to be working in an organisation where it's not aligned to their values. I'm turned on by technology and you know I'm looking for a new opportunity on an ongoing basis. So, businesses need to be adaptable to recognizing the differences between the generations. What motivates them? And what they can use in order to retain them? It's a quite an analytical HR, kind of. But in terms of open innovation, we've not really liaised or worked with government. We've tried to develop or deliver some of the training programs that we have into both local authority and local government. But there's a significant difference between the businesses that we engage with, and local authority and local government. And that is if they undertake a training course, what they want to say is "what's the impact going to be in terms of qualifications? What's the measurable?" So, we don't bother training, or doing any training in local authorities or local government, because all they want to measure is: How

many people got an ILM [Institute of Leadership and Management] level five. How many people got an MBA? How many people did that? Whereas the life science organisations that we're dealing with, tend to say “we want people to develop their skills”. Most of them got a degree already, and half of them have got PHDs. You know, doing a formal qualification puts a constraint on the content of what you can deliver. So, we don't bother to target any organisations, even via tender, that are a local authority. [If they ask:] “Please advise what qualifications going to come out of the training?” We just simply don't bother to tender for it. What we've tended to do is to find our business comes from referrals and recommendations … The other element about delivery is that, it's not what you do, it's where you do it, that dictates what you can charge. … I would not survive on South Wales rates in Oxford, and if I was to go to Oxford or London and quote a South Wales rate, I know what the response would be “Ohh, it can't be very good, not if that's all he's charging.” From my own point of view, we share ideas … We've not shared technology, but we shared materials. You know, we've developed various Excel spreadsheets for people doing financial projections, and I basically give them away. And I said people, if you want it, you can have it. Yeah, I use it anyway you want. You know what? It's not worth trying to get people to pay for them, as you go online. It's like we developed a business plan template … We give it away with guidance notes, and say to people who want it, you can have it. So, we not only share ideas, but we share materials. But I've not seen any sharing of people. Well, I work with associates on a regular basis, and I bring associates in. I've got one at the moment doing a project for me in North Wales in Welsh, because I don't speak Welsh, so it's not something I could do, but it was an opportunity was offered to me, and I said to them, “Are you interested?” So, certainly, we would share that on what we would call an associate basis. I've got a number of organisations who are looking at bringing in money through [the Enterprise Investment Scheme] and [the Seed Enterprise Investment Scheme], because there are early-stage and they've said yes, we would like to bring some funding in. So, I've seen a number of people asking for that, and I've advised and guided, and I send notes out on how you might go through this process. Yeah, I we don't see a lot of sharing of intellectual property because people are very wary about its potential value. And what they need to do is to come up with a clear strategy of when they share intellectual property. They say “we are sharing it under license. We are sharing it because we're selling it to you or we're sharing it because we are going to do a joint collaboration”. And the challenge for academia is that intellectual property is a massively complex element to commercialize. You know, there are programs that the universities are trying to do just that, but it's very challenging

because they're not geared up to it. Just the legalities of it so complex. Massively complex and fraught with all sorts of problems, because academia has been looked at as being a good type of organisation you can go to, and they'll do work for you, and not charge you. And there are programs that have been funded in order to help organisations. And then the organisation says “oh, no, no, the intellectual property is ours”. And then of course, you get a falling out because it was not clear from the outset, where the intellectual property resides. The mutual [transfer] element is the one that I would put down third [least, below transfer in or out] because it involves resource from both sides. It involves a lot of planning. It involves a lot of development. It's almost that they would say “we would like to license something in, if it's gonna be of immediate benefit for us. But we need to be absolutely clear what are we paying for. What are we getting. And if we're licensing out the people”. [I’m] always very wary, because they have to share a certain amount of information before the organisation will commit to buying. So, each is fraught with challenges, but I'd say probably from an organisational point of view, “we'll buy in that technology”, and what we've seen is more-so than them buying the technology, they buy the company. We've seen two happening, within the clients that we've got within [redacted]. They've both been bought by much larger corporations, on the basis of, they want everything they have. And if they buy the whole organisation, they are buying everything they have. And we're going through that similarly ourselves with one of the organisations that I have ... We have had an offer for the whole company, and we are in the final stages of saying “yeah, we'll put everything together, and tell you everything you're going to have”. It's a success, in that it never took off in the way that we hoped it would, but that's because we were constrained by using [National Health Service] staff, who were not available during lockdown. So we said “You know what? It's better if we sell the whole lot. And we'll get back every we'll get back our investment. We will make a lot on it, but we'll get our investment back in total and it will continue under somebody else's ownership guidance”. So we see as much as anything else, not intellectual property being sold, but entire companies. Investor intervention potentially would also increase open innovation because they might open people's eyes to, say "listen through my network, I think it would be valuable to engage with this organisation as well". In terms of open innovation, market research can bring forward concepts or opportunities that the organisation might not have been aware of. [An influence of open innovation] is organisations feeling that, either they are stalling, or they are facing a very uncertain future to vulnerability. Almost, yeah, it's vulnerability and uncertainty are going to be the main drivers, from organisations saying “we need to collaborate on an innovative basis

because if we're secure, what's our motivation? Why would we want to share with somebody else?". Now there's always this concept of synergy, where you know you've got organisations and they say "Oh yes, but we'd be better together". Yes, that's possibly true, but it takes a lot of time, effort, and energy, and one of the biggest challenges is people saying "Well, we just don't have the time to explore that right now. Everything's going really well for us. Why are we looking at something that we possibly might not do?" So I think open innovation is going to be led by organisations that are vulnerable, or have an idea and not the funds to take it forward, and say "we need we need collaborative partners as an enabler."

Prompt: Their Relationship (C1*C2)

I think if an organisation has got very high resilience, there is lesser open innovation. I think if they [have] got lesser resilience, it's one of the channels, in terms of innovation, that they need to explore in order to secure their future. If they are doing what they're doing without the need for external organisations, external collaborations, the question in many instances is, "well, why are we doing that? Why are we bringing someone else in, when we don't need to? We've got a lot of resilience. Everything's going well. Why [are] we bringing somebody in?" It's tended to be, and this is why organisations get purchased, because if they're doing well, they don't look for collaboration with external partners. They're saying "What do we need? We don't need that, thank you very much … You know, everything is going along really well". When they find things challenging, they would look to open innovation, but an organisation is wanting to get the Intellectual Property, and the organisation, in many instances. If they can't get it by collaboration, they'll get it by acquisition, as it causes a perfectly legitimate strategy.

Enterprise Five (e5i)

UK Country of Operation	Wales
Life Science Subsector	Biological Technology
Enterprise Size	Micro
Enterprise Age	6
Enterprise Respondent	Male

Prompt: Their UK Life Science Enterprise

Biotech healthcare innovation company. We've done everything from COVID vaccine work. We were, in all honesty, ahead of the curve by about four years. Yeah, I honestly thought when COVID hit, that I'd be a billionaire. It was like, this is fantastic. We had a platform that a virologist said it was comparable to Pfizer and Moderna's platform. So, we were like, this is going to be awesome. Then every university we were working with, because they didn't own any IP, or thought they were going to invent the wheel with vaccines, and they were all going to be billionaires, and they did their own thing. And as we've seen, 99% of the university products that came out were sh*t, even the Oxford one. Yeah, no longer got called Oxford Pfizer, it just got called Pfizer, because it was such a sh*tshow that Oxford were like, we don't want to be associated with it. So, I don't think a single university in the UK pumped out anything of note or worth, which was annoying … We've got quite a few different things on the boil. We're talking with [redacted] at the moment, a US-Swiss company. Umm, so I probably ranked them as a billion-dollar company. So, we're talking to them about [redacted] that we've been developing. We're developing a new [redacted]. While there's a lot of companies that say they do biomimicry, there is nothing successful out there. The product we're now getting to, sort of, what we call 'xvivo' (which is dead animal trials), so they basically take a joint, stimulate the joint to see how it grows. Then that's for us, the precursor to going into an animal trial, but our data is showing that we replicate bone, we replicate cartilage, and if it works as we expect, it will be probably the world's first true biomimicry [redacted]. So, if that all goes to plan, hopefully [redacted] picks it up, and then that goes into $100 million market. And yeah, it starts making money. We recently got funded by [Defence and Security Accelerator] and DSTL [Defence Science and Technology Laboratory]. So, the MOD [Ministry of Defence] and Home Office … It's in the [Defence and Security Accelerator] press, we haven't gone public yet, because we're putting patent work on, which we've gotten support from [redacted], which has been nice. So it's basically [a] device to [redacted]. [It] is pretty

much a bit of a game changer. We're also looking at a transition of that into [redacted], so we're preparing dossiers to go out to the [United States of America] government, and the Swedish Government, as part of our push, because Sweden has the highest incidence of [redacted]. You think it'll be the [United States of America], but [its] Sweden. So that's kind of where we're at. We're also still playing around with the virus platform. We still think there's a need for it in agriculture, and that's what that was actually designed for, which was basically looking at high-density agriculture markets. And to be honest with you, I expected something like COVID to hit in about 2030-2035. So when it came early, it was a bit disappointing, we didn't have all the data together. We did get some funding for it. We did some early animal trials, which is what got the virologist basically to the position of saying "you've got a really phenomenal platform. Just it's a shame that it wasn't ready earlier" … This is why you need to be looking at this and it's one of the reasons we're talking with companies … because if it works, they've already got an infrastructure, they've got an [research and development] team, they can help commercialize products, they've got access to multiple HMOs [Health Maintenance Organisation] in the [United States of America], and so that's where we see it being a value of opportunity cost. … So yeah, so that's kind of how I operate with products, that's what's the cost of something. How do I reduce that cost and or what is the market value that I can take and what's the opportunity costs that. Yeah, I can then take away. So we're not looking at the opportunity cost of our product, we're looking at the opportunity cost as with regards to savings. So it's very much a different approach … It's like I can change anything to anything. Whatever. Whatever I had that doesn't work that you needed to do something. Then I'll change it.

Prompt: Their Organisational Resilience (C1)

If I'm brutally honest, my policy is not to have any policies in my business. So, a lot of people develop a business plan, and they stick to it. And even when everything is going to sh*t, they will literally try and stick to that business plan. I will create a business plan around a product, but it's not around the company … We've already gone through that stage of asking the government, what do you need. You've come up with a device we know solves their problem. And now that becomes a product that we know has need, has demand … And yeah, we started that stage asking what they wanted and then changing and tweaking what we were doing. And so to me, the resilience of the business is the flexibility … One of the [redacted] basically said to his Board, that we've been doing this research, and their product doesn't work as they expected. He said "I guarantee you, by the end of the week, [redacted] will have pivoted, and

he'll have a whole line of products built on this problem". This thing that you think is a problem, he would now turn into a solution for something, and he said that's the difference … I was doing consulting work, and they got rid of me, and he said that's why we need someone like him within the company. You can see something that's a problem, and go "Well, it's only a problem when you're trying to do this with it. But if you're trying to do that, it's great". It's like the analogy that, yeah, when you're a hammer, every problem is a nail. And yeah, and that's what I want businesses to do, they've got a hammer and every single solution they're trying to fix is a nail. Whereas I'm very much the opposite, it's like I'm a claw hammer on the multi tool … But it's things are only a problem if you look at everything as having one solution. And one application. For me, the barriers to resilience is the funding cycle, that is literally the only barrier to resilience for me. There are so many things that I've got, that if I had a million pound sitting in the bank account, I'd have three or four products to market. But at the moment, because we live on grants, and because COVID was a bit of a hit as well for us, as it was for everyone. It effectively took everything we're doing, and cut two years out of the middle of it, and throw that two years away, because [of] the sector we were in, we had issues getting materials for research because we're doing vaccine work, vaccine supplies were just unavailable for most places including universities. Umm, if you were commercial, you had it. If you weren't commercial, as in, you weren't delivering a vaccine that was needed for the market, you were kind of bottom of the list. So for me, you know, COVID took a massive chunk out, and that was a level-off for everyone. I mean, businesses that were poorly managed dropped by the wayside. Yeah, a lot of businesses, small businesses went out of business. And it was just because of they weren't resilient, they couldn't manage, they couldn't adapt. Yeah. And for me it's always partnering, you know, I'd rather have 20, 30, 40% of our products, and partner with someone who can take it to market, then have 100% of that product, than have nothing to show for it. For me, with [redacted], I work on it being very segmented, and maybe even segregated … They are targeted to different companies, and different applications, with the sole aim of me saying, "If you're interested in this, you can have market distribution. You can have X, I'll take 20-30%. We'll manufacture our component. You manufacture your component. I don't care who takes it to market". Yeah, but the smart choice is obviously the big company with the name brand, and so that's how I think, for me as a company, that's how I think I deal with the lack of cash, yeah, that we need, but it gives me the resilience to be incredibly flexible … Whereas with me, my investor … in one board meeting, said your ability to, on the fly, rebuild your business plan, and then present it to people, like it's something you've

had there for six months, is amazing, because everyone else that I work with, they would literally have to go back to the drawing board, rework everything. But you have everything compartmentalized in your head. You pull out what's needed, you make it seem like it's a seamless transition, of “we know we expected this to happen and this is the business plan, we've got now to go forward”. And yeah, and that's one of the reasons he said: “Yeah, I always invest in your companies because you don't stop, you'll keep going and all it takes is one thing to go right and we're all very rich, and it's like that's the plan”. That's why I do this. So, yeah, so I mean, yeah, resilience.

Prompt: Their Open Innovation (C2)

Their [redacted] is very, very closed, and I'm assuming when you say closed or open you mean as in public information and public sharing? So our research is very, very closed, very closed loop. It is with select partners within, say, universities. We do student projects, but there's a ton of NDAs put to them … its very segregated, things are broken up into little packages, umm, and we identify universities and academics who can not only do the job, or assist with the research, but have access to students to do that … So while we do a ton of innovation, … and it is open, as in everything is explored, if we come up with something that doesn't work for something, we look at how the differences have commercial applications with regards to commercial sharing. The best example is it's very much like the agriculture market. So I used to be in agriculture, so 100 companies in the UK will have all experimented with the same thing … They don't share their information. Everyone does everything by themselves. They all lose money on it trying. Yeah, they all learn the same problems every time, because each one thinks that what they're going to have, is going to be the next big thing. For me, it's more about protecting the IP because if I submit a patent, for example, that I might be able to do that myself and do it for £1500. By then have a very tight time window of 12 months if I don't go public. Or, if I do go public, I've got 31 months to basically do my PCT [Patent Cooperation Treaty]. And a lot of companies pre-COVID, for example, will have done their 12-month block, gone public to raise money, six months later, COVID hit all of their investment monies, dried up. Their patents either, only continued in the UK, because it's £80,000 to do it in Europe. Umm. And then any IP protection they've had is gone. So it depends on the definition of open innovation. If you mean open innovation within the company, we're incredibly open. Every idea has is potentially a solution to someone else's problem. That's how I approach everything with regards to external innovation, collaboration and that we're very tight. It's NDAs, Non-

Disclosures, yeah, student projects where they sign through bits of paperwork. We own all the IP going into the university, and that's how we work. We get public interest in things that we're doing, so when we were doing the early stage of vaccines, where we got funding from an ERDF [European Regional Development Fund] project, because we use an invasive species. So there was a lot of societal local groups like PLANED [Pembrokeshire Local Action Network for Enterprise and Development], and stuff like that in Wales, who were very supportive. Helped us get funding and stuff like that, because they saw that as something that would bring back, or had the potential to bring back, cultural significance … But then, you know, when we get support from that, we would have people, on the flip-side, who would use their societal group … who saw us taking money, that [they] thought [they] could get, so [they] very much became an advocate against us. And basically, delayed one of our projects by six months, by basically lying … I basically went in there, and said there's no other way to say this, but he has lied his ass off to you guys. That's why I ended up putting in like a 150-page report to these guys, literally outlining everything that he had claimed, that was wrong, everything you did that was false, and so sometimes society is good. If someone has an agenda, and is empire building, then it's bad, because it becomes a burden. And for us it wasn't a financial burden. It was more a time burden. It wasted six months of our project … So with regards to [technology] equipment, we use everyone else's, we very rarely have the time, or the expertise, or the budget to effectively build our own [technology] … We look at what's out there, and we look at how we can utilise it to deliver what we want. So we take certain things that are used in other industries, for example, and we bring them into ours, because it actually addresses a problem that other people have solved one way, and we know we look at and go actually, we can solve it with this way. And it makes our product 1000-times cheaper, for example … So it's how technology is used. Yeah, ideas and stuff. We generally don't take. Well, no, I don't take other peoples' ideas. Knowledge on the other hand, I will, which is why we do university collaborations. Because for us to hire someone in, to cover a certain skill set could be £60,000 a year. It may cost us £5-6k to do a project with the university for a couple of months, with a couple of students, that cost waiting average metric is, well, we get better equipment in university, we get better expertise from the academic. Yeah, we've got two publications coming out in the next two to three months … For us, that's great. It's a good bit of [public relations]. We then leverage that published paper as effectively, intellectual property, going to the companies that will give us money … The publications are what the universities want, that's the metric that academics need to do, which is why they will often, unfortunately, take someone else's idea because they see

that as being a great funding avenue. And maybe three or four years down the track, before you realise they've done it, because of the way funding and academia works, and that then leads us back to why we are not very open with our innovation stuff … And you know, for me, it's just, you're picking ways to get to where you want to get to, in the business, and you know, we've got a PhD studentship … Managed to negotiate zero cost to the company. But it delivers a ton of data on yeah, on a product that we, yeah, that we're looking to do and the technology we're looking to develop.

Prompt: Their Relationship (C1*C2)

If you look at anything out there, companies that don't innovate die … So resilience comes from innovation. And innovation comes from being resilient as a business. If you're, if you're very much stuck in your ways, as I said, you've got a business plan, you stick to that. You might have some small allowances you give in that, but that's what your business is and that's what you stick to. Any business that does that, will fail. Guaranteed. There isn't a single business out there, that if their business model is this and they stick to it wholeheartedly, that they're successful in the long term. If you don't innovate, if you don't change, if you can't identify where the market's going, you as a business, you will fail. I mean, even universities were stuck in their ways for so long, and how they do things. Then the minute there's some funding cuts, then the minute, you know, we get hit by COVID, universities implode … because they couldn't adapt. There was, yeah, it took so long for them to go "How do we protect the students?" And then when something didn't work, they shut the whole university down again, and go back to the drawing board … The universities just all got hammered. There wasn't that resilience of innovation, of how do we address this? Because most academics are really innovative … I get into lovely arguments with academics, and they go "Ohh, I'm highly innovative". It's like, "No, you had this one idea for 15 years. You've just basically turned it different directions. You haven't created anything new. You literally had this idea from when you were a PhD student, that you thought was going to make you a billionaire and you're stuck with it, to the point where no one is funding you". Umm yeah, academics don't like to be told that they are not the smartest people in the room, but unfortunately reality, sometimes they are … So for me they are so closely interlinked, of basically innovation and … so everything changes. Things transition. And if you don't transition and change with them, yeah … It's the same thing with anything, whether the big biotech, you know, biomedical companies. Yeah, they're all they all acquire companies. They all acquire other groups, because if they don't, they don't have a change of

product. Yeah, and the prime example of where a lack of innovation that has caused resilience issue is antibiotics … So resilience needs innovation and you know whether it's mankind, humankind, or a company, you know, yeah. COVID is a prime example, as well, of resilience and innovation. If we didn't rapidly deploy vaccines, you would have been talking hundreds of millions of deaths … People will give you this, kind of, staged approach for their company. "Oh, we have this business plan, and we do this, and we have this management plan for adversity, and we use PRINCE2 for our business development and this, that and the other. We've got this ISO standard and we followed these to allow", and it's like, yeah, everyone has a plan till they get punched in the face, and for business, you know, COVID, you're funding doesn't come through, your product doesn't work as expected, and each one of those, what's your approach? Well if you're approach is [to] go back to your business plan, sit down, manage the problem, well, you you're three to six months down the track.

Enterprise Six (e6i)

UK Country of Operation	Scotland
Life Science Subsector	Biological Technology
Enterprise Size	Medium
Enterprise Age	34
Enterprise Respondent	Male

Prompt: Their UK Life Science Enterprise

My enterprise is into biotech research and we do produce components which are used in the research field. Those components can be used on the higher grades for commercial purposes. Also let's say in manufacturing diagnostics, therapeutic that sort of level, but the basic thing which starts is a research product, which can be used in universities or research organisations. My role within the company, I oversee a large territory. So now I'm covering complete UK and Ireland because one of my colleagues left, so I'm in a place where I have to look after the additional territory also. So earlier it was just a half of the territory, now it is complete territory which I'm managing.

Prompt: Their Organisational Resilience (C1)

The resilience which we see is to have a good balance sheet. That's what I would term it because you shouldn't end up in a place where you are in a loss, and you can't sustain in that environment. So you have to make sure you have a positive growth so that you can employ more people. You can bring in more resources into it. But if it goes in negative, it can't be sustained and that will not be a resilience for me. We do have definite strategies in place to make sure we are tidying up the current scenarios. So if, all of a sudden, we have an unexpected scenario in the global market, we are able to observe that particular issue, which came in because we had a resilient policy in place. If not, we would not be in a place to sustain that kind of impact, but as the threat comes in, we do take remedial actions and that is where our new pricing policy and other things have come in this year, when we saw the threat [unidentified] coming in last year, so because of that we have adapted to the conditions. We had issues related to BREXIT. This was something which we didn't anticipate, let's say in one way or another, because our customers were too much afraid, because we are going out with BREXIT, there will be customs and all those things, the products will not reach on time. That sort of issues were there, but that particular period of turmoil, we have managed through, and

now that customers who had issues are happy with us, that is a good sign for us. I think BREXIT was an unexpected one, so it was more of a reactive thing, which we did, because we didn't anticipate that particular part to be coming into other people, let's say, not our enterprise, but for customers, we didn't expect them to have that kind of concern. So it was more of an agile approach which we took, but the war and other scenarios, the global pricing and other scenarios, we have taken a proactive approach. When we saw this coming in, that time itself, we have done the things, and COVID also taught us that we have to do a bit more of a proactive approach. So now we have moved to that particular line. I would say yes, there is a lesson-learned [philosophy] particularly during BREXIT, because that was something which we didn't think [about] and it came out of the normal. So we did learn from that particular practice, and now with our proactive approach, it is always a part to think about different scenarios, before we put it in place. Market research influences resilience, not open innovation. Both of them are interrelated, but let's put it in this way, market research, we do due diligence to find out if there is a particular threat, or if there are issues in the market which we have to be proactively conscious about ... That particular thing would be affected by market research, and if it is a threat, then we can't do open innovation. So that way market research is important, yes.

Prompt: Their Open Innovation (C2)

We have different components within our [innovation] division, or within our group itself, so it is a mixed thing there as well, so there are certain technologies which we have developed, and we have to make sure it is a closed technology. So when you see into large scale production, it is a niche technology which we have developed, and so we can't reveal it outside. So that is why the issue of hacking and other things comes into place, because it's a niche technology, people are trying to get hold of it. We can't disclose it out in the open, but other divisions, which are not that much of an issue, we are open to collaboration … with our competitors itself. So that itself, shows our idea of things. COVID has taught us a lot of things and that is one place where we have been more collaborative after the COVID thing. Industry we have collaborated, yes, government we have collaborated, and that is during the COVID period, and now so, if there is a requirement where we have to collaborate, we are doing it and not just government. If it is a bigger body than the government, like [a] consortium of governments trying to find a solution to a cost, we are there, we are helping them. [As for] society, medical conditions and all this is a bit out of my range, so I can't comment on that point on the society part, but we do, we do definitely try to help the society. No. And [natural] environment, yes,

we have a lot of things involved with plants and animals, so we work on those particular lines as well. We do work in collaboration with universities. The thing is that the discounts which we offered to the universities, as we do know there is an issue with funding, and that is why we are giving that kind of discounts, which we normally don't practice. Ideas and knowledge, we do help in open innovations which we work on with, so it might be our normal stakeholders, it might be collaborators, it might be competitors. We are open to ideas and knowledge sharing as long as it doesn't infringe our particular IP rights, so that we are able to do technology … We do train in people, we do try to help out different sections to make sure we have a better world. So we do collaborate in that particular manner. For money and finances, this is charity work and other things which we do, but I don't think it is the right thing in this particular conversation, so I'll skip that part. We have put a certain IP out in the market, particularly during the COVID period, which we had restricted for the general public, but because it was a larger cause, we have put the IP out. I think it is right now more mutual [transfer]. Internal [factors] does influence these kind of open innovation because if you are not open to innovation, if you're internally not ready to do that, you will never do that kind of innovation because internally there are stakeholders, the senior management who has to take decisions and if they are not ready to do that, it will not happen. There is a limitation to the mid or lower-level management people who can push these particular things or ideas into place, but it is a senior people who have to do so. It is always internal, I would say … That is the main thing when it comes to open innovation, ideas can come in from lower to top management. So it's a reverse idea which goes in, and if it is a really good idea, and if everyone is in line with that particular idea, there is nothing stopping that innovation from happening. [Data protection] does affect it because unless someone gives, let's say now myself, if I don't give my consent, you can't use it. The products or the information out there, so open innovation is always affected by the GDPR regulation which has come into place. So, we do have investors, so they are more open, and that is why we are also open. So, they don't have any particular issues, let's say, on being more [openly] innovative, and because of that we are able to do [it]. But there are closed investors who comes in, and they want complete control over all things, [so] then we have to become a closed innovator.

Prompt: Their Relationship (C1*C2)

[Organisational resilience and open innovation] does associate, very well. If you don't have scope, or resilience, you can't go and do open innovations. Even if you do close innovations,

you need to have that particular resource. So when you see an organisational point of view, it is always resilience which comes in first, and then only we can be able to do these kind of [open] innovations.

Enterprise Seven (e7i)

UK Country of Operation	England
Life Science Subsector	Medical Technology
Enterprise Size	Small
Enterprise Age	4
Enterprise Respondent	Male

Prompt: Their UK Life Science Enterprise

The company I work for is in medical technology start-up / spin out, and as mentioned, it deals with medical technology, and that encompasses our device. So it's a medical device, but also a type of software platform which we promote as a [Artificial Intelligence], which is a hot, hot topic, obviously, at the moment, and has been for a few years. My function is Commercial Director, but because we're not actually commercial at this point, the best way to describe what I do is more the business development and commercial strategy.

Prompt: Their Organisational Resilience (C1)

Those would be what I've been doing actually and that's the first time in my career because this is the first role I've been in where the company hasn't been commercially ready. So yeah, and I think I can give them a bit of insight into … the resilience of a company, as well, especially when they're when they're starting up. … So like I said, it's not commercial. The company, there was a bit of naivety, and this isn't so much a criticism, it's just the fact, it's quite common and we're startups, there was a bit of naivety, through the founders, and the brokers, and potentially, the investment managers, as to how quickly they'd be commercial. It was a very, like I said, naive expectation, they also had to pivot because the product they thought they were going to lead with, wasn't the right product. And I can come on to that, and happily talk about that. So what I ended up doing, instead of, I think, in the dreamland which was within quarter of a year, we start selling things, and become a unicorn. Essentially, what I ended up doing instead was building a foundation, so that we've got lots of future customers, distribution partners, collaborators in the healthcare industry, key opinion leaders that we've built. I've built relationships with many across Europe, particularly in the UK, for obvious reasons, that's where I'm based. So what we've got is a collaboration agreements with them, innovation hubs, funding. We go through the funding applications. So I then strategize on how we're going to sell, and also which is one of my favourite parts, about the shortfall. Silver lining [is] having a

product that was commercially ready, is that we get to actually influence what that product looks like. So a lot of what I've been doing is, especially this year so far, has been gathering feedback on a prototype and saying “This is what we're doing. This is the end goal, so please don't think this is what we think is clinically acceptable, but this is a demonstration of it. It will have the same functionality”. Plus I get feedback, and it's been brilliant, because I deal a lot with Point-of-Care. I think it might be changed to Point-of-Need to, but it's Point-of-Care, essentially any care given next to the patient. That sounds like it could be pretty much anything, but it's when we're talking about diagnostics. It's quite a relatively new field. It just means that instead of for our particular example, instead of sending a blood sample to a lab, which could be the next town over, it could be in the same hospital. Instead of that sort of transport process, and then feed them back the results of the clinician, or the patient, you have a device that can actually get that can replicate that test to the same standard, or extremely close, within a 10% failure rate of the gold standard lab, and do that next to the patient or out in the field. And it's really about disrupting patient pathways … Our particular organisation is not quite resilient, but as a result I think I've learned a lot from looking at that. It is not trying to pass the buck, but it's not my fault. But as a result, you do get to sort of live with these issues and see. You know this came about because I was thinking recently, and have been for a while, there is a lot of naivety in the industry, especially from investment brokers and investors, and we can happily go on to that later on when it's appropriate. But essentially about the naivety, the type of investor you want for medtech have expectations on their side. I've learned a huge amount, mainly because I've been dealing with only medical devices for 15 years, so that's all I know. The market, I know; the customer, I didn't. I didn't really know the upper echelon above that. I didn't know the investment side, the creation of a product side; and now I do [have] a couple of years of experience … Resilience to me is just going to be, I guess, how I'd look at it in this particular circumstance, which of course is bespoke, would be how likely the company is to survive and be successful. That would be how I'd see it … I'd happily give my previous company. It's in the same sector. It was a very clever innovative device. It is a very clever, innovative device because the results are highly accurate, highly, highly accurate, fantastic, and a new type of technology that wasn't possible until camera technology has shrunk and become affordable. And then, led by AI, I always find little bit funny saying AI, because to me AI doesn't truly exist. It's more algorithms essentially but very, very good algorithms. This company brought out a product … They started creating a very clever product because all they saw, and this is what a lot of startups see, [is] what we can improve, so that the market will

want it. That's how they see it, which is this logic to that don't get me wrong, but the two big things you need to focus on are with the healthcare, especially maybe it's the same across all sectors, but at healthcare is, you've got to focus on a problem, because if you're with public health and private, especially in this country, people don't have time to deal with anything else at the moment, maybe back in the day they did when I first started, you could give people a little [time?]. The clever bits of kit that were clever but not essential. Now it is a case of are you addressing these top five problems or one of them? You know, are you addressing backlog of oncology? Are you addressing the demand from the government to say we need to have 50 virtual ward beds by the end of 2023? Are you addressing the problems we've got ambulances queuing up and being used as patient beds? No, no, no, you're on the wrong track. You're in the wrong industry. You need to go elsewhere or go to another country where they got the problem that suits yours … An example of a problem where somebody creates something that doesn't address an actual problem, or challenge in healthcare, is my current company. They created the software platform that is very, very clever. The premise is fantastic … It's like precision medicine. You alerted quick quicker, so it's like a precision medicine at very powerful. The problem is, is that it's an overhaul of the way a clinician, like a haematologist or a GP or an oncologist would interpret blood data, because you're saying, guess what we can do this. And they said that's great, but I've got bigger problems. The parameters of what's normal on a blood test don't bother me right now. Safe, valuable, the pipe dream is actually huge because it involves data and data now is becoming it's worth in gold. It's gold, you know and it's pure gold. So you can get this, you can sell it to, you can sell your innovation to a pharmacy company and you become a billionaire company, and there is as a result. But the problem is, is there's no traction and I prove that essentially going to stakeholders. You wouldn't believe from school governors, offshore GPs, you name it in hospitals. Of course. I was there everywhere. And the general consensus was, yeah, it's pretty cool. And I could see that that would be useful. And in the future, we'll probably see that in the future, that sort of type of overhaul will be there because it will, but it's not solving the big problems right now. And you want to be a company that makes money. You're not going to make money very quickly that way. So that was an example of where [the market is not ready yet]. We will have seen it [all] before with other technology over the years too. We used to every year to distribute something different, so I'll add to the portfolio, and you bang on the mark, sometimes the market just isn't ready and then four years later that you would have been brilliant. You know it would have been fantastic. So their problem was they didn't focus, they didn't create that company and that product to address

an actual problem, that healthcare practitioners were saying “Help us”. You know, the government is flogging us, it's on the news, those are the problems. They're right in front of us there. They're the ones, that get the attention … Their problem or their good news, is they've got $170 million of investment which is a tremendous amount. They have squandered a lot of that because they the platform wasn't stable. It wasn't ready for the market, they pretty much should have addressed those very obvious problems because they are obvious to anyone. But if they would have just spoken to anybody, like myself, or a point of care professional in a hospital … and market themselves as point of care. So they knew what that was gone to a point of care person and said this is what we've got … If you haven't got any quality controls for your test, no, because we don't need it, because it's imagery, we don't care because we get governed on showing that we do in quality control measures … [For] most [National Health Service] hospitals, and pretty much most health organisations, to be honest, and then they expect to run pretty much the … top notch of technology innovation. So maybe in military and energy, might be above it, but healthcare is up there … That investment money, $20 million investment money, has to go back to basically re-engineer the device … So resilience, there would be if it wasn't a smart use of investment, there's a lot of naivety. You don't know if it was a case of “Do they know where they were going to place this device, when they were making it?” They said, point of care. But I just see these as really easy issues to have avoided. For me, there's no excuse. Kudos to the same people who did fantastic things, that meant that we didn't have other problems. So I'm not saying they're useless, but it is a case of it would have taken a very minimal amount of effort to know these things, and because I learned them very quickly … I didn't know any of this, apart from a few of them. But it took me a few months … so that would be an example there, resilience-wise of a massive drain of money. Luckily, they've got loads of it, and a big lab investor, so they've got a very good investor in that. And they come from the same space. So if you if you've got an investment company, you understand that the returns on mostly life sciences and medical tech, you're talking three years, I'd say would be healthy, expectation five would be about right, eight would be a good one if you wanted to say “ohh I want to invest and get four or five times or more the amount back”, but a lot of venture capitalists like returns within 12 months. That's the way they work … OK, our aim is to get 12 months to give you return not happening. It's very rare. It's very, very rare. So these are huge problems that will affect resilience … They started off by looking at the wrong product, and then they pivoted to, and fair play to them, they did pivot to address an actual problem … They were already building a device, but all the money ended up being focused, or at least most of

it, on the device … Our investment in contrast to the one I mentioned was $5million; so, like $170m versus $5m, so it's a tiny amount of investment. And COVID hit investment potential massively because, I think the economics and healthcare just went all over the place, or investment looked at what would solve COVID. They all jumped on the COVID bandwagon, and if you go to a medtech hall in an exhibition … There's a whole hall taken up with machines that all do the same thing. It's very saturated. I was impressed how quickly they came out, but there's so many competitors. And so the problem was then, as we started running out of money on our organisation, and the CEO, against the advice from the Board of Directors, hired double the amount of people that they should have. Our run rate, our burn rate was tremendous. He had to let go over two thirds of the workforce. So I had to let go of those people, which of course, slowed down our race to bring out this device. [We are] reactive, as of I think it was May or June last year, and now we are more proactive. And now that there's a lot more transparency of the budget. There's full transparency, at least for me, of what the expectations were from our bosses [who] are the investors essentially, that's how you think any company such as ours should look at that money, and look at what we do, until we start selling and making revenue stream from healthcare practitioners, for example. And even then, our bosses are the investors as long as they align to what is, morally, the right strategic move because it was reactive, now it's proactive … Considering that staff were let go, and I mean, like uh, a lot of the company, we're on a reduced wage, in order to take the strain off. It was a choice, you know, take the strain off the company. And is it and just basically string out the money as long as possible, for us to get another big lump of investment. And then unfortunately the company will have learned from its mistakes, like a lot of these companies do. But as so many, you can avoid and with the right just by getting the right people to advise early on. From my point of view, from what I know, no, I don't think [responses to threats are] recorded. I don't think so. I think if we look at the big barriers, my current companies had, that is they were spending too much, they didn't have enough money. And I think everybody who could, just learned the lesson. But no, there was no recording of it … Using like black box thinking is … where it's a different level … Essentially like that's how it should be run in healthcare. And when it comes to healthcare tech, it should be that, you know, with some of the things I said mixed in, that's how it should be. But no, I can't think of a way we recorded any threat. I tell you the only thing that they record when it comes to threats to a company survival is competition. They’re so obsessed and it's just a case of don't worry about it. If they're opening the doors or marketing, that's fine because as long as we're aware of the opportunity that's the main thing. I think, yeah,

a lot of a lot of these organisations too, especially the smaller companies, my current one [is] very, very paranoid about competition, extremely paranoid to the point where it's just pointless. It's like there's no point. You know there's going to be competition. If there wasn't, it means we're not in the right market. You know there has to be competition because it means that there's something to go for and there's a big enough that they're getting invested in … Customer support, you could be just as good, if not even a little bit worse when it comes to what your technology does. But if your customer support, or just support in general, your collaboration [will] probably be better with your partner with the healthcare organisation is top notch. You win, you really win … I get that obviously [we] don't want to be let down. But if a company won't let you down with supplies and their technology is superior, I think they'll win. But yeah, it's still a very personable industry. And again, a company could say we're going to launch in the UK. But you've got to support it. It's you know just because it's user friendly, it does not mean they're going to pick it up and use it. These people are so busy and so stressed. You know, it's as if you've got a really hold their hand. Does that sound like belittling? It's more just, you've just got to help them as much as possible to help yourself. Money [as an influence] … It's with it sounds cold and horrible, but it's just the case of money equals survival. That's the resilience. Money equals success. That's the resilience. If there is. If you couldn't have a tangible link between open innovation and the success of your company. Which is basically is measured by money. It's money, you know, all you get you, you get a grant by being be by opening up your innovation, you get a grant. It's money. Or you get to work with a great University Hospital that have an excellent sort of lab where they say we're gonna give you loads of time and you can do what you want. That's also money because you'd have to pay for that if it wasn't for that case. So it's money. In my opinion, but then I'm biased, right? Because I'm commercial. Yeah, I mean, resilience wise, definitely, because of the investment. The investment and has been affected by it, which is global economy in general, which the Ukraine War affected, COVID hit, especially because focus went elsewhere. Although decentralization was actually boosted as a result of COVID, to stop people from having to travel as far. The resilience when it comes to human resource structure is huge because you've got to know what you need to know, what problems you're solving within your organisation, what you need, which direction you're going in, and my examples previously sort of reflect upon that. But yeah, human resource structure, and who you hire when, and why, and what qualities you're looking for. There's a lot of naivety because most of the time these people don't know … Especially last year [2022], it was a lot more difficult to raise money … People are a lot more

wary, in regard to investing, probably because of all the naivety that has gone on. You know, where they expect returns, or you want an investor who actually knows point of care, you don't want somebody who just says “oh wait, I know operating theatres”. In a perfect world, you want them to know exactly what you're dealing with, because then they can help you with finance and understand, but also, they can probably offer some good advice, or at least, some good networking. So that was a barrier for us, because we lost a lot of [our] workforce. I'd say we are a skeleton crew. We are constantly looking for more investment. The market, like I said, I've got a list as long as your arm of people that want to trial this, when it comes out, because I've spoken about where it could be disrupting their pathway, and they can see the benefits, and that was genius by me. That was just because I threw out the net, then people reacted quick enough, came back to me and said “We could see this really influence oncology or emergency. Great talk to me about that”, they explained … I can just say “look, this is what they're finding, or this is what they're saying”. That's how the interest is generated. [The] market is there. It's just a case of finding investors to pretty much outsource the manufacturing. So another barrier when it comes to a spin-out is they go with their own team, and if you can't pay the right wages, it means you might not attract some of the best people, or the people you need, or you have. Somebody doing a hybrid role, and then you probably don't have the facilities to manufacture. So, it's quite a good idea to yes develop the science that the algorithms with your own team, but then probably to almost certainly outsource. I mean even … with all that money, if I would go back and run the company, I would have outsourced the manufacturing to a company that view these pitfalls.

Prompt: Their Open Innovation (C2)

Open innovation, umm, I don't know what it is really. I think protecting the IP when it comes to opening, but allowing a massive cross-collaboration when it comes to everything else, that isn't absolutely precious, and could result in the company just losing its edge. I think everything else should be open because you get a lot of outside views, and this is another reason why I try to align as much as possible, with what healthcare customers are going to want, and that's [the] transparency they really like. I spoke to a [health board] CEO … and I said “In your experience from the people working with you, what is the trait that you look for when it comes to working with a partner outside of your organisation?" … "Of course, [in] medical tech". Immediately without any delay, he just said “transparency”, and then when he said that to me, I started thinking, actually if I just sort of think of the different definitions of that word, that's what I'm

hearing from the nurses, to the clinical leads, to estates and facilities, you know it's transparency. Transparency, and I think it just ties in, then, to when it comes to opening innovation, you've just got to allow the transparency [in] healthcare. I think most people, … they've become suspicious if you're not open and transparent with them. Umm, you know, it's probably because they've been burned so many times, I imagine especially because it seems to be across the board. I can go through that and talking about collaboration, yeah, so industry [stakeholders]. Absolutely manufacturing and investment, though they would come under those for me that are really important for us right now. I signed up … a large med-tech company as a distributor for a device, going forward, which again, like I said, the market is there, they were fantastic, and they wouldn't have blamed [us]. But if they're a little bit cagey, because they could see us as a threat, if you brought something else out, but instead they were smart, and said that solved a big problem for us, because our customers keep asking for this, in parallel with what we're already supplying. You do get a lot of these huge companies who will look at the smaller ones to solve problems, or they'll look at them for PR [Public relations]. So if they can go to their customers and say we fostered a company, and you're going to really like what they do. And this is what we're hoping to bring. It makes their customers go "Oh, good, you're [actioning] all the problems I keep on mentioning and you're doing something [about it]" … [Large companies] will work with these [small] companies that provide a solution, even if it's not theirs, almost to them it's like, yes, it's disrupting the patient pathway, but I don't truly believe it is. I think their motives are brownie points. I think they just want to be able to say to their customers "Look at this, look what we brought you. You know, this is going to help you". I think that they don't quite understand the patient pathway surprisingly. So I wouldn't say they think about it as in-depth as maybe they could. At the end of the day, we win because they're the customer, then they buy the technology, to then place with the customer who uses their drug, and then the technology monitors the patient and it's great. It's great for everybody. But the motive is more brownie points because they just have the money to be able to spend and lock in that business or at least promote the loyalty … So government, mainly for grants, and I tell you who's been fantastic, I would say, the Department of International Trade. They're really big on trying to link with the right people, but their effort is there. They have definitely been told by the government, "You need to be doing this with that company, we either need to bring trade to our country or you need to make sure something is made in our country, is brought somewhere else". You know, like when we get [international] custom, they are fantastic. That was a surprise to me. I didn't realise how heavily involved they were. Academia

crosses over massively, as you can imagine, into our customer base because the doctors, the professors, the clinical leads especially, they usually are based also at the university. … They're great for the likes of grant partners … They get money from the grant as well as the organisations, such as ourselves. So they're big when it comes to raising funds, and, of course, custom. And I think I think that brings me onto the point of open innovation. I think there could be a lot more crossover, when it comes to getting these students in, who are learning in the industry, hopefully some of the best practice as well as lots of points of view. So it would be great to have more people like that, or more of an open environment, where these people can come through, learn a lot about what it's going to be like outside of academia, if that's where they're going or if they need to work with them. And likewise, we get all this fantastic education, knowledge, and ability from these people, who could really help, especially the smaller companies and the big ones as well. Society is the overarching way to measure how we can make a market impact. So if I hear … "there's a tremendous amount of backlog in the oncology sector because of COVID, and [that we] then [have] burnout of staff". I know that there is a huge problem that needs to be addressed … It makes things very, very interesting when you're dealing with a big problem, that your solution can help to address. It's never going to solve all of it, but it will definitely help you become fascinated … So that's probably why I like it because you can start formulating business cases and it's interesting … When it comes to open innovation, need to open up with these companies to allow these people to actually start pointing out where the market's going to go. To say this is going to solve the most problems, if you apply your tech, or enhance your tech, or change it. So it will be because this is where we're going to go. They see what happens in the future … Product creation in regard to if you bring in somebody who is an expert, who is the optics for our type of device, that's essential technologies. No, apart from buying-in competitors' [technology] devices well, not so much. Compared to most, so that they can do testing to see how we compare for like lab devices. So that would be where the innovation happens there. But I mean again, the only way I could see that happening … if you went [to] those companies, [none] would be happy with that, unless you're not looking at their customer base, or you are potentially going to be taken under their wing, because they see your product as something that be fantastic for their portfolio. We would love that to have happened. I'm trying to make it happen with some of the big pharmaceutical [redacted] companies because I know that [redacted] are doing it with my previous company. And I just think actually with another company, now I think but there are other companies out there that will want to be able to compete, and show that they're doing

things as well. People, we actually really lucky. So we worked with [redacted] … And then we got a PhD students come over, and they basically helped with projects. It was just a case of this is what we're doing right now. We haven't really got a time to do anything else, but hopefully this will be OK, and it was, it really helped them. And I loved that, that was fantastic … The Board of directors who are from all sorts of different backgrounds. You generally want them from medtech, although you would be flabbergasted. Intellectual property wise, especially in medtech, [is] very, very guarded. At least from my experience, you do not get crossovers there. If [redacted, industry] came to us and said "We are going to help you, by taking you under our wing. But we want your intellectual property". There'll be a problem. There'll be a lot of people that wouldn't like that. I actually would be like "Yeah, right now we could do with that, [if it] means we survived, and we bring this to market, and we help a lot of these patient pathways". Because, obviously, I'm invested with my relationships that I've formed of these oncologists and emergency consultants and nurses, then great, I don't care whatever brings this out, and it [is] fit for purpose, I'm happy, but it would be difficult. We're always looking to collaborate. Nobody knows who we are, and the more people we can collaborate with, the more people we know. So yes, very open in movement, in regard to what's coming in, what's coming out. We, to be perfectly honest with you, if we were to collaborate with [redacted]. As one example or university, there's probably not so much, apart from just experience of what we've gone through, we can give back. I'm sure I speak for them as well, but we would love it if we gave more back. We'd love it if people come to us, and they learn, and they can then deliver knowledge, or expertise, or some sort of resource out there that makes an influence, makes an impact. I mean, that's pretty much the mentality you really should have, in my opinion, when you're dealing with medical technology. And because that's the whole point. It's not like a secret box. Again, it's the transparency side. We'd love to be, we are open, we'd love to be more open. We'd love to be able to offer more, and we're [a] very small company. But I would love that.

Prompt: Their Relationship (C1*C2)

I think that in lots of other industries, I can definitely see how they [organisational resilience and open innovation] intertwine, especially the newer type of techie/agile companies' innovation. I was at a … startup hub, but it's mainly for people that are starting businesses. They could use their resources, and what they like to do this. So this is right up your street. If you want me to introduce you to anybody. But they what they do there is they have all these previous. So you have a graphic designer who makes logos on behalf of like a marketing and

websites on behalf of these great companies. And you've got marketeers that study social media and how to market your products and social media. You have person that now does corporate finance but actually is an expert when it comes to self-assessment and corporate. Become successful, hopefully, but then they do come back. They come back and they run educational events as a as a favour. And they like to. You can tell they like it, you know, they're happy too. And they're nice. So I see it like in, in lots of other areas where there's a there's a knowledge exchange. They even have something that is a knowledge exchange, which to me, I think is great for what it does. But also I think it's a very good way to avoid tax because you don't have to pay the other person. So I'm thinking that's quite clever. You know, that's a good, especially if you're small and you need that money and it's good idea. So, with medtech … the crossover is a little bit more difficult between open innovation and resilience, it shouldn't be, but there's more paranoia. It could be one of these things where, because I'm in it, I'm more blinded by what could be obvious … There's a huge amount of crossover, but off the top of my head, not so much. But in other industry, absolutely, absolutely.

Enterprise Eight (e8i)

UK Country of Operation	Scotland
Life Science Subsector	Biological Technology
Enterprise Size	Micro
Enterprise Age	6
Enterprise Respondent	Male

Prompt: Their UK Life Science Enterprise

We're a company that's been working [redacted] for the past four, five years … I'm Technical Director in the company.

Prompt: Their Organisational Resilience (C1)

Resilience comes with a lot of overseas potential customers, who basically, can see the need for this type of equipment, right? That's in the third world, in Asia, and also in the Middle East. The [National Health Service] don't seem to have any care about it whatsoever. We received the Freedom of Information Act from the [National Health Service], which basically they don't seem to be monitoring [redacted] in any respect, right? And that is one of the problems we have. We have managed to get through to Innovate UK, and we're waiting for their feedback, to see what they do. I think resilience, yes, we've been at it for five years, and basically, we still keep going, because at the end of the day, we can save one life, you know, that would make it much worthwhile. I think at the moment, we're feeling complete failure, because basically, we have spent a lot of money from the company, directors and co-founders, into the getting this developed, and basically from a UK aspect, nobody seems to want to go along this line. I think the problem with that is that the [redacted] market is saturated by multinational, very large companies, that don't want to see a change within that market. They make millions out of selling [redacted] solutions … I think really because it is a new completely new project and the new method. Yes, we've got to prove it. We have proved it because basically the test we've done so far … So I think basically we are getting some sort of inroad into it now that we haven't had before. I think there's a learning process every day of your life, right? And basically, at the age I am now, to me, every day you learn something new, right? … And that's my view on it. I think along the route. Yes, we've learned a lot of things from what we've been doing, some good, some bad. I think most of the people you talk to, especially nurses, especially healthcare workers, can see the possibility of what we've got. Where I think, unfortunately,

some of the academics that are in the [National Health Service], just stick to their normal. What they're happy, with rather than looking at new on further, forward developments. I think resilience comes from the perseverance of continuing along the line. Alright, as long as you're continuing on that line, you may get distracted, you may be, disruptive in some respects. And basically it's dealing with that disruptive[ness], when it happens, and then overcoming it by mitigation and moving forward. Consistency, I guess.

Prompt: Their Open Innovation (C2)

I think we use internal and external. I think the technical side of it, because I've come from that industry, is yes, where I am. But to me, it is a learning curve of everybody. Basically, you speak to all the organisations to see what they do want. I mean to say, at the moment, [it] surprises me that hospital-acquired infections cost the [National Health Service] £2.9bn a year, right? It causes 22,000 deaths. It equates for 79,000 nurses being off sick with the illness. And it takes up 21% of all [National Health Service] beds, you know? So that's the information you get from the outside, that is the benefit for us. I think with the project, yes, it's so easy to be insular, and not look at the outside, what's happening? But when you get those figures, just for the UK, and then you take that into a worldwide market, it becomes tremendous, what they are spending and what the government is spending on [redacted]. When I'm not saying our way forward is the answer to everything, but at least to us, it brings in a way that you can monitor, and also save costs, and the most important thing is save a life. We work with academia. We worked with government, right and basically government grants help, is quite good in a lot of respects. I think from [the] academic point of view, some of the people who dealt with Professors. I really don't take it on seriously. We've found a problem, with like [redacted, Scottish academia] university where basically the project you have, in order to test it, it doesn't really have to meet CE [Conformity with European standards] approval. [Redacted] university won't allow a piece of equipment in, without being CE approved, [that's a] barrier straight away. I think being a Scottish company, we try to keep it [Scottish]. Not that I'm for Scottish independence, but we try to keep it within Scotland, you know? Basically, to me, it's like our suppliers and people that we deal with for tooling and all that. I'd rather it be within a locality. You can go and see [them], right, rather than having unfortunately travelled down to London, or the South of England, which involves costs and everything else, yeah. I think one thing with competitors, [and] the system we have, market research, and our CEO, has been to many international exhibitions worldwide, and he's been in the industry for 35 years. Basically in industry, none

of them we can see as a competitor, because nobody is using what we would call [redacted]. I know it's difficult to substantiate that, but basically everybody has a competitor, right. We do have a competitor on [redacted], which is [in] America … Yet the UK and [the Department of Health and Social Care] government doesn't seem to take any notice of that … It's usually about two or three years before the UK wake up to what's happening. In research and development, yes, we've discussed with patients how they feel about [redacted] … Basically, I think most of them are really concerned about that because the World Health Organisation is just published a report that [redacted] is one of the most serious affects within the nursing or healthcare industry. I think we have connected because basically we've been looking for investors. Whilst everybody we've talked to or discussed with are very interested in the project. I think really, from that point of view, we need to get into a situation where we have to get a finished product, and put it out for evaluation, and that is the stumbling block we've been at. Well, basically we … the government, under Innovate UK, we have received feedback from their assessors. On three applications … We didn't get the award. So what we're doing now is, we have somebody on board, who is an assessor with 'Innovate UK', and they are helping us to get the right application. I find that when you're dealing with a lot of the 'Innovate UK' grants, and they seem to write it in the wording that they want to receive it in. And I think it's sometimes very limited, where you only have 400 words to express, or put something as an answer down. Especially in this kind of technical field, as well … All of it [transferring all resources]. So that's why we have been secretive. I think if we could get through to the stage where we [have] got the complete IP, we would then look at licensing out to other companies worldwide. I think basically it's equal [mutual transferal] because basically you can only receive information on [what] you put information out, and I think the world is now easily communicated, that basically the transfer of information becomes readily available, right? And basically, that can only help people to invent device things. I'm surprised that nobody else, as far as we know, has come up with this system … I think [influences] really comes down to internal and external, because as you go through life, you're affected, not by just what you're doing, but what's happening, and you've got to monitor and see what is happening in the rest of the industry, and the rest of the world. The legislations that are being affected and adapt and change to all those roots.

Prompt: Their Relationship (C1*C2)

I think openness is one of the things that everybody should be, providing you're not coming across any intellectual property … We have attended many conferences where we put forward the idea, and you know people have accepted it. They come back with quite a few answers, as to why and what, and I think discussion, and anything, can only be better for innovation, yeah. I don't think it enhances it [resilience] because basically people are getting to know what is becoming available, yeah or what could become available. And I'm not saying I'm the only person, or we are the only company that can do this. There are probably major manufacturers out there that could bring it to market very quickly, because I see the need for it, and whether we could do that by getting the IP and then licensing, it could be a very open way of doing it.

Enterprise Nine (e9i)

UK Country of Operation	Scotland
Life Science Subsector	Medical Technology
Enterprise Size	Micro
Enterprise Age	5
Enterprise Respondent	Male

Prompt: Their UK Life Science Enterprise

I'm one of the founders of [redacted]. We are a startup that's been starting up for an awful long time now, more than five years. Still, in the very much the startup phase. My background and my colleagues background are mainly in building [redacted] … So, it's very important for the future, but it's got some problems at the moment because the cost is high and our current machines generate too much radiation, so it's not widely available. So, we're attempting to make change that to reduce the costs, reduce the radiation, to make it widely available worldwide, so very ambitious, which isn't easy in the UK. And that's what we basically do. So, we've got a design ready, we built a proof of concept. Our technology, we have our ISO 13485 [International Standardisation Organisation, Medical Devices] … We have our patent, but we've got all the ducks lined up, if you like. We're just looking for the next stage to go ahead and build the first complete machine.

Prompt: Their Organisational Resilience (C1)

To us, resilience is mainly talking about reduction of risk. Our risk comes in many forms. Risk or something we take seriously, as you know. And that is both technical risk and more importantly commercial risk and so on. So, I'd put those, those are the two broad categories of technical risk, commercial risk. If we can afford risks, we will be resilient, that's fair enough … We're ISO [International Standardisation Organisation] certified to build medical devices. We have a QMS [Quality Management System], which is quite rigorous and is audited every year. So, certainly, a lot of this now is risk-based. You know, that's the way a lot of these QMS are going is risk-based. So, I would say throughout our business, although we don't look at it. Resilience as an end in itself, … it's a by-product of our away we work, which is a risk-based approach. [At this] stage of our development, the biggest issue is of course we're small. We're very small startup. We haven't got a lot of funding and that's the biggest barrier, if you like to us putting both. You know, putting in place and necessary, you know resilience, if you like,

just by its nature. When you're a small enterprise, there is a lot of commercial risk and there's a lot of danger involved … Talking about threats, we do part of our QMS, we do the normal SWOT [Strengths, Weaknesses, Opportunities, Threats] analysis. We take an anticipatory approach, because of, yeah, because we're sort of pushed that way because of our QMS. We are supposed to be anticipatory. Our SWOT analysis is a is a good example that we carry out and review every six months or so to identify threats and risks. We do record responses to threats. Again, we haven't had many because of the state we're at stage, we're at of our of the business. However, again, you know fall back on the same old answer. You know we have to review this as part of the procedures we have. You know we have a very sort of strict reporting as being a medical company. We have a quite a strict policy of requirements to review you know and we have to look. Things like changes in regulations, you know, we have to review that we have a formal process for reviewing things with regulations and so on … Both BREXIT and COVID were serious. I mean BREXIT is a, you know, almost suicidal for a country like the UK. Ridiculously, BREXIT isn't the problem. But obviously leaving the single market was ridiculous. It's ridiculous and probably will cause us to leave the UK. Particularly actually, you know, businesses of CE marking. The nightmare now, no, we're not partners. The UK and the idea that anyone else is going to recognize the UK's regulations is ridiculous. It's not going to happen. So that will impact some really the medical device industry in the UK. And that's, you know, obviously people try and do it offshore and COVID had a major impact that shuts down our access our office as we were renting a building that wasn't able to be available so. So that was that, really put us back, I'd say two years. So, we basically went into hibernation rather than, you know, ruin the company. We just put everything in the hibernation for a couple of years and we now coming out of that. COVID was a short-term disaster. BREXIT is a long-term disaster. The biggest influence of resilience, you're driven from the regulation structure and the QMS needed to have resilience. You know, I would say that even things like requirements of, you know, CE marking with reporting of issues and QMS medical requirements to report issues and potential issues. Building resilience. So external factors, you know, forced on you. Uh, another aspect might be the other direction of less resilience. We all know that our scientists are not necessarily the most organised and formal. Trying to organise a group of scientists produce anything as a bit like herding cats and trying to get them to follow a process is sometimes ordinarily impossible. I've worked in big labs, you know, and working with scientists in my team. It's often the problem to get processes in place formally. Very, very difficult, lot of resistance and that obviously impacts resilience. We are making the same

mistakes all the time. Why didn't we learn from the first time? Why haven't we got more formal processes? So, this is the ongoing battle in a in a scientific environment, trying to get up to date with best practices. So yeah, involving scientists is always difficult, especially in academia, but generally is, is something that causes a I would say difficulty in resilience. Obviously, hire a lot of cheap Russians now and Ukrainians. Uh, make it make certainly makes it harder to potential any potential because we are very international. We got people throughout Europe, but I would imagine the Russia-Ukraine War would make it now hard to work with Russian institutes. So, I've worked with Russian institutes in the past, you know, very, very good people, but I would not say in our case, none of those would have a big impact on [organisational resilience].

Prompt: Their Open Innovation (C2)

Basically open, although we have initially used mostly our own internal funding and we did deliberately keep below the radar, to keep what we're doing quite a close secret … However in saying that we have links to universities and this year we published our first paper at a conference because we decided to open out a little bit. Just because some people thought we're not taking this seriously because we haven't published. So, we did publish some of our ideas at an international conference this year, so we're opening up. We were quite closed and now we're opening up. In terms of stakeholders, we had a government grant when we moved the business to the UK, came to Scotland it was very easy to get an initial grant. Money has been very difficult, unfortunately, so initial grants were good, so that we can get certain engagement with the government. We've always been working closely with [redacted] University. We've looked for other partners, but coming facing down there. So yes, my background and my colleagues' backgrounds are in big science. That's where we come from … So naturally we have interaction with experts in these institutions. So, I'd say academia certainly however not on the basis of sort of shared IP, you know keeping the IP for ourselves … We're probably going to work with … with industry … to do some further work, hopefully this year. We have a contract with them. So yeah, we interact with the government labs, government funding agencies. Academia and industry, obviously, we subcontract, you know, we subcontract work, not really our core technology, but we subcontract a lot of our prototyping and things out to industry. And we've looked at potential collaborations with other medical device, large medical device companies internationally, but we are the market leaders. We do interact with cancer patients, but we're not a B2C [Business-to-Customer], you know we're very much a B2B business. So and it's a

bit unfair to talk too much. I mean we use their input, there's a lot of YouTube videos about [redacted] and so on, so we use that for our marketing purposes. In terms of investors and hospitals, we don't interact directly, other than sometimes we help with referrals to our contacts … Certainly, ideas are transferred. You know, we interact with some former colleagues of mine and the academia … gave a lot of good input early on. They can look at our ideas to refine our product before we really started full development. So yes, certainly a change of ideas. Well, well now obviously keeping a little bit under the hood, but basically there was a lot of exchange ideas. IP, no, we keep hold of the IP we know. In terms of people, we certainly want to nick where we can from academia and other research labs. When we grow, we will take people back, and the research labs we probably won't hire. Why would you hire a post-doc researcher through a university and pay twice as much, than when you can hire them directly? … We have enough knowledge to know who we want, and we probably will hire the people directly rather than have academic partnerships and with all the fully economic cost issues associated. Where you get your human resources and obviously having links to universities means you can have a wider talent pool, but also, you know, maybe as I said before, nick them and give them a decent salary. Uh, you know? But so not really strongly. I would say other than where you get your talent from. External investment would be nice to have. We've had a first round of investment. We now looking how we do the second round. Unfortunately it might cause us to leave the UK. The UK aren't really switched on to big ideas. Most people are after a quick buck, they're small minded. They're not really see the big picture and the long-term. People are very negative in the UK, they all be can't possibly compete with other people as you go to the [United States of America], they say can you do this, great, you know, so we may move either to Switzerland or the [United States of America] for the next big investment. We're not attend intending to try and sell to the [National Health Service]. It's just too much of a nightmare. Our market is Asia and the Middle East. Our technology is cheap enough that it can be used worldwide, and that's where the biggest growth market will be. You know, not saying we wouldn't consider the [National Health Service], but we originally tried to raise enough funding to build the first one and keep it, and then we were going to let the [National Health Service] use it for free in Scotland, with the idea of course that it's worth its weight in gold. When you go out to Asia and they say, what was it being used, you say the [National Health Service] are using it, it would have been a good marketing tool, but we haven't come up with enough funding to do that. That's why an even bigger chunk of funding needed to have basically hire your own people and machines for development, so absolutely. I see healthcare covering a lot of different

things. Maybe it's a little different for medical devices, than the typical model of drug discovery, which means particularly successful in the UK. You know when you do a lot of drug discovery, the investors seem to expect is you take it for a few years, develop it, and then sell the idea on to a big American company. So, I don't believe UK gains much. The UK is probably losing out, because we do all the hard work and they're quite happy to give it away for a good price. And so alternatively, to make a quick buck, you sell-up rather than going into production. Costs influence open innovation, I mean, may not be an obvious one, but you know I mentioned earlier, you know fully economic cost issues, like working with academia. Not very good profitable. No, not a very cost effective factor. It causes people to go to that model, as a lot of grants are assigned towards university work. A large part of grants are based on working with a university. A lot of funding that comes from grants. And so a lot of grants have that aspect that pushes companies to go the academic route for open innovation. That's the way to get some help. The government don't know it's a bit of an artificial thing. Another interesting one, is in terms of IP. You know, the Americans have, if I'm not wrong. The Americans have this rule that you can still patent something a year after it's been published. I don't know that was the case and if it's still the case that is obviously a big factor that has allowed the Americans, if they still do it, to be more open, because you're not so paranoid about not being able to patent something if it's been talked about in the past. And generally, the issue of patent secrecy is a big hindrance to open innovation. Well, we're not at the stage with our investors that they brought this up as a major issue. You know, look can imagine some investors saying we want to keep it private and we've talked potential investors that weren't impressed that we haven't published. That's why we did do it. So you know either way.

Prompt: Their Relationship (C1*C2)

I'm not convinced there's a strong correlation between innovation, uh, openness of innovation and resilience. But I'm not convinced. Initially, my initial thought too I wouldn't see a natural correlation on in either direction. That may be wrong. Yeah, there is a risk that though the way you know that you know you people might tell you on here, yeah … Obviously it depends a lot on resources. If you're a multinational company with 20,000 employees, you have the opportunity to do things internally, whereas if you're a, you know, a couple of guys in the garage, you don't have that opportunity and you're forced to be more open.

Enterprise Ten (e10i)

UK Country of Operation	Northern Ireland
Life Science Subsector	Biological Technology
Enterprise Size	Micro
Enterprise Age	2
Enterprise Respondent	Male

Prompt: Their UK Life Science Enterprise

I work for a company called [redacted], we're a Northern Ireland-based micro company. There are four members of staff were a spinout from [redacted] University. We spun-out in, on paper, technically in February of 2021. That's when the company was incorporated, but we had really spun-out, in proper terms of any actual thing happening with the company, by September-October of 2021. The company has spun-out of it's base IP that is licensed out from the university's research team … So essentially, an AI-based platform for drug discovery … And so we're at the stage we raised, when we spied from [redacted] and we raised a pre-seed round of around £900,000 from various sources (so about a $1m) and we're currently on sort of that VC [Venture Capitalist] pathway to raise a sort of a further full-seed round towards the end of this year. So I'm one of the founders of the company, I'm the CFO [Chief Financial Officer] and CCO [Chief Commercial Officer], which basically means that anything that's not technical, I do it. And so if it's payroll, if it's, you know, agreements, if it's making a deal, it's anything to do with biz dev [Business Development] or business operations that would be me. I jumped into the company having worked with the research team in the university, so I'm not research background myself. My background was actually in the tech transfer office in the university, so I was previously the head of IP and commercialization in Queens had worked with this team quite closely over probably three or four years through the university process of accelerator programs and development and commercialization. And yeah, we gelled as a team. So I jumped in to kind of fill the commercial role. And then my business partner was a postdoc … and on the computation biology side. But he's an experienced guy. He came from the financial services sector. And he's kind of the inventor of the platform. And so I supposed together we've spun it out and then obviously raised some money to build it from there. So that's. Yeah, that's pretty much what we do.

Prompt: Their Organisational Resilience (C1)

I honestly don't think about resilience in any great depth at all. And you know, I don't really know how even I would begin to define that. I know what the MBA [Master of Business Administration] would say but in terms of organisational resilience for essentially a micro business as an early-stage spin-out, you're not necessarily worried about it, you know. As a founder, I'm not worried about resilience. You're really worried about trying to survive, and that survival is really from investment, particularly within their sector. The biotech space, which is largely a kind of intellectual property space, largely as a sort of a value-build type of scenario. You're continually looking to move to that next stage of "we've raised some money that will get us to X proof point. We have to reset there; then we raise more money to take us to the next proof point", and it is sort of like a game of Russian dolls in reverse, to sort of try and build it out. So, I think resilience is, you know, I think if you can talk about resilience, you know, as in is there a resilience in the company, if we lost a key member of staff, we're just too small. If we lose me or [colleague] with his technical background, there's really a gap that probably the company doesn't realistically come back from. Maybe in terms of thinking about resilience, some of the things we talk about maybe indirectly is about risk mitigation, and we talk with that quite a bit. We've talked about that with our Board, most recently to sort of manage risk of our development platform or technical platform that we use, which is obviously very tied closely to [redacted, colleague name]'s technical understanding of how to operate it. We're looking to build out. We're looking to work with external consultants and independent subcontractors to try and build out that platform into something that is sort of more independently workable. It doesn't exist just solely in brains here. There is a sort of a system of architecture that can be deployed across the team. And I think, yeah, beyond that, if I was hit by a bus, this sort of the technical risk is last, but obviously the business operations would be probably quite significant. I don't often think about it and maybe yeah maybe the closest thing that we do think that is aligned to it would be in terms of risks for the for the business. The pandemic has largely helped. From a biotech investment raising point-of-view, COVID has kind of brought it front and centre. And I think some investors, that might have otherwise been interested, or certainly infectious disease side, which is where we started off with our platform. And you know, I think that has brought a lot of that to the forefront. So I think in that kind of context, it has helped, I think beyond that the biggest sort of practical risk for us was access to lab space. So, we utilised lab space within the context of the university. Out of our

team of four, two of us (so, 50%) are biology based in the lab day-to-day. So, the sort of the issues around COVID and accessing labs were largely sorted out by the time that we had opened up and the universities and companies had a largely managed to sort of put systems in place to deal with that. So and then beyond that we're largely of virtual company. So while we're headquartered in Northern Ireland, we're obviously linked to the university. And you know from an ecosystem perspective, our team are spread across the UK … so you know, we're entirely kind of digital again. That's pretty common as you will know and should probably find in the sector where you have sort of digital teams. Biotechs now tend to operate as sort of a hub-and-spoke type of approach where sort of that idea of open innovation is inherent, where you pull in expertise from Contract Research Organisations and so on. Where we're maybe more integrated than some other [Artificial Intelligence] driven biotechs (or maybe 'techbios' as is the term that they use a lot now). Some of those companies will be just purely in silico – so, just on the software side and then they will outsource all of the biology … We work with partners, and we will outsource that, subcontract that to quite often academic partners. We work with [redacted] and [redacted] and all of those partners is they have the systems, the animal houses, the licenses and so on and place that we don't have and wouldn't intend to put in place. A lot of biotechs will operate on that type of model. Probably, the fact that we are kind of a platform company, means that we have the biology piece in-house. But really I think if we were a single asset company, the likelihood that we would be entirely a hub-and-spoke with a core management team in the company and then all of the sort of the resources around that essentially can then contract it in. So that tends to be quite a common model now. I think it's a mix [of pro-active and re-active resilience]. We have a risk register, so we run that through with the Board. We anticipate certain risks and mitigate those, as far as we reasonably can. The issue of mitigation is there's only certain things that you can do to mitigate certain risks and yes you can mitigate any risk but any mitigation action that you take takes time and money. Obviously within any kind of startup enterprise, time and money are the resources that are in short supply. Risk is inherent in a startup because the time and money are less, so things that we can realistically mitigate are much more limited. But as I said, we try and mitigate those things where we can. And then, in other cases, we can try and react where we can. So, you know the sort of the startup space particularly knowledge-intensive deep tech advances space, it's pretty much a roller coaster. You're up and you're down from any given day-to-day, week-to-week, Yesterday I thought we're going to be rich, but I think we're all looking for new jobs in 12 months. You'll get different information and insight, whereby new data will arise from

the programs - because we run multiple programs, at different times, and at different stages, so that all impacts your kind of thinking. Of course, there's no point in getting too hyped-up about a good outcome, or too down about a bad outcome, you know? So I think I think we are proactive where we can, but personally I think it's impossible for an early stage company with those limited resources to be hugely proactive. It's also impossible to predict, you know, every single thing that you could be resilient against. For the likes of us, you know it's actually a pity that we started out sort of mid-pandemic but really by the time we started in 2021, the chunk of the pandemic was over. In some ways, we were a year too late, and we missed an opportunity because we work in drug discovery and infectious disease. Suddenly in March of 2020, there was a huge opportunity that we missed out on because we actually weren't around at that particular point in time … [COVID] wouldn't actually be an issue for us being mostly a virtual company. It would be actually a sort of a kind of healthcare threat would actually be more likely to be a sort of a business opportunity but obviously there are other sort of threats that exist like sort of geopolitical threats like the Northern Ireland protocol has been something that we kicked around for quite a bit on our risk register, as an identified risk, but we have no way of impacting that risk. We have no way of even having a voice in the sort of the conversation and the risk ultimately for us is again sort of mitigated somewhat by the fact that we're virtual and by the fact that we can set-up base in the Republic of Ireland tomorrow if we wanted or needed to. So again, there are things like that where just the size of the business allows a degree of flexibility, where if you aren't really, really proactive, it doesn't matter. I think resilience is influenced … [by] time and resources. You have got to build resilience, and you need to invest in resilience, and it takes both time and it takes money or a mixture of both. And so maybe you could argue that there needs to be a need and a senior management focus and they need to think about it in that way. But even in the context where they think about mitigating risk and how it plays a part. They then still need to go away and invest resources in that.

Prompt: Their Open Innovation (C2)

We're porous both in terms of stuff coming in, but also in terms of trying to leak out for others' innovation. We exist on the basis that open innovation is a concept, or at least, a business model, because where our practice is to utilise our platform for internal discovery, which we take through discovery and preclinical validation stages. And then our goal is ultimately in licensing and partnering. Whether that's co-development, or whether that's pure licensing, it really doesn't matter. But that is ultimately our business model. And so, we have four lead

programs, and now six that we would class as investigatory. The goal is ultimately that a number of those will move through to the to the next stage and we will then license those out … which would take us to phase one which would require us to raise more investment for that particular program. And whether we do that in-house, or we spin-out that program out as a special purpose vehicle with a single asset in that there it doesn't really matter a degree of flexibility. Our own barrier in terms of stuff coming in, it's entirely permeable. The value of my background in the tech transfer side and the university, so IP technology licensing is my thing. We've obviously licensed in the platform from the university, the university has where spin-out in the university has an equity stake on that. But we've also spent plenty of time actually looking at other opportunities, other technologies that might be in licensing. Types of opportunities from both [redacted], and whether they fall into the kind of the computational side, or whether they fall into the kind of the more the sort of the compound drug side of things. Ultimately for us to move an asset through the system of discovery to validation, our AI platform is the thing that we use to start generating those, but we're kind of not myopic, and also not solely limited to that. If there's a nice opportunity that exists most typically in the third-level sector then we would be open to taking that in-licensing and then essentially moving it through the same cascade. The fact that it has an emerged from that AI model, it's not the end of the world because as long as the asset ultimately has value, in and of itself, we don't really care where it comes from. And I think what we find of open innovation is that It can be difficult because you always have to figure out the symmetry of objectives and interests between the partners that you would work with. And so where we've had conversations with maybe early stage biotech companies, there's a dance that has to be done to figure it out. Are you competitive? Are you precompetitive? Where do you kind of fit within this sort of mix?" … The dance is similar with universities as well because they have been (and I say this as someone who comes from the tech transfer sector) over tech transfer-rised. [It] used to be a case of academics would go out and talk about their ideas, and give their ideas away; and all that doesn't happen ... I remember one conversation with an academic team. They were in the food space and they had a technology that I thought, you know, on the basis of what they put out there into the world, their kind of public disclosure, could be interesting for us. It was, I thought it might have the potential to increase, to be essentially an encapsulation delivery technology for some of our bio-actives. And they really said very little about it other than we have this novel encapsulation technology, which is based on the particular foodstuff, might be applicable in this sector. So reach out to the [Tech Transfer Office], and they said "yeah, absolutely. It

sounds great. Let's set up an NDA", so I said, OK, we'll look what's you know." Ideally you don't get into an NDA until you've figured out if there is something here. Usually you can talk about what the thing can do, rather than how the thing does it, in order to avoid these things. But anyways, so I said that we'll do the NDA. So we worked up an NDA, I drafted it in one hour, and it took the university a week to eventually sign-off the call. Then with the academics, was they still couldn't even get into anything, beyond what was in the non-confidential explainer, even though we'd signed NDA because they can't really tell you how it's working. So we were in this position where it's a case of, unless we actually know what you're actually doing here, we can't evaluate whether it's sort of fits, and whether it could work. So it just didn't really fit. But you had this slightly awkward dance where they really weren't prepared to give away anything and really, until you start having a conversation and start, until you have a framework for sharing information. And you know that you can't get into anything, and typically at least in a company-to-company [B2B] scenario, once you've signed a non-disclosure agreement, then at least everyone understands there is that framework, and actually in the academic side they don't even understand. They sign the NDA just because it's kind of the thing on the to do checklist. But then they still don't actually get into the sharing mode. You're left in this sort of scenario, where you can't really go forward. So we drop that conversation. And then all our conversations with teams, where our sort of cascade for figuring out: Do we want something … Ask them to present their data, anonymize all of their compounds, don't tell us any sequences or structures, we don't want to know at this point in time, just show us your data that shows that shows efficacy and whatever model it is. Show us that data, and if we think that data looks sort of good, relative to what we've got, then the next step for us, would be a Material Transfer Agreement … Then the next step then in theory for us would be then to start an in-licensing negotiation process. But we've never that step with any external technology because even the ones that we've taken in … and an issue that is quite common, is reproducibility of data. And particularly in the academic sector … One of the other things that we can work with on, not just academics, but other biotechs, is not just compounds into our cascade, but also biology expertise. So one of the things that we don't have as explained, we have a number of different programs … We're not experts in, we're not doctors or clinicians and therefore, we're not experts in disease. In fact, we're not necessarily experts in any one of those six or seven diseases that we're working on, and we can't be and, we can't bring that expertise into the company. So a model that we would work to is where we would look for funding, and we would pull in the disease partner, we call it the strategic partner. But

really it's a sort of a disease expert partner and then work with that partner in a collaborative and a jointly-funded way. And we would agree a collaboration agreement with them, and that collaboration agreement would set out terms as to how we'll access and share foreground IP, if that's the case, who will manage it and who will commercialize it? Obviously, from our point of view, because we're the commercial partner, we want to commercialize everything, but that will be done them. If it's a university for example, it would be done with a royalty arrangement, back to the university, so that they see an upside, and as part of the deal. So that sort of strategic partner model is also baked into our program structure. And so we have a number of strategic partners and live programs and there's other programs where we're looking currently for that strategic partner in different disease areas. The whole kind of open innovation side, it's in some ways it's a very kind of nature of what we do and it's the very nature of the way the company is built. And it's so it's entirely permeable on both inward and outbound, off the sides of the business. From the point of view of the government support, so we work a lot with any of the UK. We've had Innovate UK funding, ICURe [Innovation-to-Commercialisation of University Research] programme was the sort of the catalyst, and an accelerator program that we were on, that we then we then spun out the company. … We plan to work with MHRA [Medicines and Healthcare products Regulatory Agency], for example, in terms of our regulatory pathway for programs. But again, we're too early stage … we certainly utilise, and will utilise, going forward, a lot of those governments support mechanisms. And again, it's that's pretty common with the type of company that we are and the type of enterprise that we are sort of knowledge-driven, [Venture Capitalist]-backed, university spin-out, most of them will tend to be fairly au fait with leveraging those types of programs and resources from the state essentially. So obviously since BREXIT, the Innovate UK portfolio has been sort of greatly ratcheted up, so we avail of things like the biomedical catalyst program or grants from Innovate UK and things like that. Patients is an interesting one in that like we, you know, we are never going to be selling directly to a patient, that is not just not how our industry works, and we would never realistically be able to build the resources and have a long enough payback period to build out certain products to market that may take 20-years … That's not how it works, but interacting with patients is really, really important when you're trying to plan your discovery programs … There are obviously questions around the commercial and patient unmet needs, and what is the sort of the market opportunity? So we probably don't do it [innovate with society] as much as some of the other sort of larger companies would because they will be able to set-up and invest money and time and patient-centric groups and focus groups. And we don't really have that

sort of type of flexibility. But for certain programs, … We have worked with patient advocates and experts into that on a part-time consultancy basis, just to advise and help inform some of the clinical decision making because actually some of those patient advocates are more knowledgeable than the regular GP [General Practitioner] down the street … Getting that sort of insight from patients is really, really helpful. So we don't necessarily have a patient advocate on every program that we do, but where we can get the information either through case study or wherever we can get it directly into the program, we try and do that. It can be a quite difficult thing to do because we're so far away from the patients. Generally speaking it takes a lot of time and effort to engage and find the right person and all of that type of thing. But it is kind of part of the process and in some of our programs. I think we've covered them [resources] all. I would agree all of those things will in some way transfer across the enterprise barrier. Because we're a startup at the earlier stage and we lack resource, we lack time, we lack money, we raise an OK pre-seed round, but £1m or $1m is not going to get you far in the space that we're in. Money/finance probably has to be transferred downstream, but again, we're then transferring money and sort of financing to universities. And like I say, we're funding … technologies, ideas/knowledge, intellectual property: they're all just different sides of the essentially what is the same coin in my mind. Intellectual property is how you're sort of protecting [them] … and wrapping them up in a kind of a legal wrapper. That forms a core part of our negotiation of agreements and collaborations. We would typically not transfer a technology, that is the crown jewels. There are things that have to be core because they're inherent to the company and that is how the company creates its value, and so our AI platform … is not something that we really transfer either side of that permeable barrier that sits exclusively within the company [in-house] and the things that go into that are ideas and disease targets. What disease do we want to point that system at? … So we don't have all the ideas, all the people and experts, that other biotechs and academics will … We're a kind of a startup where we lack a whole load of things. We have expertise and competence in certain things and there's certain things that we cannot do, like regulatory, as we don't have the expertise in-house. We need to latch on to other sort of companies and bring in other companies to help inform that the detail on how that works, whether it is partnering, whether it is paid for sort of contract work. Whether it is sort of licensing, I think the detail of that really, really probably will always come down to the legals, and it will always come down to trying to figure out how can we get the best possible matchup. These two, three, or four entities coming together in this consortium, they're all sort of an island of misfit toys, and you're trying to find the best fit with the other misfit toys to plug into your

kind of overall shape, and then be plenty out there that won't fit for a whole host of reasons. [I] was talking about this just the other day at the Board meeting, when we were talking about spending a lot of time over the last few months perfecting our model, and really thinking about our model around strategic partnerships so we're absolutely clear that our strategic partners need to have a number of things they need to bring: disease expertise in our programmatic area that we don't have, they need to be happy to work on the type of terms that we're talking about which are largely collaborative, where we ultimately will be the commercial driver. But there will be some sort of royalty, sort of sharing piece to that or if they're sort of a biotech company where we can naturally carve up the results so that there's a little bit of an upside for everyone that's involved. And then the last thing then is it's people we're not going to work with any d*ckheads. Because we don't need to work with d*ckheads. Because why bother? So there's plenty of academics that we've had conversations with, and they're just not people that you would want to engage with. And we've also had plenty of good conversations that have started up, but building that relationship takes time. And so for example, … there was actually a personal connection to where a head of [research and development] actually had worked previously, not in the lab, but in the same university, as the team, and that was where the connection is, because there's a degree of personal trust between those individuals … so that's a really core part. That kind of social peace is key, and I think that if that is lacking, then you need to spend time to really build that up. You end up having to almost compartmentalize your engagement into bits of ever-increasing stages, where you start out small, you structure it in a way where there may not be a lot of time, a lot of investment, but you're kind of feeling each other out, and you can see what each other can do. You see how each other works. Make sure there are no d*ckheads hidden in the woodpile, and you can kind of then move to the next stage of going OK, that went pretty well, everybody seems pretty sound here, everybody seems to know what they're doing as well. It's alright being nice, but if you know where your at, you know there's no good deals either, and so then we move on to the next stage, maybe we invest a little bit more, invest a little bit more money, a little bit more time, we sort of iterate through this kind of processes. But having that sort of embedded social connection to start, accelerates you through all of that, so you can go straight to a heavy investment with a greater degree of confidence, as you know right from the get-go. So I think that social piece is really key for open innovation … We're a small team, so we don't have enough resource and runway to be spending a lot of time figuring out social dynamics and wasting time around etiquette. Yeah, if there's any conflict, you'd be much better off killing it quickly … I've always been quite mindful

… that one of the big things for me personally, in any type of engagement, is equity and fairness, and I my negotiation style is soft, but when I get presented with a hard negotiator who's taking a really unfair stance, then flip, I'm the opposite, and I really like to dig in … We'll take a sort of either an open innovation type model, or maybe they [stakeholders] don't even call it open innovation, they'll just call it 'partnering', but say "we want what we want and we want everything and we want our cake and you should be happy to work with us". Most people who take that approach, they don't think they're taking that approach. It's just their natural stance. Ultimately is never gone to work. Fairness and equity has to be at the heart of any type of partnership, or any type of open innovation relationship … You want to be parsimonious about it if you're trying to win this deal. There are negotiator types who they set out to win deals. I don't see that as being conducive to even the concept of open innovation because you just find it an impossibility to put those relationships together. And in cases when I've seen the bargaining power of large companies push their way towards that position, it typically doesn't work, either because individuals get hacked off, or people feel unrewarded or feel unaccounted for. There's a sort of an asymmetry of reward and then those partners feel that they stop putting effort into the relations. So the result might still be there. And on paper in principle, but you don't really get a genuine sort of interaction between the parties. The factors that influence open innovation, I think you could go back to the confidence, not necessarily the maturity of the company, but the confidence of the company in terms of what it can do, and what it can offer in its own value … If you have everything at home, you don't need to be going out on the town to kind of get it elsewhere. And so if you're a highly vertically integrated company, and you've got tons of cash in the bank, if you have got a super-duper sort of visionary management team, and if you're confident that you're applying a recruitment strategy where you're getting the best of the best.

Prompt: Their Relationship (C1*C2)

I have no idea. I don't know [if they relate]. I don't know that they are. I think openness is related to confidence. I think that's the case for an individual. If it's the case for a company, then I think it is to do with how confident you are in your own competence, in your own ability to manage your resources, as well to manage your technology. And all of those things lead to openness. I think a lot of early-stage companies would not be inherently resilient, because they don't have the time or the resources or the money to really build resilience. If you kind of think of resilience as a wall or foundations, you don't necessarily have the time to invest in that, and

yet they typically in this space, or in some of the most open companies, because they're running about everywhere there, going from here-to-there, working with different companies and different people. And some of that is scattergun. They're just trying to survive. They're just trying to find where the value is. They're trying to find that kind of product-market fit. Open innovation comes down to that sort of confidence. We, as a biotech, would always be looking to kind of partner with the bigger companies because ultimately that's the value chain, and that's where the eventual value is. It's maybe a little bit more unusual for a company like us to be so open, in terms of talking to other universities and partners, bringing their technology into our cascade to be tested and trialled. Maybe that's a little bit where we're maybe slightly different within that context. I don't honestly know. I think it comes down to the confidence that we have in the expertise, and the ability, and the resources, but also the team that we have. So yes, if we were not very confident in terms of our ability to drive our own stuff forward, then we would probably lack the confidence to bring in anyone else and do the same with that or move that forward, or maybe lack the confidence to be able to decide which is worth the investment. Or maybe lack of confidence to just know what is good, and what is bad, or not necessarily bad but not worth investing in. Some things might not be bad, but they're not necessarily worth an investment. That would be my take. I would say it being more linked to kind of confidence company or team confidence necessarily, then maybe resilience.

Enterprise Eleven (e11i)

UK Country of Operation	England
Life Science Subsector	Biological Technology
Enterprise Size	Micro
Enterprise Age	6
Enterprise Respondent	Female

Prompt: Their UK Life Science Enterprise

I am a CEO of a woman-owned small business. A biotech company and I mentioned woman-owned small business because in the United States [of America] there are many advantages to that. The there are grants and contracts set aside from government, and grantor agencies. So, this is an important reason why, when we're discussing uh, how the how the company has decided to go forward, those things play into it. It's not just, uh, the opportunities at hand, but the future opportunities too. Establishing in a foreign country is extremely difficult, so right away, you have to start doing your homework of what you're eligible for, and of course there's a funding consideration. How do you get funding for setting up a whole operation? But that is when networking comes in. So that we achieve that by attending virtual webinars which fortunately, uh, save us a lot of travel back and forth and we ultimately set up a lab in San Diego. Uh to enable us to work with some US vendors who were giving us some advantages, as well as opportunities to apply for free and sponsored lab space, all sorts of things based on our products, which I'll describe in a minute. We had won a 'Horizon 2020' grant from our UK company. And it was basically just like it is now a virtual company, meaning we don't have a lot of bricks and mortar. That's where the overhead goes into the lab: equipment, supplies, and personnel. Our headquarters (where I am as CEO) can literally be anywhere in the world. And what I do is get up at any hour and stay till midnight, working with different continents. Because now we are at a stage of sourcing raw material and working out the shipping and logistics for the buyers. Fortunately, the internet makes all of this feasible. So uh, but let me go back to the 'Horizon 2020: Phase One' grant, which was exciting. It was in the BioMed category … So we did win 'Horizon 2020: Phase One' with great enthusiasm. We set up our relationships with labs and personnel and etcetera for Phase Two, submitted the grand, we had [a European Union] coach everyone's padding us on the head. This is fantastic, et cetera, et cetera and we missed winning Phase Two by one point. Ohh worse, I asked the coach why and he said because of BREXIT. You're no longer eligible for [European Union] funding. And the

problem was UK did not jump in with funding to make up for that. So you talk about enterprise resilience, I have to laugh because I don't see enterprise resilience. I see narrow minded, short sighted, politically-motivated measure that created a brain-drain in the UK. So I would be very harsh because this hit us very badly. Our coach left the [European Union] Medical Agency, moved to Netherlands. You cannot imagine in the field of biotech how everybody left the [European Union] infrastructure. Not right away. I mean, they were really hoping there would be a turn around at one point. But no, it is apparently definitive.

Prompt: Their Organisational Resilience (C1)

In our opinion, there is no enterprise resilience in the UK. I'm sorry to say this so harsh. Let me tell you what happened to my company since we moved … This is a booming, booming industry who in the UK is focused on the bioeconomy. I mean, we'd go back in a heartbeat if we got two things, one funding, and to some sort of awareness or support for the bioeconomy. Because that is the climate crisis is urgent. Every country in the world is looking to biofuels or renewable energy … When we look back at the UK, we still have our company active, we pay the money every year. It's still an active little company. There are some UK grants and they're so narrow in their description. It's as if they were written for a particular company to win. And frankly, is discouraging in itself. It means either the writer of the grant or the reviewer has somebody a winner in mind … You are surviving. You have survived. And you know, I'm a hunter-gatherer. If I find I can pick better berries somewhere else, I'm moving on. And it's just survival. Bigger, established companies can have the cushion to be playing along, probably because they have incentives that we are not in entitled to. But the whole the whole situation, I see, as very gloomy. Yeah, Europe is a gangbuster in innovation, right now. So, either you're [the UK] going to get their hand-me-down innovation or you get in the game of developing your own.

Prompt: Their Open Innovation (C2)

What are you going to find with open innovation? You're going to find that you are on the short end of the deal, because you're going to be relying on companies that have funding, have access to funding and have access to talent. Because the talent aspect, no matter how great your universities are, are already five years behind the curve. Ever since BREXIT, that's just the way it is. To top, people have been taken elsewhere. And curiously, since we won the Horizon 2020 Phase One grant, the European Innovation Council is including us in some of their

webinars. It's all prefaced with, “you've gotta move to [a European Union] country”. So, either the UK, as I see this, has to make a friends with the [European Union], in terms of grants and innovation, because who are you going to practice open innovation with, but [European Union] companies.

Prompt: Their Relationship (C1*C2)

The politics of it [BREXIT] is, you know, messy. But what are you going to do? Deal with it and get back in [to the European Union] for the future. Because otherwise, the UK has made a decision that is … It's bringing you back to the 1950s and you talk about organisational resilience, all you want and open innovation, but you don't want open innovation, you want to have some proprietary innovation. So you want to build your own industry. Open innovation means you're sharing everything. And you're going in from a from a position of weakness, in a partnership. It's really a pity and I just don't know what the how my words are going to change anything. Probably not. But my purpose is to encourage UK companies to move [to the European Union] ... For an economy, or an intellectual base, or you know, when opportunities are better elsewhere, you've lost your edge. I give mixed feelings about open innovation because I like my patents. [We are a] private company, I'm not a university. Universities like open innovation, but inventors don't. So, it's not a question of open innovation. If you have open innovation, you have to protect the patents of the inventor. Many of the programs for open innovation say that you're giving away your trade secrets … I'm not likely to post them on the Internet. That are published to give us a shadow of what our inventions are. So, we understand patents are not perfect. And we have paid for patents in the [United States of America] and UK. But it's extremely expensive to put in place, and most startups can't afford that. But I see open innovation as a concoction of universities … It does not protect the inventor. And you're talking about enterprise resilience. Resilience is coming from the inventor. It's not coming from a university. With all due respect, it's the inventor who's trying something new and risky. And it needs support for there to be something new to emerge. The door closed on us and like when the when we lost the ‘Horizon 2020’ grant, there was no way they were going to fund that. It was a blow, and it was a long time ago that we faced survival, so we jumped into action. And started networking like crazy, and fortunately found a lot of opportunities to network. You may not be aware. Also going beyond America. It depends on who your buyers are. Some buyers don't care where you source your material. But today, there are a lot of restrictions. As you can imagine, they're politically motivated. There's a lot of piracy

… and that is also shrinking the world. So, the more that Western countries cooperate is becoming extremely critical … We find that there are regulatory restrictions on where we can sell. So, we've achieved regulatory approval in the [United States of America] and some in the in the [European Union], not in the UK, we don't have the money for more, so it's another reason why the UK is being side-lined. You know, we would welcome funding to overcome those hurdles. Uh, you know, attorneys who can work this out with your [European Union] counterparts because it's just going to keep the door closed. We love the UK, we don't currently have any partners or investors from the UK … What UK could do is contact the 'Horizon 2020' winners and start telling them you know about your opportunities.

Enterprise Twelve (e12i)

UK Country of Operation	Scotland
Life Science Subsector	Pharmaceuticals
Enterprise Size	Small
Enterprise Age	6
Enterprise Respondent	Female

Prompt: Their UK Life Science Enterprise

My background's medicine and I've had over 35 years of clinical research experience, as well as working in different therapeutic areas of medicine. So, I'm well qualified to lead a team of clinical research people in our [Contract Research Organisation]. And so, you know, my background is varied I suppose, since being in Scotland for the last 20 years, I started off by working in [redacted], and I was the one that with [redacted] ... We put together the first [redacted] Audit. That's the easiest way to describe it in summary. And we did that for the Scottish Government from 2003-2005, and then the Scottish Government accepted our audit, and the changes that needed to be made. I was the medical facilitator, and I went to all the hospitals in Scotland that had [redacted]. And the islands as well and put our suggestions forward. Because, in those days, I don't know if you know, that [redacted] patients had a very high mortality rate in Scotland, so we had to structure something so that when patients came to the hospital, they weren't just put into a medical ward, and left until they were seen by a physician. But they were actually brought in, and we had a stroke unit, you know, organised throughout Scotland, so that they would come in, they would be analysed, and they'd get their [redacted], and whatever else they needed, very quickly and that decreased the mortality. So I was very happy to be able to work in that area and my professorship was through [redacted]. So I was well qualified and to work in [redacted]. After that, there was no more funding and I had gone into work at [redacted] hospital, and after that I did some drug discovery work in phase one. Uh, I had done previous work in clinical research in Australia as well, so I was qualified to work in that area, and from there, when the drug development unit finished at [redacted], I went to work in oncology at [redacted], and I was running a tech side-project for Marie Curie, which then brought people in their last days of life, to be able to die at home. And I sort of did that for 18 months, and then funding again was pulled. So I went to work as a Director of Research at a [Contract Research Organisation] in [redacted]. So it worked there and we decided, my husband and I, at that time, we were sick of being a sort of going from job-

to-job, because, you know, funding had exhausted. So we thought we'd start up her own clinical research company. So that was registered in 2009, and by that time I've been around Scotland about six times to all the major hospitals, so I had really good contacts, international contacts as well, so, you know, I could sort have started off by talking to these people, and seeing if they needed clinical trials, because I'd already been managing several clinical trials through [redacted]. And [redacted] started as just [for] drugs, medical device, and we thought we'd work within Scotland, naively, but, you know, within the UK, but you really have to internationalize if your company's going to survive, and especially back then in 2009. I don't know if you remember, there was a lot of financial crisis at that time and we were lucky to get a private investor. We put all our money into the company, just to start it. And we had a private investor come in as well and that sort of really helped us along the way at that period. I mean, it was the worst time to start there, I suppose. But, you know, when is a good time, put it that way, because as you know, we're a [Contract Research Organisation]. You have really good days, where you might be on a high, getting a lot of money, and then there'll be nothing coming in for a time. So it's like waves that work, you know? Within about, I'd say two or three years after starting, we have always had an interest in nutraceuticals and food supplements, so we opened up sites in Latvia and that's [redacted] there. And this Latvian site went really well, because they pay a lot for [over-the-counter] medicine, they can't afford to go to doctors, because they're on low wages. I mean, they do, but it costs quite a lot of money. I think the last time I was there, [it] was about €70 to see a doctor. And then you have to pay for the medicines, on top. So, OTC is really, really going quite well over there in Eastern Europe. So in those days when we started, everything was fine in Eastern Europe and we were working in Russia … So that's our Eastern history, which is really quite strong. And then we decided that we needed to start another company, which was software digital company. So we started on our organisation, so we're not the usual [Contract Research Organisation], we are really diverse. You know we do a lot of different things that [Contract Research Organisations] don't do. Yeah. And we do a lot of Horizon grant studies, and things like that. Usually you don't see a lot of [Contract Research Organisations] applying for Horizon studies. I think because of the challenge, and you do need a good academic team behind you, for these Horizon ones. It's very hard to get them … So that's sort of the background of where we are and what we do. So we've got several companies saying we go right across the board, different therapeutic areas, the phase one to phase four.

Prompt: Their Organisational Resilience (C1)

We have a very good Project Manager, who's our Quality Assurance Manager as well. She's got a lot of up-to-date qualifications in quality and regulations. We also have a specialist in Latvia who works with … [the] regulatory agency in medicine over there and he also knows all the Latvian regulations that we need that are that are country specific. So, we also do in-house, we have [an] e-learning project. So, we've got 42 different courses, that people can do from anywhere in the world, they just have to register it through us. And, of course, QA [Quality Assurance] and regulatory is among those courses, so we are up to date. If you knew our PM, I think it's more proactive [resilience]. She's always on to everybody about, yeah, keeping up to date. I mean, of course, in every [Contract Research Organisation], you're not going to win every study that you bid for, and you know, you might put three months work into some of them, and a lot of time, a lot of effort, which is usually free. And because you have to put, you can't really charge to do a proposal, because so many others will do it for free. You would lose out if you said "Alright, I'll do it for £10,000". They'll say "Forget it", so you have to work for, you know, for free. Basically to put these bid proposals up and it's so disappointing cause a lot of the time, you think you're going to get it, and you don't. So our policy is just put it behind you, and move on. You can't keep going back, and feeling sorry that you didn't get it because there's others out there that we have to strive for, and it's hard to do, it really is. But you know, you just have [to]. Some of them don't [give feedback]. They just say "No, we're not doing it. We've chosen somebody else". And I mean, even if you ask, sometimes they just don't answer you, or they come back and say "well, you were too expensive". But they don't say anymore. Because we have to cover our costs, we have to make a margin. You can't just, you know, put your cost down without any margin. You have to make something so that you can pay your staff. So you know, you're juggling because you don't know what the client total budget is. And if you are above that expectation, you've lost out anyhow. If you're below, you're sort of on-par with the others that are in the group, you know, hopefully. And so you know. It's just really difficult, and especially today as things are getting more expensive, clients don't want to pay. And that's where Eastern Europe comes in, because it's cheaper, it's much cheaper than the UK. If you put [National Health Service] prices against European prices in Eastern Europe, it's a no-brainer who they're going to go with. Yeah, it's about three to four times higher in the UK. It's amazing, it really is. And we also work with Jordan, because our Business Manager is Jordanian, and their prices are dirt cheap. I mean Egypt, Jordan, Lebanon,

they're really, really cheap, even cheaper than Eastern Europe. So, it depends on your client … If the client specifically says they only want to work in the UK, then we have to give them the [National Health Service] price, plus our margin. You know, and that's expensive. And they have to be aware of that. You know, when they're asking for UK prices, [but] if they asked for European prices, because they want to go and work there to get a market in Europe, then we can give them Latvian prices. Yeah. And then we can sometimes say, would you like another price with that, because we work with India as well as Jordan and you know Romania, they're all cheaper sort of options. So sometimes we will give them two or three proposals, you know, and they can choose, which we have done with one of our projects, because we do want to win, so we have to work really hard but that's all free work. Resilience is a question that's quite open itself, because it could mean many different things in a company. Firstly, I think being resilient to work against negative pressures, you know within the company. It's so stressful in our industry, or for our company, I don't know about others. I think it's the same. You know, I've worked with universities who have worked with us for several years, and then they've done the dirty on us, actually. And then we've had to pull out, and you have to be really resilient, cause your names out there and yeah, you know universities like their own IP. And working with universities, you have to be very, very careful with the way contracts are set up; watching your back … Yes, we have NDAs, the first step is an NDA before we get to any other discussion. But NDAs are not legally binding. And nor are MSAs [Master Service Agreements], so like, even though you've signed an NDA, you've talked to [them] and they said "Yes, you know, we're going to do this study, we'll sign the Master Services Agreement to say yes, we're all in collaboration". And those have got CDAs [Confidential Disclosure Agreements] in them as well. I don't, they're not legally binding, so they could just turn around and say "oh, well, after all this, we've got no funding. So see you later". You know, it's so that, you know, resilience with working with universities, working with hospitals is oh-so difficult, because we're seen as competition. Because take [redacted] … that's one thing that you wouldn't know about Scottish hospitals, really bad. That was the same, I suppose in England, if you have got a [Contract Research Organisation], and they're on your doorstep, and they're working as well as the hospitals, who have got their own clinical trial units within the hospital, we are seen like competitors to them, which is so stupid because they get about 50 or 60 studies through their desk a week, from all over the world, because they are a hospital, and people think to go directly to the hospital, because they'll be able to do this study, and they don't go via [Contract Research Organisations], so it's very hard to get on the rung, and try and find studies, if you're a [Contract

Research Organisations], so it's a different aspect. Then we try and work with our close hospital in [redacted] … So I'm in the back of the hospital. Right. … they, in 15 years, have never wanted to work with us. Yeah, because they think we're taking their money away, and we're taking their studies away. We're very small company compared to hospitals who have so many big studies. So that's another way of, you know, you have to be resilient. You have to be tough to be in this game, because people just walk over [you]. So that other big institutions, hospitals, universities, you know. It's very, very difficult for a [Contract Research Organisation] to work with them. You try to but it's hard.

Prompt: Their Open Innovation (C2)

Yeah, it's very much open, because we're a small company, and so we have this small team, you know, here [redacted] and in Latvia. And then from there, when we get studies because as I said, some of them, we don't get, some, we do. So you don't want to be paying for people to sit here, and do nothing. We wait until we win a study, and then we subcontract [redacted], so then you know they're there, they're on the ground. And we supervise everything that's happening through our Project Managers. Yes, so that's the sort of way we work, but our team, is like, we're very friendly bunch because we're a small team. Everyone knows each other really well. So everyone knows what's happening within the company, and every Wednesday morning we have our team meeting, so everyone has to say what's been happening in the last week, so everyone knows. Yeah, we do actually [work with industry]. Some [Contract Research Organisations] are not able to do these studies in other countries, but their client wants them to, so they ask us if we would be able. So, it's the client who is contracting, and they're subcontracting again, and said they'll contract us, because we can do the work. So it works like that, yeah. So we, we do work with other people in other [Contract Research Organisations]. It's not like, all the time, but because [Contract Research Organisations] like to keep their work to themselves, in-house, but they know that we could [have] international, 30 partners, worldwide. So you know, they know that we could do the work. Yeah [we do also work with society], because you know … that everything's changing and clinical trials. We've been in a bid for a very big Horizon study that's just finished, and now they've started up their own, external I suppose, spin-out, and that was to do with blockchain in clinical trials. So, in that, there was the two European group patient groups, and we worked with them for three years, and it was really interesting. Because they have their own perspective on e-consent, and other things like e-prescriptions, and things like that. So that was interesting to get their thoughts on

how we should move forward with that. And they're also now in the new spin out, so that they can give guidance on what they think should be done moving forward, and this is the way clinical trials are now going, that you the patient does have a voice, and they can say, you know, that they want to know whatever about the study, or be involved in the study, And we have to listen to that because they're the ones that are volunteering to do the clinical trials. [It] never used to be like that. It's only been, you know, just the last few years that patient groups have really come to the fore. We don't do it [collaborate with the natural environment] directly because we, I don't know if you know much about clinical trials, but you have to start with preclinical, which is animal studies. Yeah, and because you need to know that the drug might or the device is working, so the client, before they come to us for human studies, they will do preclinical work. It'll be on mice, rats, dogs, or whatever, and then they'll get the results of that. And if the result is positive, then they can move to phase one. There are four phases, and the four phases take 14 years, to get a drug to market. Yeah. So you do you preclinical toxicology studies, which is about six months to one year, depending on what they're doing and then onto human studies, if it's OK. And that's phase one to look at safety and efficacy, then phase two, the larger population with safety, with efficacy. Sorry, then phase three, like several hundreds to thousands of people, and then you can market the drug. And then you can go to post-marketing if you want after that, so it's a long, long haul. Yeah, it's hard because I suppose that's equal because we do, as I said, work with other companies, and they give us work in return. If there's a new study coming in, and they'll let us know, or they'll do things, and as far as data management statistics, yeah, that's inter-transferable as well.

Prompt: Their Relationship (C1*C2)

Yeah, I think it has to be very [related], because if it's not, [then] you become very insular, and yeah, in our industry, the way our company works, it's very much an open book. And I think I think it's better to be like that, because then you can collaborate more with people … What is difficult in this company, as I've just explained to you, you need to be open so that you can spread your wings. If you don't, if you don't collaborate with people worldwide, then it's very difficult for [Contract Research Organisations] to survive, and you'll find if you look up statistics in the last four or five years, 60% of private [Contract Research Organisations] like mine have gone bust.

Enterprise Thirteen (e13i)

UK Country of Operation	England
Life Science Subsector	Agricultural Technology
Enterprise Size	Micro
Enterprise Age	2
Enterprise Respondent	Male

Prompt: Their UK Life Science Enterprise

I've been involved in animal health for the last 35 years. Prior to that was a research scientist. [redacted] research, just looking mainly after the trials and so on. We sort of looking forward towards retiring, one of my colleagues who I've known, was familiar with my company, which goes back decades, and they'd stayed in touch, occasionally bounce ideas off each other, and he'd had looked at a product which was dwindling in the market, because the owner has had illness, and basically it was an [redacted] … So there's a niche in it, and just about the time we launched it, obviously. We didn't really launch it. It was interesting … So our products not really out in the market as such, it will be really going live this autumn. We're a very small company, we have limited resources … So that's sort of the products really. And so we're at that stage of carrying on the research trying to grow, grow sales and get customers. So we're finding the social media is actually really helping.

Prompt: Their Organisational Resilience (C1)

So again, branding [redacted], animal health, there's a low investment. So when you say resilience, I see that as being able to survive. And so, what we've decided to do, we put an initial investment, and each of the directors put in money, and the idea is now to grow organically. So, we not prepared at our stage in life, because we're all, I mean the youngest ones will be 60 this year, and the oldest, 72. I'm in the middle. The idea that we will grow it organically, and the idea would be to build it up into a reasonable company, within sort of two to three years, and then sell it on and retire. That's the plan. There's a lot of movement towards regenerative farming, so to be more natural and so on. But we've only got a limited amount of space on our island here … [People in the sector] are having to sort of go and get a second job to actually make ends meet, so there's no scope to have like your family, your sons and daughters coming in, because there's just not enough income coming in … And so that's the big risk mark point of view. And money. Yeah, I mean the long days, it's a way of life, as much

as anything. From the point of view of, we have got to get in [to the market] as quick as we can stay at the top and stay ahead of the game. So we've made a big leap, we call ours a second generation product.

Prompt: Their Open Innovation (C2)

It's really hard to get funding, to get the government to help. There are initiatives and investment to help you, but it's very work intensive, to actually get funding … So I think the amount of time we spent trying to get funding, we decided how much time we [have] got, when we're busy, to seek, even £56,000. If that took out 20% of our time, we have got to restructure our business, which is going to be able to provide the product for our customers. The other thing we've struggled with is, we've had to do change, make some changes to the product. So, we will find that it's stability wasn't as good as we expected, and the previous owners hadn't really done any stability studies. So although they were saying he had one or two year shelf life, in actual fact we were finding that some … were depleting within three months. So it wasn't stable, so it had to work with our producer, our manufacturer. Luckily, they've got a good lab there and so we are working with the industry. I suppose in that case, we are working with our manufacturer to affect the product, and between us, we sort of know various contacts to get other stuff done. So that's sort of where we are with that … One idea we did discuss it fully with our in our partnership, is whether we should include our manufacturers as a partner. Because [we have] got a successful business. And [they're] producing our product for us, but we're very small in their [eyes], but if we make this product successful, I could see that they would be interested to get further. So if we grow, I think, I suppose none of us are business people, [to] have the skills necessary to put that together. It really needs someone who can take it to a new level, and I've experienced that, and the company that I work with in New Zealand, where they, they had a good product, and some investors bought it, and then really developed it. And now that company is market leader, a world global leader actually, and I work with them for 10 years as a Sales Manager for Europe for [animal health] equipment. That's too late in my career working career to sort of think about that [now], but if someone came along, and said "we really like your idea and we can think we can do this". It's negotiating a deal and understanding how those sort of deals work. I don't think any of our partners did really … I mean, [redacted] university is not that far away and they do have that have an interest in [redacted] … We haven't really developed a good relationship with them yet, it's a bit early days. And I think they were hoping that [we] would come along, with a big bag of money, but

we haven't. Technology wise, risky. Obviously, people could take our product and copy it. We [have] got IP on the original formulation, but we're vulnerable, I'd say … I suppose the difficulty we have is we'd have to spend a considerable amount of money, and I'm talking big six-figure sums to actually work out what's actually going on … I suppose the intellectual property, sort of comes up as the one that we're eager to patent, which gives some protection for the investment. The difficulty with intellectual property is you really need the funds to protect it, so someone says "ohh, we like the idea. We're gonna steal it from you. See you in court". Who's got the bigger bank account, and he's going to win. We have a license to produce this product. The original product, which we still produce for the person who had it. Uh, and we're not licensing it out yet. We haven't been approached and probably, we're too early-stage ideas-wise, I suppose. We are learning … Which would actually give an online development, to a new extension of the product, and so that's one idea we've already done … Then we've got a sellable product, which will actually help reduce costs.

Prompt: Their Relationship (C1*C2)

[We] would probably feel vulnerable at the moment because it's so early. Umm, so [when] we're a bit more resilient, we might be a bit bolder about being more open.

Enterprise Fourteen (e14i)

UK Country of Operation	England
Life Science Subsector	Animal Health
Enterprise Size	Micro
Enterprise Age	35
Enterprise Respondent	Male

Prompt: Their UK Life Science Enterprise

Basically, [redacted] is about 15 years old now. It was brought about because we were importing some very expensive disinfectants from Germany, and the use of disinfectants is very sort of haphazard, especially within an expensive disinfectant, and someone suggested we should have a measuring device. So [redacted] was born from the idea, of having a system which could be easy to measure safer. We designed it, got a patent for safety, but also because it has the ability to have an audit system, which is something we could see coming down the line because of diseases … and these are impacting you know, the whole nation. And our economy, as such. And there needs to be a rapid response, so we designed the [redacted] … We were very small company, and nobody knew us and we needed a rebranding opportunity … And it's [now] very noticeable. In fact, it's probably now the market leader after 15 years, well recognized by the [government and industry] … There's been a variety of uses for it and its grown, but it's been a really small part of our business … But we realised that obviously, we're not going to have the whole market, but we wanted it to be used everywhere to get our brand name out there. So it's a great promotional activity. We've used it for competitions [prizes].

Prompt: Their Organisational Resilience (C1)

OK, so I would say that the [redacted] … was a disaster, really from a financial point of view, because although I had expectations, having been a product manager of selling 10,000 units within two years, I think we've just took 20-25,000 after 15 years. So as an investment, the tooling which costs about £150,000 was a big ask, but from a point of view of what it performed for us, was worth far more, under the line, if you like, by promoting our company, because everybody knew the name [redacted] within a few years, and it sticks because it's quite a good name … And so now we've just closed [redacted], just as COVID started actually, because of BREXIT … We've never really been successful in exporting, apart from some to America.

We've had some interest recently from France … so that may grow. Ideally we would have liked it to be a global product. I [am] still looking for someone to partner it really, to take it to perhaps [to] America or Europe, and so on … Bio-security still very high on the agenda … if you cannot control [disease] and have good bio-security, you can eliminate it … And we were involved with the drug company regarding [a] trial … Well, it's been our best ever year. And so, it's typical when a disease happens. No-one responds until they have a problem. And I know this from my days as a Vaccine Product Manager … You know, they won't make the investment initially, until they have something to drive them. So, it either comes from the government, saying you will do this … So I think the driving factor has been quality assurance … All our business has been driven by other peoples' problems, which is good because if you got a solution, that's good. So, we're part of the solution … And it's from the selling point of view is being driven by consumer pressure to for the produced retailers to be carbon neutral, which is it's a bit like cryptocurrency in my opinion. I think the public don't realise these things, so the [redacted] is a risky business. You know, you you're at the beck and call of the retailers.

Prompt: Their Open Innovation (C2)

I'd say it was just closed [innovation]. We just produced, got a patent, and produce it hoping that no-one else would copy it too soon. And so far, there's been some other models around, but luckily for [us], they're not just clever … So that was a personal investment, high risk, from the point of view of its functionality works well, and continue to grow really. I think, probably, out of those [stakeholder] groups, we are (trying to) work with [redacted] University on a project. They were looking for funding from the Welsh Government, so as, I think most scientists with things like this … Normally you would have had a group of institutes which would look at this, they were killed off by Maggie Thatcher, probably about 30 years ago. So, because they expected everything to be self-funding, within a very short period. So now you've got a very limited number of institutes, and then a limited number of scientists as well, are always difficult. They need money to fund their work, and techniques. Actually, the British are very good at developing things, and having techniques, and then it just turns to ending up [with] someone else has the benefits from it, and you probably won't be aware. From technology, we haven't really got any direct links to any sort of scientists at the moment, other than our own knowledge, which one of our partners is really good at. So actually, the three of us actually, sort of, got aspects about what we do, and know, which work together quite well. So as a group we're, sort of, effective, and we're very open, and communicating with each other, about what

we're doing. I think that we haven't gone to crowdfunding. It's a good idea. And I think it would probably attract interest. So, if we were to go for crowdfunding, I don't know how to do it. If someone came along and said we could crowdfund for you, and we'll take 10%, we'd say "Yeah, go ahead". I think the worry is we're just so small, and we haven't really got [the resources]. I suppose that we've been sort of learning as we've been going along, and every time we do, we find something else out to think [about]. "Ohh, OK, so we need to know about that". No, not [hiring-in people] at the moment. We've gone to this step of actually employing, indirectly, a very good journalists, I suppose. And she's been driving our social media and website. And she's a very good writer, as well. So, it's some of the skills that we haven't got, that we needed to sort of buy in.

Prompt: Their Relationship (C1*C2)

Well, that's continues to surprise me, but it's been driven by things outside our control … We've used it [open innovation] for promotional activities with companies … That's where I would have liked to have gone with a bigger company … But it's never happened yet. I will keep my eye out if I see an opportunity. I thought were nearly there with the largest one of the chemical companies … We're, sort of, getting there, we have a bit [of a] closer relationship this year. We're going to run a competition using their product, along with ours. So in an area [that] they're not stronger in … You never would have imagined that, you know, Putin decides to do what he did, and how the whole world goes into apoplexy. But it's happened, and I suppose it teaches us a lesson, that we need to be more self-reliant. And that's something that, yeah, no, the whole country needs to be more self-reliant … It's interesting, because we did this after the Second World War. That's why a lot of the [research] institutes were brought about. It was about 20 around the country, at one point, and then doubt about five [exist now], probably.

Enterprise Fifteen (e15i)

UK Country of Operation	England
Life Science Subsector	Biological Technology
Enterprise Size	Micro
Enterprise Age	5
Enterprise Respondent	Female

Prompt: Their UK Life Science Enterprise

OK, so we're a Contract Research Organisation and we specialize in doing human challenge studies and providing preclinical (so in-vivo and ex-vivo) services … I am the Scientific Communications Officer, so I specialise in strategy, business development, marketing, etcetera.

Prompt: Their Organisational Resilience (C1)

In terms of resilience, I think it's about being robust, and being able to weather storms. So for example, for us, COVID was quite a big challenge, just because all forms of contracts etcetera ceased. … So that was I think that was quite a good way of showing how resilient we can be, and innovative, and working around problems, and trying to find solutions. I mean, we're trying to kind of prevent any shocks to the business, going forward, by kind of making sure we have a healthy pipeline of work, etcetera. So, I think we are generally quite [a] resilient company, because I think that there'll always be a need for research. I think we were quite reactive to COVID, just because we weren't really expecting it, but I mean now I suppose everyone has to anticipate all sorts of problems in the future. So we do try and mitigate the hits that might come in the future, and obviously making sure we keep on top of it, but it's quite hard to anticipate every single possible problem. You know, if there was a fire next week, I mean, we probably be prepared because everything is fireproof. But I don't know if [there] was another pandemic, we'd all know how to react, but there are some things that we just can't foresee. I think probably certain characteristics [influence organisational resilience], but also that comes from depending on who your client base is, and who you're dealing with. Just because if you're in a naturally volatile market, then you probably aren't as resilient as somewhere if you're operating in quite stable environment. We're quite a young company, so I feel like there is still time, at the moment we haven't really experienced any [barriers to resilience]. The biggest thing is before

I joined, someone else resigned, but then I filled the position, so beyond that, I mean, there haven't really been any crises.

Prompt: Their Open Innovation (C2)

We do publish our results, and findings, from studies, but I would say lots of the work with clients is done in-house, and the IP is ours, and we don't really discuss it. Yeah, it's quite closed otherwise. [Open innovation is defined], probably in the sense of slightly more academic approaches. So, if you look at universities, where you might share information, probably slightly more freely. Rather, whereas in the commercial world, you know your IP and your innovation is the one thing that gives you a competitive advantage, [and you] need that to keep you going, so that's probably more closed off innovation. I would say industry is definitely the one that we've collaborated with. We don't really collaborate with academia. Our two founders are academics, and we employ a lot of ex-academics and PHD's, But I would say we don't really collaborate with people in academia at the moment. We do no work with the government. I mean, we have to recruit people for our clinical trials, but we don't really … so we use mouse models as well in our preclinical services. So yes, I suppose they're natural environment too, yeah. It's a very small the market that we operate in, very small and very niche, and our expertise are very, very specific. There are very few people … there is one that does something that's very similar to what we do, and we don't really collaborate with them. We work on our own. We're very small, independent [Contract Research Organisation] and the academic reputation that we have is what draws clients in. So, we don't really collaborate with competitors. [Open innovation is influenced by] probably somewhere where there is no competition. And what that, you know, there is nothing to be gained from being closed off. Whereas I think operating in a slightly more public [way], like in the private industry. There's a lot to gain in terms of reputation, in terms of monetary kind of things, you know. Making money, profit, competition. So there's a lot to gain from not being closed off anywhere. Innovation, for example. … Actually, what we do is for the public good.

Prompt: Their Relationship (C1*C2)

So open innovation [is] more important than resilience. No, I think you don't need resilience. I think you need resilience for closed innovation, because if you are doing something where you're not collaborating with others, and you're just doing it yourself, you have to be able to be resilient and weather the storm. Whereas, if you are openly innovating with other people, then

it doesn't matter because if you're not, you know, resilient. And as we said before, it's like in a non-competitive market, for example non-profits, you don't have to be resilient, because there are always alternatives. Whereas, if you're in a very closed off environment, I think, at least in my opinion, and you're not resilient, and it goes wrong, then you know that's it. You're done.

Enterprise Sixteen (e16i)

UK Country of Operation	England
Life Science Subsector	Pharmaceuticals
Enterprise Size	Micro
Enterprise Age	15
Enterprise Respondent	Male

Prompt: Their UK Life Science Enterprise

We support people who do mainly small drug companies and university groups and government agencies and analysing and drugs in bodily fluids, so blood, urine, tissues, etcetera. And we started 2008. There, originally, were two of us, and we worked for another [Contract Research Organisation], who decided they didn't need our groove(sp.?), so we thought we had a couple of clients who were desperate for us to carry on, and we bought the equipment and we started off here. The main people we work with, well, we do some work with other [Contract Research Organisations], [but we] work with small pharmaceutical companies and university groups and government agencies.

Prompt: Their Organisational Resilience (C1)

Yeah, it's difficult. Because, now, there's me sort of doing the day-to-day work, and my colleague just comes in when I need him. He's semi-retired, so I suppose if I'm ill, And there's a problem there. And so, he can come in and do some stuff, but the resilience is difficult for a small company like ours. Well, I can suggest Steve to come in and help out, and the other thing is we've got two mass spectrometers. So if one goes down, then we can hook up [the other] one, then we can use as well so. And so that's the other thing. A redundancy of equipment. There is a problem that one of our major clients hasn't given us work for about a year because of things they've been doing within themselves. That's putting everything in jeopardy at the moment. They were upgrading their laboratories, and it took longer than we thought, so they couldn't do any lab work. So it's been a bit of a tough time. I've just been talking to my accountant just now. And so, that's the major problem with only do[ing] small studies. Although we've got a lot of people, a lot of possible clients, they send the small studies, so it's only a few £1000. That's a good day here and there, if the other ones seem to have dried up a bit now, as well for some reason. Although one of the universities came to us and set that right, but that's the trouble with the universities, they have to write their proposals. … We're a bit

strapped for cash, at the moment, after you have to make decisions within the next month or so. Over the COVID period, it's all checked over. The people still send us samples. People still seem to be working. And so it went down, the amount of money that we got in, yeah, because, well, being a small company, with our turnover about £90,000 a year. So it's probably dropped to about £40-50,000, which was which was enough to keep me going, because I don't have much money out of the company. Luckily, I've got income from others. But the last year, because of this major client not giving us work, as a major [setback]. It's [about] being aware. But then it's picking the right time to act. You know, because if you act too quickly, then you might be doing something that you don't need. Anticipating it, but not acting too early. There's probably a quite a few external factors like your clients. Making sure they know the works coming in. Really, that's the major thing.

Prompt: Their Open Innovation (C2)

When we look at grants or things like that from like Innovate UK. Then it's our clients who get them, not ours. Because we're a supporter of the clients, so unless we did well quite a few years ago and we did, somewhat, with another company. Where we got a grant. For looking at something novel with them. And it was shared between the two companies. Because we were both looking at something novel, and that's we got that but, most of it goes to our clients. So we're doing all the drug, you know the drug research. … In the 80s and 90s, everybody was doing stuff in-house. But now you're getting all these small companies getting the money from the big companies. So it's [all] sort of outsourced to the small companies. And that's what we find. The difficulty is getting to the small companies, before the big boys get hold of them. So, when they are starting off is our ideal time. So yeah, we've done it. I've tried to do it through all of our clients, all word of mouth. Well, it was one client who came to us. They couldn't find anybody else to do the work. Found us on the internet and asked if we could do it. And we did that. And that worked. That was something that turned from £10,000 to £100,000. And that was many years ago. But yeah, things like that can happen. Somebody comes here and says "Can you do this?", you do it. And then there's a load on the back of it. Because most of our clients are word of mouth, none of the marketing seems to get through to anybody, and I don't know whether it's because they want to go to the bigger [Contract Research Organisations], because they'll do everything. Because we do things, as we would say, better than the [Contract Research Organisations], because we've got the time and the all professions manually … The thing that we find with our larger competitors, is that they don't always give the clients all of

the story. And they say, well, here's the results. Whereas we'll discuss with our clients, and as we say in our literature, we like to be a laboratory-down-the-corridor for our clients. You know that they could ring us up anytime and ask us and we discuss the results with them, … because they don't necessarily understand the implications of the, you know, they understand the generality, but they don't understand the specifics of the results. So sometimes it can be misinterpreted. So, we can help them interpret it better. And so they're getting the better deal for cheaper, really. But they don't seem to realise that. They [larger industry] do the minimum requirement. Years ago, when we, Steve and I, worked for another company, another small [Contract Research Organisation]. There was one of our clients that said to Steve, "can you come over to Switzerland to this company, because there's a problem? There's a problem with the assay, and we're going to check what's going wrong, and you're an expert in the assay". So, he went over there, came back, and it was a forehead-slapping moment, because he said "We sat there in this meeting with this big [Contract Research Organisation], and they said … "we need a purchase order". Because that's on their side, and money was the reason, you know, they just want to do loads of samples, get their money, and that's it. We got our part [done], we bring you the results. Because we have thought, with a university group, they said they'd had this work done by a big company and … they refuse to send them the derived, raw data basically. We couldn't work out exactly what was going on because there was there wasn't enough data there to [know] … what the results mean. They obviously want you to do more studies, so that they get more money. I was going to say the other thing with the big businesses, it's less intimate. And the scientists can come to us and talk to us about things. It goes through the Project Manager, who has got nothing to do with the day-to-day running, and it might not get down to the person who is day-to-day running. … So, you know, there's things like being big, doesn't mean it's good. I was thinking of my time in pharmaceutical industry. Well, we're part of it now. Where the things like the DMDG (the Drug Metabolism Discussion Group). So you're going to meetings, and other people are sorts of discussing work that they've done, that they can discuss. … And then they DMDG also do courses on different things for people, and so in that respect yes. … they've been like a university department of people, we [are] popping in and out of each other's lab discussing stuff and get ideas about. So I think it has to be called collaborative, to a certain [extent], you know. You can't keep everything secret, because you don't learn. And, yes, you have got fairly collaborative environments. At the moment, we have had two PhD students. … We tend to help them facilitate it, and mentor them, [as] part of their thesis for the analysis and suggest changes. And discuss stuff with them. So it's not just use the

equipment. Well, to be honest, I think scientists [influence open innovation]. Because they tend to fire ideas off each other. So that's why these meetings are important to go to. Because you go, and then you have a discussion with somebody, and find out what they're doing, something that is useful for you. So yeah, I think it's basically science family, as it were.

Prompt: Their Relationship (C1*C2)

No, I suppose. That's a difficult one because resilience is more within the company. And it's more, like, operational procedures, a lot of it. As the openness tends to, as I said, transcend companies, and it's more to do with individual people, and people wanting to know things, you know, knowledge. … I think it's a difficult one because … One of the things for resilience is people. If you have that mindset of openness, then I think it probably allows you to become more resilient, if you see what I mean. It's a difficult one. You can't be too open. You know, obviously you've got your commercial secrets. So you can't talk about maybe, compound x, but you can't put the structure of compound x. And in our case, it's our clients that we have to protect. We're sending stuff over to China, and they just nick the compounds and they don't care about any copyrights. So that's why I think a lot of stuff has come back from China. Rather than my very in-house [Contract Research Organsiaiton]. … you have to be commercially sensitive. We, especially so, because it's our clients data. We are one small pharmaceutical company … We [currently] have no clients. For we have about £80,000 in the bank, and no clients for about a couple of years. … I went to a meeting here and found out one of the groups here was doing things that we were interested in. So I asked them if they were interested in us doing that, and then that's when we got connected to here. And it's been doing OK until, sort of, recently. So, we've been here, ticking along for 15 years now. I don't know how much longer, just because we rely too much on a small number of clients, and that's where that goes in with your resilience. If you [have] only got them.

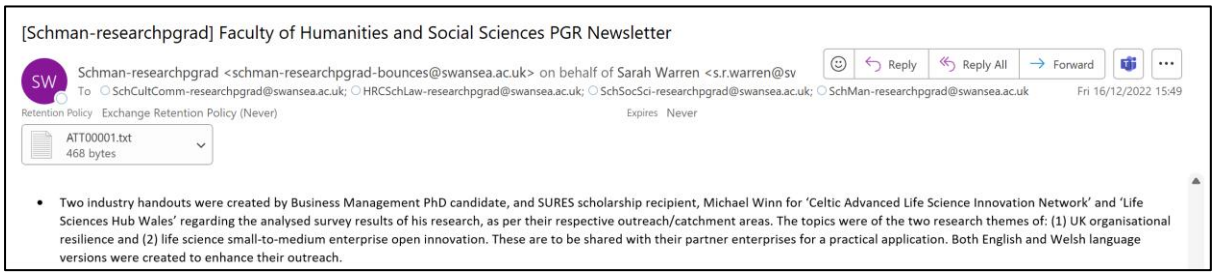
Appendix R: Dissemination of Non-Traditional Research Outputs

LinkedIn Promotion of Industry Reports

CALIN	Life Sciences Hub Wales
	

At the time of writing, LinkedIn reported the impact of the reports as having 273 impressions for the CALIN, with 31.5% of those cited as being from micro and SMEs. Likewise, the report for the Life Sciences Hub Wales has 664 impressions, with 17% of those cited as being from micro and small-sized enterprises.

Email Promotion of Industry Reports to Academic Peers (Cropped)



[Schman-researchpgrad] Faculty of Humanities and Social Sciences PGR Newsletter

SW

Schman-researchpgrad <schman-researchpgrad-bounces@swansea.ac.uk> on behalf of Sarah Warren <s.r.warren@sv

Reply | Reply All | Forward

To SchCultComm-researchpgrad@swansea.ac.uk; HRCSchLaw-researchpgrad@swansea.ac.uk; SchSocSci-researchpgrad@swansea.ac.uk; SchMan-researchpgrad@swansea.ac.uk

Fri 16/12/2022 15:49

Retention Policy Exchange Retention Policy (Never)

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- Two industry handouts were created by Business Management PhD candidate, and SURES scholarship recipient, Michael Winn for 'Celtic Advanced Life Science Innovation Network' and 'Life Sciences Hub Wales' regarding the analysed survey results of his research, as per their respective outreach/catchment areas. The topics were of the two research themes of: (1) UK organisational resilience and (2) life science small-to-medium enterprise open innovation. These are to be shared with their partner enterprises for a practical application. Both English and Welsh language versions were created to enhance their outreach.

Chapter 8: References

Acquaah, M., Amoako-Gyampah, K., & Jayaram, J. (2011). Resilience in Family and Nonfamily Firms: An Examination of the Relationships between Manufacturing Strategy, Competitive Strategy, and Firm Performance. *International Journal of Production Research*, 49(18), 5527–5544. https://doi.org/10.1080/00207543.2011.563834

Adams, R., Bessant, J., & Phelps, R. (2006). Innovation Management Measurement: A Review. *International Journal of Management Reviews*, 8(1), 21–47. https://doi.org/10.1111/j.1468-2370.2006.00119.x

Alberto, B., Ferraris, A., De, B. P., & Bernardo, B. (2022). Challenges to Open Innovation in Traditional SMEs: An Analysis of Pre-Competitive Projects in University-Industry-Government Collaboration. *International Entrepreneurship and Management Journal*, 18(1), 89-104. https://doi.org/10.1007/s11365-020-00727-1

Albright, S. C. & Winston, W. L. (2020). *Business Analytics: Data Analysis and Decision Making* (7th ed.). Cengage.

Almirall, E., & Casadesus-Masanell, R. (2010). Open versus Closed Innovation: A Model of Discovery and Divergence. *The Academy of Management Review*, 35(1), 27-47. https://doi.org/10.5465/AMR.2010.45577790

Annarelli, A., & Nonino, F. (2016). Strategic and Operational Management of Organizational Resilience: Current State of Research and Future Directions. *Omega*, 62, 1-18. https://doi.org/10.1016/j.omega.2015.08.004

Asthana, S., Jones, R., & Sheaff, R. (2019). Why does the NHS Struggle to Adopt eHealth Innovations? A Review of Macro, Meso and Micro Factors. *BioMed Central Health Services Research*, 19, 1-7. https://doi.org/10.1186/s12913-019-4790-x

Audretsch, D. B., & Belitski, M. (2013). The Missing Pillar: The Creativity Theory of Knowledge Spillover Entrepreneurship. *Small Business Economics*, 41(4), 819–836. https://doi.org/10.1007/s11187-013-9508-6

Audretsch, D. B., Lehmann, E. E., & Warning, S. (2004). University Spillovers: Does the Kind of Science Matter? *Industry and Innovation*, 11(3), 193–205. https://doi.org/10.1080/1366271042000265375

Auzzir, Z. (2019). *A Business Continuity Management (BCM) Framework for Disaster Resilient SMEs in Malaysia* [Doctoral Dissertation]. University of Huddersfield Repository. http://eprints.hud.ac.uk/id/eprint/34944/

Aylward, M., Phillips, C., & Howson, H., (2013). *Simply Prudent Healthcare* (Discussion Paper). Bevan Commission. https://bevancommission.org/simply-prudent-healthcare-achieving-better-care-and-value-for-money-in-wales/

Bacon, E. (2019). *Open Innovation Ecosystems: A Multi-Method Assessment of Knowledge Transfer Success* [Doctoral Dissertation, Swansea University]. Cronfa. https://cronfa.swan.ac.uk/Record/cronfa59511

Bagheri, M. (2021). *Linking the Degree of Internationalization and Small and Medium-Sized Firm Performance through Entrepreneurial Orientation and Open Innovation: A Moderated Mediation Model* [Doctoral Dissertation, Bangor University]. British Library EThOS. https://ethos.bl.uk/OrderDetails.do?uin=uk.bl.ethos.844879

Bak, O., Shaw, S., Colicchia, C., & Kumar, V. (2020). A Systematic Literature Review of Supply Chain Resilience in Small-Medium Enterprises (SMEs): A Call for Further Research. *IEEE Transactions on Engineering Management*, 1–14. https://doi.org/10.1109/TEM.2020.3016988

Baracchi, C. (2015). *The Bloomsbury Companion to Aristotle*. Bloomsbury Academic.

Barão, A., De Vasconcelos, J. B., Rocha, Á., & Pereira, R. (2017). A Knowledge Management Approach to Capture Organizational Learning Networks. *International Journal of Information Management*, 37(6), 735-740. https://doi.org/10.1016/j.ijinfomgt.2017.07.013

Barton, D. (2023). *Business Population Estimates for the UK and the Regions 2022*. Department for Business, Energy, and Industrial Strategy. https://www.gov.uk/government/statistics/business-population-estimates-2023/business-population-estimates-for-the-uk-and-regions-2023-statistical-release

British Broadcasting Corporation. (2024). *Legislation*. Bitesize. https://www.bbc.co.uk/bitesize/guides/zcs4ng8/revision/2

Bell, E., Harley, B., & Bryman, A. (2022). *Business Research Methods* (6th ed.). Oxford University Press.

Belussi, F., Sammarra, A., & Sedita, S. R. (2010). Learning at the Boundaries in an Open Regional Innovation System: A Focus on Firms' Innovation Strategies in the Emilia Romagna Life Science Industry. *Research Policy*, 39(6). https://doi.org/10.1016/j.respol.2010.01.014a

Bessant, J. & Tidd, J. (2015). *Innovation and Entrepreneurship* (3rd ed.). Wiley Textbooks.

Bernstein, S. (2015). Does Going Public Affect Innovation? *The Journal of Finance*, 70(4), 1365–1403. https://doi.org/10.1111/jofi.12275

Beynon, M. J., Jones, P., & Pickernell, D. (2020a). SME Development Strategy and Product/Service Innovation Intention: A NCaRBS Analysis of the role of Uncertainty. *International Journal of Entrepreneurship and Innovation*, 21(1), 3-16. https://doi.org/10.1177/1465750318807401

Beynon, M. J., Jones, P., Pickernell, D., & Huang, S. (2020b). Growth and Innovation of SMEs in Local Enterprise Partnerships Regions: A Configurational Analysis using fsQCA. *International Journal of Entrepreneurship and Innovation*, 21(2), 83-100. https://doi.org/10.1177/1465750319846827

Biedenbach, T. & Jacobsson, M. (2016). The Open Secret of Values: The Roles of Values and Axiology in Project Research. *Project Management Journal*, 47(3), 139–155. https://doi.org/10.1177/875697281604700312

Bogers, M., Chesbrough, H., & Moedas, C. (2018). Open Innovation: Research, Practices, and Policies. *California Management Review*, 60(2), 5-16. https://doi.org/10.1177/0008125617745086

Bowen, R. (2017). *Internationalisation of Food and Drink SMEs: Towards a Recipe for Success* [Doctoral Thesis]. Aberystwyth University Repository. http://hdl.handle.net/2160/001d31b7-cdf7-42fd-bcb0-4e87223b5250

Branicki, L. J., Sullivan-Taylor, B., & Livschitz, S. R. (2018). How Entrepreneurial Resilience Generates Resilient SMEs. *International Journal of Entrepreneurial Behaviour & Research*, 24(7), 1244–1263. https://doi.org/10.1108/IJEBR-11-2016-0396

Braun, V., & Clarke, V. (2022). *Thematic Analysis: A Practical Guide*. SAGE.

British Standards Institute. (2021). *Organizational Resilience Index Report*. https://www.bsigroup.com/globalassets/localfiles/en-gb/organizational-resilience/bsi-organisational-resilience-index-report-2021.pdf

Brunswicker, S., & Vanhaverbeke, W. (2015). Open Innovation in Small and Medium-Sized Enterprises (SMEs): External Knowledge Sourcing Strategies and Internal Organizational Facilitators. *Journal of Small Business Management*, 53(4), 1241-1263. https://doi.org/10.1111/jsbm.12120

Bryman, A., & Cramer, D. (2011). *Quantitative Data Analysis with IBM SPSS 17, 18 and 19: A Guide for Social Scientists*. Hove: Routledge.

Buckley, B. (2022). *Data Protection Policy*. Swansea University. https://www.swansea.ac.uk/about-us/compliance/data-protection/data-protection-policy/

Burnard, K., & Bhamra, R. (2011). Organisational Resilience: Development of a Conceptual Framework for Organisational Responses. *International Journal of Production Research*, 49(18), 5581–5599. https://doi.org/10.1080/00207543.2011.563827

Burnett, K. A., & Danson, M. (2016). Sustainability and Small Enterprises in Scotland's Remote Rural 'Margins'. *Local Economy*, 31(5), 539-553. https://doi.org/10.1177/0269094216655518

Burnett, K. A., & Danson, M. (2017). Enterprise and Entrepreneurship on Islands and Remote Rural Environments. *International Journal of Entrepreneurship and Innovation*, 18(1), 25-35. https://doi.org/10.1177/1465750316686237

Burr, V. (2015). *Social Constructionism* (3rd ed.). Routledge.

Caliendo, M., Fossen, F. M., & Kritikos, A. S. (2009). Risk Attitudes of Nascent Entrepreneurs. *Small Business Economics*, 153–167. https://doi.org/10.1007/s11187-007-9078-6

CALIN. (2023). *About*. https://www.calin.wales/en/about

Camm, J., Fry, M. J., & Ohlmann, J. W. (2021). *Business Analytics* (4th ed.). Cengage Learning, Inc.

Carayannis, E. G. & Campbell, D. F. J. (2011). Open Innovation Diplomacy and a 21st Century Fractal Research, Education and Innovation (FREIE) Ecosystem: Building on the Quadruple and Quintuple Helix Innovation Concepts and the 'Mode 3' Knowledge Production System. *Journal of the Knowledge Economy*, 2(3), 327–372. https://doi.org/10.1007/s13132-011-0058-3

Carayannis, E. G., Grigoroudis, E., Stamati, D., & Valvi, T. (2021). Social Business Model Innovation: A Quadruple/Quintuple Helix-Based Social Innovation Ecosystem. *IEEE Transactions on Engineering Management*, 68(1), 235–248. https://doi.org/10.1109/TEM.2019.2914408

Chesbrough, H. (2003). *Open Innovation*. Harvard Business School Press.

Chesbrough, H. (2019). *Open Innovation Results* (1st ed.). Oxford University Press.

Chiesa, V., Coughlan, P., & Voss, C. A. (1996). Development of a Technical Innovation Audit. *The Journal of Product Innovation Management*, 13(2), 105–136. https://doi.org/10.1111/1540-5885.1320105

Cohen. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.). Lawrence Erlbaum Associates.

Cole, G. A. & Kelly, P. (2020). *Management Theory and Practice* (9th ed.). Cengage Learning EMEA.

Collis, J., & Hussey, R. (2021). *Business Research: A Practical Guide for Students* (5th ed.). London: Red Globe Press.

Coltman, T., Devinney, T. M., Midgley, D. F., & Venaik, S. (2008). Formative versus Reflective Measurement Models: Two Applications of Formative Measurement. *Journal of Business Research*, 61(12), 1250–1262. https://doi.org/10.1016/j.jbusres.2008.01.013

Conz, E., Denicolai, S., & Zucchella, A. (2017). The Resilience Strategies of SMEs in Mature Clusters. *Journal of Enterprising Communities: People and Places in the Global Economy*, 11(1). https://doi.org/10.1108/JEC-02-2015-0015

Cormican, K., & O'Sullivan, D. (2004). Auditing Best Practice for Effective Product Innovation Management. *Technovation*, 24(10), 819-829. https://doi.org/10.1016/S0166-4972(03)00013-0

Crowther, D., & Green, M. (2004). *Organisational Theory*. Chartered Institute of Personnel and Development.

Daft, R. L. (2001). *Organization Theory and Design* (7th ed.). South Western College Publishing.

Dahlander, L., & Piezunka, H. (2014). Open to Suggestions: How Organizations Elicit Suggestions Through Proactive and Reactive Attention. *Research Policy*, 43(5), 812-827. https://doi.org/10.1016/j.respol.2013.06.006

Dahles, H., & Susilowati, T. P. (2015). Business Resilience in Times of Growth and Crisis (G. Waitt, ed.). *Annals of Tourism Research*, 51, 34-50. https://doi.org/10.1016/j.annals.2015.01.002

Daniel, L. J., de Villiers Scheepers, M. J., Miles, M. P., & de Klerk, S. (2022). Understanding Entrepreneurial Ecosystems Using Complex Adaptive Systems Theory: Getting the Big Picture for Economic Development, Practice, and Policy. *Entrepreneurship and Regional Development*, *34*(9–10), 911–934. https://doi.org/10.1080/08985626.2022.2083691

Davies, F. (2018). *An Evaluation of Corporate Social Responsibility (CSR) in Small and Medium-Sized Enterprises (SMEs): The Role of Moral Perspectives* [Doctoral Thesis, Swansea University]. British Library EThOS. https://ethos.bl.uk/OrderDetails.do?uin=uk.bl.ethos.767089

Davies, F., Howson, T., Boy, F., Joyce, N., & Davies, G. (2020). *BUCANIER: A Cross-Border Innovation Ecosystem*. European Conference on Innovation and Entrepreneurship, 2020-, 203–211.

Davies, G. H., Roderick, S., & Williams, M. (2017). *A Sub-Regional Innovation Ecosystem? Life Sciences and Health in the Swansea Bay City Region.* Proceedings of the European Conference on Innovation and Entrepreneurship, 182-189.

Dayan, M. (2020). How will BREXIT Affect the Supply of Medicines? *British Medical Journal*, 371. https://doi.org/10.1136/bmj.m4303

Denscombe, M. (2017). *The Good Research Guide: for Small-Scale Social Research Projects: For Small-Scale Social Research Projects.* McGraw-Hill Education.

Department for Business Energy and Industrial Strategy. (2023). *BEIS Small and Medium Enterprises (SMEs) Action Plan: 2022-2025*. Crown. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1132723/beis-sme-action-plan-2022-to-2025.pdf

de Vaus, D. A. (2014). *Surveys in Social Research* (6th ed.). Routledge.

Donaldson, L. (2001). *The Contingency Theory of Organizations*. SAGE.

Doz, Y. L., & Kosonen, M. (2008). *Fast Strategy: How Strategic Agility Will Help You Stay Ahead of the Game*. Pearson/Longman. https://books.google.co.uk/books?id=AoX0xT-09oQC

Duchek, S. (2020). Organizational Resilience: A Capability-Based Conceptualization. *Business Research*, 13(1), 215–246. https://doi.org/10.1007/s40685-019-0085-7

Enkel, E., Gassmann, O., & Chesbrough, H. (2009). Open R&D and Open Innovation: Exploring the Phenomenon. *R and D Management*, 39(4), 311-316. https://doi.org/10.1111/j.1467-9310.2009.00570.x

Equality and Human Rights Commission. (2021). *Protected Characteristics*. https://www.equalityhumanrights.com/equality/equality-act-2010/protected-characteristics

Escoffier, L., La Vopa, A., Speser, P. L., & Satinsky, D. (2016). *Open Innovation Essentials for Small and Medium Enterprises* (1st ed.). Business Expert Press.

Euchner, J. (2011). The Evolution of Open Innovation: An Interview with Henry Chesbrough. *Research Technology Management*, 54(5), 13-18. https://doi.org/10.5437/08956308X5405003

Evans, J. R. (2016). *Business Analytics: Methods, Models, and Decisions* (2nd ed.). Pearson Education.

Faulkner, A., & Kent, J. (2001). Innovation and Regulation in Human Implant Technologies: Developing Comparative Approaches. *Social Science & Medicine*, 53(7), 895–913. https://doi.org/10.1016/S0277-9536(00)00389-0

Fearne, A., Wagner, B., McDougall, N., & Loseby, D. (2021). The Power of Purpose: Lessons in Agility from the Ventilator Challenge. *Supply Chain Management*, 26(6), 753–766.

Field, A. (2018). *Discovering Statistics using IBM SPSS Statistics* (5th ed.). SAGE.

Fielding, N., Lee, R., & Blank, G. (2017). *The SAGE Handbook of Online Research Methods*. SAGE. https://doi.org/10.4135/9781473957992

Florida, R., Adler, P., & Mellander, C. (2017). The City as Innovation Machine. *Regional Studies*, 51(1), 86–96. https://doi.org/10.1080/00343404.2016.1255324

Forés, B. & Camisón, C. (2016). Does Incremental and Radical Innovation Performance Depend on Different Types of Knowledge Accumulation Capabilities and Organizational Size? *Journal of Business Research*, 69(2), 831–848. https://doi.org/10.1016/j.jbusres.2015.07.006

Fortuin, F. T., & Omta, S. W. (2008). *The Dark Side of Open Innovation: A Survey of Failed Inter-Company Cooperation.* In J. H. Trienekens (Eds.), 8th International Conference on Management in AgriFood Chains and Networks (pp. 1-10). Wageningen Academic Publishers. https://library.wur.nl/WebQuery/wurpubs/fulltext/3010

Fraser of Allander Institute (2017). *The Economic Contribution of the Pharmaceutical Sector in Scotland*. University of Strathclyde Business School. https://fraserofallander.org/wp-content/uploads/2021/02/2017-11-Economic-impact-of-Scottish-Pharmaceutical-Sector.pdf

Flyvbjerg, B. (2006). *Making Organization Research Matter: Power, Values and Phronesis*. In Clegg, S. R., Hardy, C., Lawrence, T. B., & Nord, W. R. (Eds.), *The SAGE Handbook of Organization Studies* (2nd ed., pp. 370-387). SAGE.

Galbraith, B., McAdam, R., Woods, J., & McGowen, T. (2017). Putting Policy into Practice: An Exploratory Study of SME Innovation Support in a Peripheral UK Region. *Entrepreneurship and Regional Development*, 29(7-8), 668-691. https://doi.org/10.1080/08985626.2017.1325939

García-Vidales, M.-Y., Maldonado-Guzmán, G., & Pinzón-Castro, S.-Y. (2019). The Influence of Open Innovation Practices on Business Performance in Mexican Family and Non-Family SMEs. *Estudios Gerenciales*, 35(153), 370–378. https://doi.org/10.18046/j.estger.2019.153.3202

Garengo, P., & Bernardi, G. (2007). Organizational Capability in SMEs: Performance Measurement as a Key System in Supporting Company Development. *International Journal of Productivity and Performance Management*, 56(5/6), 518-532. https://doi.org/10.1108/17410400710757178

Gauriot, R., & Page, L. (2019). Does Success Breed Success? A Quasi-Experiment on Strategic Momentum in Dynamic Contests. *The Economic Journal*, 129(624), 3107–3136. https://doi.org/10.1093/ej/uez040

Ghio, N., Guerini, M., Lehmann, E. E., & Rossi-Lamastra, C. (2015). The Emergence of the Knowledge Spillover Theory of Entrepreneurship. *Small Business Economics*, 44(1), 1-18. https://doi.org/10.1007/s11187-014-9588-y

Given, L. M. (2008). *The SAGE Encyclopedia of Qualitative Research Methods*. SAGE.

Goldberg, A. (2020). *How Collaboration will Strengthen the Future of Cell and Gene Therapies* (White Paper). Ernst and Young. https://assets.ey.com/content/dam/ey-sites/ey-com/en_gl/topics/life-sciences/ey-pointellis-cell-and-gene-therapy-whitepaper-final2.pdf

Gough, J. (2021). *Business Insights and Impact on the UK Economy*. Office for National Statistics. Crown. https://www.ons.gov.uk/businessindustryandtrade/business/businessservices/bulletins/businessinsightsandimpactontheukeconomy/25february2021

Graham, I. D., Logan, J., Harrison, M. B., Straus, S. E., Tetroe, J., Caswell, W., & Robinson, N. (2006). Lost in Knowledge Translation: Time for a map? *The Journal of Continuing Education in the Health Professions*, 26(1), 13–24. https://doi.org/10.1002/chp.47

Gray, D., & Jones, K. F. (2016). Using Organisational Development and Learning Methods to Develop Resilience for Sustainable Futures with SMEs and Micro Businesses: The Case of the "Business Alliance". *Journal of Small Business and Enterprise Development*, 23(2), 474-494. https://doi.org/10.1108/JSBED-03-2015-0031

Gray, C. D. & Kinnear, P. R. (2017). *SPSS 19 Made Simple*. Routledge.

Green, E., Ritchie, F., Bradley, P., & Parry, G. (2021). Financial Resilience, Income Dependence and Organisational Survival in UK Charities. *Voluntas*, 32(5), 992–1008. https://doi.org/10.1007/s11266-020-00311-9

Hartman, R. S. (1961). The Logic of Value. *The Review of Metaphysics*, 14(3), 389-432. http://www.jstor.org/stable/20123831

Hatch, M. J., & Cunliffe, A. L. (2006). *Organization Theory: Modern, Symbolic, and Postmodern Perspectives* (2nd ed.). Oxford University Press.

Hausman, A. (2005). Innovativeness among Small Businesses: Theory and Propositions for Future Research. *Industrial Marketing Management*, 34(8), 773–782. https://doi.org/10.1016/j.indmarman.2004.12.009

Hayman, A. M. (2021). *SME Innovation and Growth: Towards a Support Framework* [Doctoral Thesis, Anglia Ruskin University]. Anglia Ruskin University Repository. https://aru.figshare.com/articles/thesis/SME_Innovation_and_Growth_Towards_a_Support_Framework/23767182

Health Research Authority. (2021). *Making Results Public*. National Health Service. https://www.hra.nhs.uk/planning-and-improving-research/policies-standards-legislation/research-transparency/making-results-public/

Heidegger, M. (2014). *Introduction to Metaphysics* (G. Fried & R. Polt, Trans.; 2nd ed.). Yale University Press. (Original work published 1953)

Henderson, A. (2015). Investment in Life Sciences in Scotland: Challenges and Opportunities. *Journal of Commercial Biotechnology*, 21(4), 29-34. https://commercialbiotechnology.com/article-detail/?id=719

Herbane, B. (2010). Small Business Research: Time for a Crisis-Based View. *International Small Business Journal*, 28(1), 43–64. https://doi.org/10.1177/0266242609350804

Herbane, B. (2019). Rethinking Organizational Resilience and Strategic Renewal in SMEs. *Entrepreneurship and Regional Development*, 31(5-6), 476–495. https://doi.org/10.1080/08985626.2018.1541594

Herbane, B. (2020). Locational Contiguity and Business Continuity: Perceived Organizational Resilience of Small- and Medium-Sized Enterprises in U.K. Business Parks. *SAGE Open*, 115. https://doi.org/10.1177/2158244020927417

HM Government. (2021). *Life Science Vision: Build Back Better, Our Plan for Growth*. Crown. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1013597/life-sciences-vision-2021.pdf

Hoang, H., & Rothaermel, F. T. (2016). How to Manage Alliances Strategically. *Sloan Management Review*. https://sloanreview.mit.edu/article/how-to-manage-alliances-strategically/

Honderich, J. (2005). *The Oxford Companion to Philosophy* (2nd ed.). Oxford University Publishing.

Howson, T. & Davies, G. (2018). *From Mind to Market: Innovation Insights from the Welsh Life Sciences and Health Ecosystem*. European Conference on Innovation and Entrepreneurship, 2018-, 309–318.

Howson, T., Davies, G., Joyce, N., & Davies, F. (2019). *Bench to Bedside: A Tool to Support Life Science and Health Innovation Management*. European Conference on Innovation and Entrepreneurship, 1, 383–391.

Hulley, Cummings, S. R., Browner, W. S., Grady, D. G., & Newman, T. B. (2013). *Designing Clinical Research* (4th ed.). Wolters Kluwer/Lippincott Williams & Wilkins.

Iborra, M., Safón, V., & Dolz, C. (2020). What Explains the Resilience of SMEs? Ambidexterity Capability and Strategic Consistency. *Long Range Planning*, 53(6). https://doi.org/10.1016/j.lrp.2019.101947

IBM. (2022). *IBM SPSS Statistics Base 28*. https://www.ibm.com/docs/en/SSLVMB_28.0.0/pdf/IBM_SPSS_Statistics_Base.pdf

Jackson, K., & Bazeley, P. (2019). *Qualitative Data Analysis with NVivo* (3rd ed.). SAGE.

Jarvis, C. B., Mackenzie, S. B., Podsakoff, P. M., Giliatt, N., & Mee, J. F. (2003). A Critical Review of Construct Indicators and Measurement Model Misspecification in Marketing and Consumer Research. *The Journal of Consumer Research*, 30(2), 199–218. https://doi.org/10.1086/376806

Jarvis, P. (2019). *Company of One*. Penguin Business.

Jones, P., Patz, R., Thomas, B., & McCarthy, S. (2014). Micro-Sized Enterprises, Innovation and Universities: A Welsh Perspective. *Industry & Higher Education*, 28(1), 39-49. https://doi.org/10.5367/ihe.2014.0192

Ju, J. (2023). How Open Innovation Drives Intellectual Capital to Superior Organizational Resilience: Evidence from China's ICT Sector. *Journal of Intellectual Capital*. https://doi.org/10.1108/JIC-12-2022-0251

Kim, W. C., & Mauborgne, R. (2005). *Blue Ocean Strategy: How to Create Uncontested Market Space and Make the Competition Irrelevant*. Harvard Business School Press.

Kirkpatrick, A., O'Connor, J., Campbell, A., & Cooper, M. (2023). *Web Content Accessibility Guidelines (WCAG) 2.1*. World Wide Web Consortium. https://www.w3.org/TR/WCAG21/

Kmieciak, R., & Michna, A. (2018). Knowledge Management Orientation, Innovativeness, and Competitive Intensity: Evidence from Polish SMEs. *Knowledge Management Research & Practice*, 16(4), 559-572. https://doi.org/10.1080/14778238.2018.1514997

Korber, S., & McNaughton, R. B. (2018). Resilience and Entrepreneurship: A Systematic Literature Review. *International Journal of Entrepreneurial Behavior & Research*, 24(7). https://doi.org/10.1108/IJEBR-10-2016-0356

Kraemer, H. & Blasey, C. (2016). How Many Subjects? Statistical Power Analysis in Research (2nd ed.). SAGE.

Kumar, M., Rich, N., Kumar, M., & Liu, Y. (2021). Creating Highly Reliable Health Care Organisations Through Reverse Exchanges. *Supply Chain Management*, 26(3), 371–384. https://doi.org/10.1108/SCM-03-2020-0123

Lai, Y., Saridakis, G., Blackburn, R., & Johnstone, S. (2016). Are the HR Responses of Small Firms Different from Large Firms in Times of Recession? *Journal of Business Venturing*, 31(1), 113-131. https://doi.org/10.1016/j.jbusvent.2015.04.005

Lawrence, P. R., & Lorsch, J. William. (1969). *Organization and Environment: Managing Differentiation and Integration.* Irwin.

Lengnick-Hall, C. A., Beck, T. E., & Lengnick-Hall, M. (2011). Developing a Capacity for Organizational Resilience through Strategic Human Resource Management. *Human Resource Management Review*, 21(3), 243-255. https://doi.org/10.1016/j.hrmr.2010.07.001

Lettieri, E., Bartoli, L., & Masella, C. (2013). Coordinating Intra-Sector Services in Healthcare: Requirements and Elements that Managers Should Take into Account. *European Management Journal*, 31(6), 591-601. https://doi.org/10.1016/j.emj.2013.05.004

Li, Y., Li, X., Liu, Y., & Barnes, B. R. (2011). Knowledge Communication, Exploitation and Internal Innovation: The Moderating Effects of Internal Controls in SMEs. *R and D Management*, 41(2), 156-172. https://doi.org/10.1111/j.1467-9310.2011.00634.x

Life Sciences Scotland. (2023). *Animal Health, Agritech & Aquaculture*. https://www.lifesciencesscotland.com/animal-agriculture-technology-aquaculture

Lopes, A. P., & de Carvalho, M. M. (2018). Evolution of the Open Innovation Paradigm: Towards a Contingent Conceptual Model. *Technological Forecasting & Social Change*, 132, 284-298. https://doi.org/10.1016/j.techfore.2018.02.014

Malerba, F., & Orsenigo, L. (2015). The Evolution of the Pharmaceutical Industry. *Business History*, 57(5), 664-687. https://doi.org/10.1080/00076791.2014.975119

Marangos, S., & Warren, L. (2017). A Mapping for Managers: Open Innovation for R&D Intensive SMEs in the Life Sciences Sector. *European Journal of Innovation Management*, 20(2), 210-229. https://doi.org/10.1108/EJIM-12-2015-0133

Marom, S., Lussier, R. N., & Sonfield, M. (2019). Entrepreneurial Strategy: The Relationship between Firm Size and Levels of Innovation and Risk in Small Businesses. *Journal of Small Business Strategy*, 29(3), 33-45. https://www.proquest.com/docview/2354876185

Márquez, F. O. S., & Ortiz, G. E. R. (2020). Entrepreneurship and Micro Enterprise: A Theoretical Approach to its Differences. *Journal of Entrepreneurship Education*, 23, 1–6.

Mayho, S., Mumford, D., Ellis, L., Lloyd, D. C., Redmond, E. C., & Clifton, N. (2024). The Evolution of Regional Triple Helix Food Sector SME Interventions: A Longitudinal Study, Wales, UK. *European Planning Studies*. https://doi.org/10.1080/09654313.2024.2325021

McAvoy, J. & Brace, N. (2014). *Investigating Methods*. The Open University.

Metz, T. (2011). *The Good, The True, and The Beautiful: Toward a Unified Account of Great Meaning in Life*. Religious Studies, 47(4), 389–409. https://doi.org/10.1017/S0034412510000569

Meyer, A. D. (1982). Adapting to Environmental Jolts. *Administrative Science Quarterly*, 27(4), 515-537. https://doi.org/10.2307/2392528

Microsoft. (2023). *General Data Protection Regulation Summary*. Microsoft Compliance. https://learn.microsoft.com/en-us/compliance/regulatory/gdpr

Mina, A., Ramlogan, R., Tampubolon, G., & Metcalfe, J. S. (2007). Mapping Evolutionary Trajectories: Applications to the Growth and Transformation of Medical Knowledge. *Research Policy*, 36(5), 789–806. https://doi.org/10.1016/j.respol.2006.12.007

Minari, J., Yoshizawa, G., & Shinomiya, N. (2020). COVID-19 and the Boundaries of Open Science and Innovation. *EMBO Reports*, 21(11). https://doi.org/10.15252/embr.202051773

Mirghaderi, S. A., Sheikh Aboumasoudi, A., & Amindoust, A. (2023). Developing an Open Innovation Model in the Startup Ecosystem Industries based on the Attitude of Organizational Resilience and Blue Ocean Strategy. *Computers & Industrial Engineering*, 181, 109301–. https://doi.org/10.1016/j.cie.2023.109301

Moore, N. (2016). Beyond the Referendum. *British Medical Journal*, 353, 1-3. https://doi.org/10.1136/bmj.i3591

Morrison, M. (2021). *The Promises and Challenges of Biomodifying Technologies for the UK*. Open Access Government. https://www.openaccessgovernment.org/biomodifying-technologies/68041/

Muijs, D. (2011). *Doing Quantitative Research in Education with SPSS* (2nd ed.). SAGE.

Neale, B., Berry, J., & McGreal, S. (2007). Regional Spatial Policy for Economic Growth: Lessons from the Deployment of Collaborative Planning in Northern Ireland. *Urban Studies*, 44(3), 439-455. https://doi.org/10.1080/00420980601131928

Nickolas, S. (2023). *Correlation Coefficients: Positive, Negative, and Zero*. Investopedia. https://www.investopedia.com/ask/answers/032515/what-does-it-mean-if-correlation-coefficient-positive-negative-or-zero.asp

Niemimaa, M., Järveläinen, J., & Heikkilä, M. (2019). Business Continuity of Business Models: Evaluating the Resilience of Business Models for Contingencies. *International Journal of Information Management*, 49, 208-216. https://doi.org/10.1016/j.ijinfomgt.2019.04.010

Nietzsche, F. (1997). *Twilight of the Idols* (R. Polt, Trans.). University of Massachusetts Boston. https://faculty.umb.edu/gary_zabel/Phil_100/Nietzsche_files/Friedrich-Nietzsche-Twilight-of-the-Idols-or-How-to-Philosophize-With-the-Hammer-Translated-by-Richard-Polt.pdf (Original work published 1889)

Nietzsche, F. (1968). *The Will to Power* (W. Kaufmann & R. J. Hollingdale, Trans). Vintage Books, New York. (Original work published 1901)

Nikolić, N., Jovanović, I., Nikolić, Đ., Mihajlović, I., & Schulte, P. (2019). Investigation of the Factors Influencing SME Failure as a Function of Its Prevention and Fast Recovery after Failure. *Entrepreneurship Research Journal*, 9(3). https://doi.org/10.1515/erj-2017-0030

Nilsson, N., & Minssen, T. (2018). Unlocking the Full Potential of Open Innovation in the Life Sciences through a Classification System. *Drug Discovery Today*, 23(4), 771-775. https://doi.org/10.1016/j.drudis.2018.01.002

North, D., & Smallbone, D. (2000). Innovative Activity in SMEs and Rural Economic Development: Some Evidence from England. *European Planning Studies*, 8(1), 87-106. https://doi.org/10.1080/096543100110947

Nummela, N., Loane, S., Bell, J., & Matlay, H. (2006). Change in SME Internationalisation: An Irish Perspective. *Journal of Small Business and Enterprise Development*, 13(4), 562-583. https://doi.org/10.1108/14626000610705750

O'Gorman, C., Byrne, O., & Pandya, D. (2008). How Scientists Commercialise New Knowledge via Entrepreneurship. *The Journal of Technology Transfer*, 33(1), 23–43. https://doi.org/10.1007/s10961-006-9010-2

Office for Life Sciences. (2011). *Strategy for UK Life Sciences* (Report 11/1429). Crown. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/32457/11-1429-strategy-for-uk-life-sciences.pdf

Office for Life Sciences. (2017). *Life Sciences Industrial Strategy*. Crown. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/650447/LifeSciencesIndustrialStrategy_acc2.pdf

Office for Life Sciences. (2020). *Bioscience and Health Technology Sector Statistics*. Crown. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1015316/Bioscience_and_Health_Technology_Statistics_2019_v2.pdf

Office for Life Sciences. (2022). *Life Science Competitiveness Indicators 2022: User Guide*. Crown. https://www.gov.uk/government/publications/life-science-sector-data-2022/life-science-competitiveness-indicators-2022-user-guide

Office for Life Sciences. (2023). *Life Sciences Competitiveness Indicators*. Crown. https://www.gov.uk/government/publications/life-sciences-sector-data-2023/life-sciences-competitiveness-indicators-2023

Oliver, D. (2017). When 'Resilience' Becomes a Dirty Word. *British Medical Journal*, 358. https://doi.org/10.1136/bmj.j3604

Omachonu, V. K., & Einspruch, N. G. (2010). Innovation in Healthcare Delivery Systems: A Conceptual Framework. *The Innovation Journal*, 15(1), 1–20.

Pal, R., Torstensson, H., & Mattila, H. (2014). Antecedents of Organizational Resilience in Economic Crises: An Empirical Study of Swedish Textile and Clothing SMEs. *International Journal of Production Economics*, 147, 410–428. https://doi.org/10.1016/j.ijpe.2013.02.031

Pallant, J. (2020). *SPSS Survival Manual* (7th ed.). Open University Press.

Pescaroli, G., Velazquez, O., Alcántara-Ayala, I., Galasso, C., Kostkova, P., & Alexander, D. (2020). A Likert Scale-Based Model for Benchmarking Operational Capacity, Organizational Resilience, and Disaster Risk Reduction. *International Journal of Disaster Risk Science*, 11, 404-409. https://doi.org/10.1007/s13753-020-00276-9

Pickernell, D., Clifton, N., & Senyard, J. (2009). Universities, SMEs and Innovation Frameworks: Think Global, Act Local? *Industry & Higher Education*, 23(2), 79–89. https://doi.org/10.5367/000000009788146575

Pickernell, D., Jones, P., & Beynon, M. J. (2019). Innovation performance and the role of clustering at the local enterprise level: a fuzzy-set qualitative comparative analysis approach. *Entrepreneurship and Regional Development*, 31(1-2), 82–103. https://doi.org/10.1080/08985626.2018.1537149

Pisano, G. (2011). Gary Pisano. *Nature Biotechnology*, 29(3), 183–183. https://doi.org/10.1038/nbt.1817

Plummer, L. A., & Acs, Z. J. (2014). Localized Competition in the Knowledge Spillover Theory of Entrepreneurship. *Journal of Business Venturing*, 29(1), 121-136. https://doi.org/10.1016/j.jbusvent.2012.10.003

Pontika, N., Knoth, P., Cancellieri, M., & Pearce, S. (2015). *Fostering Open Science to Research using a Taxonomy and an eLearning Portal*. i-KNOW '15: Proceedings of the 15th International Conference on Knowledge Technologies and Data-Driven Business (pp. 1-8). Graz, Austria: Open Research Online (Open University). http://oro.open.ac.uk/44719/2/kmi_foster_iknow.pdf

Porter, M. E. (1998). *On Competition*. Boston: Harvard Business School Publishing.

Porter, M. E. (2004). *Competitive Strategy*. Free Press.

Pugh, R. (2017). Universities and Economic Development in Lagging Regions: 'Triple Helix' Policy in Wales. *Regional Studies*, 51(7), 982-993. https://doi.org/10.1080/00343404.2016.1171306

Qualtrics (2023a). *Data Protection & Privacy*. https://www.qualtrics.com/support/survey-platform/getting-started/data-protection-privacy/

Qualtrics (2023b). *Interpreting Residual Plots to Improve Your Regression*. https://www.qualtrics.com/support/stats-iq/analyses/regression-guides/interpreting-residual-plots-improve-regression/

Qualtrics (2023c). *Survey vs Questionnaire: The Differences for Market Research*. https://www.qualtrics.com/uk/experience-management/research/survey-vs-questionnaire/

Radziwon, A., Bogers, M. L. A., Chesbrough, H., & Minssen, T. (2022). Ecosystem effectuation: Creating new value through open innovation during a pandemic. *R and D Management*, 52(2), 376–390. https://doi.org/10.1111/radm.12631

Ramos-Villagrasa, P. J., Marques-Quinteiro, P., Navarro, J., & Rico, R. (2018). Teams as Complex Adaptive Systems: Reviewing 17 Years of Research. *Small Group Research*, *49*(2), 135–176. https://doi.org/10.1177/1046496417713849

Raymond, L., & St-Pierre, J. (2010). R&D as a Determinant of Innovation in Manufacturing SMEs: An Attempt at Empirical Clarification. *Technovation*, 30(1), 48-56. https://doi.org/10.1016/j.technovation.2009.05.005

Rees, D. J., Bates, V., Thomas, R. A., Brooks, S. B., Laing, H., Davies, G. H., Williams, M., Phillips, L., & Dwivedi, Y. K. (2021). Collaborating to Deliver Value in Health Care: Exploring Conditions Required for Successful Healthcare and Life Science Sector Collaboration. *Transforming Government: People, Process and Policy*, 15(1), 169-190. https://doi.org/10.1108/TG-05-2020-0074

Reid, G. (2020). *Strength in Diversity. Universities Wales*. https://uniswales.ac.uk/sites/default/files/2021-09/Strength-in-Diversity-Professor-Graeme-Reid-FINAL.pdf

Restuccia, M., de Brentani, U., Legoux, R., & Ouellet, J.-F. (2016). Product Life-Cycle Management and Distributor Contribution to New Product Development. *The Journal of Product Innovation Management*, 33(1), 69–89. https://doi.org/10.1111/jpim.12261

Rezaei, N. (2020). COVID-19 and Medical Biotechnology. *Avicenna Journal of Medical Biotechnology*, 12(3), 139.

Richter, S., Yeh, R., Weinrob, R., Chen, Z., Patel, K., & Astor, A. (2018). *Profiles in Innovation: The Genome Revolution*. Goldman Sachs. https://ia802506.us.archive.org/34/items/goldmann-sachs-die-genom-revoulution-gesunde-menschen-sind-schlecht-furs-geschaft/Goldman%20Sachs%20-%20Profiles%20in%20Innovation%20-%20The%20Genome%20Revolution.pdf

Ridley, M. (2011). *The Rational Optimist* (1st ed.). Fourth Estate.

Ries, E. (2011). *The Lean Startup* (1st ed.). Penguin.

Ries, E. (2017). *The Startup Way* (1st ed.). Penguin.

Roberts, J. K., Pavlakis, A. E., & Richards, M. P. (2021). It's More Complicated Than It Seems: Virtual Qualitative Research in the COVID-19 Era. *International Journal of Qualitative Methods*, 20, 160940692110029–. https://doi.org/10.1177/16094069211002959

Robson, C., & McCartan, K. (2016). *Real World Research: A Resource for Users of Social Research Methods in Applied Settings* (4th ed.). John Wiley & Sons Ltd.

Romero, I., & Martínez-Román, J. A. (2012). Self-Employment and Innovation. Exploring the Determinants of Innovative Behavior in Small Businesses. *Research Policy*, 41(1), 178–189. https://doi.org/10.1016/j.respol.2011.07.005

Rothaermel, F. T., & Deeds, D. L. (2006). Alliance Type, Alliance Experience and Alliance Management Capability in High-Technology Ventures. *Journal of Business Venturing*, 21(4), 429-460. https://doi.org/10.1016/j.jbusvent.2005.02.006

Salge, T. O., Farchi, T., Barrett, M. I., & Dopson, S. (2013). When Does Search Openness Really Matter? A Contingency Study of Health-Care Innovation Projects. *Journal of Product Innovation Management*, 30(4), 659-676. https://doi.org/10.1111/jpim.12015

Santoro, G., Bertoldi, B., Giachino, C., & Candelo, E. (2020). Exploring the Relationship between Entrepreneurial Resilience and Success: The Moderating Role of Stakeholders' Engagement. *Journal of Business Research*, 119, 142–150. https://doi.org/10.1016/j.jbusres.2018.11.052

Santoro, G., Ferraris, A., Giacosa, E., & Giovando, G. (2016). How SMEs Engage in Open Innovation: A Survey. *Journal of the Knowledge Economy*, 9(2), 561-574. https://doi.org/10.1007/s13132-015-0350-8

Saunders, M. N. K., Lewis, P., & Thornhill, A. (2023). *Research Methods for Business Students* (9th ed.). Pearson Education Limited.

Schabacker, A., Levy, L.-A., Evans, N. J., Fowler, J. M., & Dickey, E. A. (2019). Assessing Cyberbiosecurity Vulnerabilities and Infrastructure Resilience. *Frontiers in Bioengineering and Biotechnology*, 7, 61. https://doi.org/10.3389/fbioe.2019.00061

Schrödinger, E. (1935). The Present Situation in Quantum Mechanics. *Naturwissenschaften*, 23, 807–812. https://doi.org/10.1007/BF01491891

Scottish Government. (2020). *Rural Planning Policy to 2050: Research Findings*. Crown. https://www.gov.scot/publications/rural-planning-policy-2050-research-inform-preparation-npf4/

Scott, M. G., Scullin, C., Hogg, A, Fleming, G. F., & McElnay, J. C. (2015). Integrated Medicines Management to Medicines Optimisation in Northern Ireland (2000–2014): A Review. *European Journal of Hospital Pharmacy: Science and Practice*, 22(4), 222-228. https://doi.org/10.1136/ejhpharm-2014-000512

Scott, W. R., & Davis, G. F. (2007). *Organizations and Organizing: Rational, Natural, and Open System Perspectives* (1st ed.). Pearson Prentice Hall.

Shaw, B. (2023). *Business Demography, UK*. Office for National Statistics, Open Government Licence. https://www.ons.gov.uk/businessindustryandtrade/business/activitysizeandlocation/bulletins/businessdemography/2022

Shore, A., Pittaway, L., & Bortolotti, T. (2023). From Negative Emotions to Personal Growth: Failure and Re-entry into Entrepreneurship. *British Journal of Management*. https://doi.org/10.1111/1467-8551.12785

Smith, A. (1977). *The Wealth of Nations* (W. Letwin, ed.). Dent. (Original work published 1776)

Steedman, M., & Taylor, K. (2019). *10 Years On: Measuring the Return from Pharmaceutical Innovation*. Centre for Health Solutions, Deloitte. https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/life-sciences-health-care/deloitte-uk-ten-years-on-measuring-the-return-2019.pdf

Steedman, M., Taylor, K., Properzi, F., Ronte, H., & Haughey, J. (2019). *Intelligent Biopharma: Forging the Links Across the Value Chain*. Deloitte Insights. https://www2.deloitte.com/us/en/insights/industry/life-sciences/rise-of-artificial-intelligence-in-biopharma-industry.html

Stokes, P. (2011). *Key Concepts in Business and Management Research Methods*. Palgrave Macmillan.

Stubbs, E. (2014). *Big Data, Big Innovation: Enabling Competitive Differentiation Through Business Analytics* (1st ed.). Wiley.

Sullivan-Taylor, B., & Branicki, L. (2011). Creating Resilient SMEs: Why One Size Might Not Fit All. *International Journal of Production Research*, 49(18), 5565-5579. https://doi.org/10.1080/00207543.2011.563837

Swansea University. (2020). *Strategic Equality Plan 2020-2024*. https://www.swansea.ac.uk/jobs-at-swansea/equality-and-diversity/what-we-do/monitoring/

Swansea University. (2022). *Research Privacy Notice*. https://www.swansea.ac.uk/about-us/compliance/data-protection/research-privacy-notice/

Swansea University. (2023). *General Health and Safety*. MyUni. https://myuni.swansea.ac.uk/living-in-swansea/health-and-safety/postgraduates/policies-and-procedures/general-health-and-safety/#risk-assessment=is-expanded

Sy, M., O'Leary, N., Nagraj, S., El-Awaisi, A., O'Carroll, V., & Xyrichis, A. (2020). Doing Interprofessional Research in the COVID-19 Era. *Journal of Interprofessional Care*, 34(5), 600–606. https://doi.org/10.1080/13561820.2020.1791808

Syed, M. (2015). *Black Box Thinking* (1st ed.). John Murray.

Syed, M. (2019). *Rebel Ideas*. John Murray.

Tabachnick, B. G., & Fidell, L. S. (2013). *Using Multivariate Statistics* (6th ed.). Pearson Education Limited.

Tannenbaum, R., & Schmidt, W. H. (1958). How to Choose a Leadership Pattern. *Harvard Business Review*, 36(2), p. 95-101. Harvard Business School Publishing Corporation.

Taylor, F. W. (2004). *The Principles of Scientific Management*. Project Gutenberg. (Original work published 1911)

ten Ham, R. M., Hoekman, J., Hövels, A. M., Broekmans, A. W., Leufkens, H. G., & Klungel, O. H. (2018). Challenges in Advanced Therapy Medicinal Product Development: A Survey among Companies in Europe. *Molecular Therapy: Methods & Clinical Development*, 11, 121-130. https://doi.org/10.1016/j.omtm.2018.10.003

The Lancet. (2018). *UK Life Science Research: Time to Burst the Biomedical Bubble*. 392(10143), 187. https://doi.org/10.1016/S0140-6736(18)31609-X

The Lancet. (2020). *Looking Beyond BREXIT*. 395, 390. https://doi.org/10.1016/S0140-6736(20)30291-9

Tidd, J. & Bessant, J. (2021). *Managing Innovation: Integrating Technological, Market and Organizational Change* (7th ed.). John Wiley & Sons.

Treanor, L., Noke, H., Marlow, S., & Mosey, S. (2021). Developing Entrepreneurial Competences in Biotechnology Early Career Researchers to Support Long-Term Entrepreneurial Career Outcomes. *Technological Forecasting & Social Change*, 164, 1-12. https://doi.org/10.1016/j.techfore.2020.120031

Trott, P. & Hartmann, D. (2013). *Open Innovation: Old Ideas in a Fancy Tuxedo Remedy a False Dichotomy*. In Tidd, J. (Eds.). *Open Innovation Research, Management and Practice* (chapter 13, pp. 359–386). Imperial College Press. https://doi.org/10.1142/9781783262816_0014

UK Parliament. (2018). *A Revolution from Within: Transforming Health and Care in Wales*. Crown. https://www.gov.wales/sites/default/files/publications/2018-01/Review-health-social-care-report-final.pdf

van de Vrande, V., de Jong, J. P., Vanhaverbeke, W., & de Rochemont, M. (2009). Open Innovation in SMEs: Trends, Motives and Management Challenges. *Technovation*, 29(6-7), 423-437. https://doi.org/10.1016/j.technovation.2008.10.001

Varis, M., & Littunen, H. (2010). Types of Innovation, Sources of Information and Performance in Entrepreneurial SMEs. *European Journal of Innovation Management*, 13(2), 128-154. https://doi.org/10.1108/14601061011040221

Veer, T., Lorenz, A. & Blind, K. (2013). How Open is too Open? The 'Dark Side' of Openness along the Innovation Value Chain. *R and D Management*, 29(1),3–15.

Veer, T., Lorenz, A., & Blind, K. (2016). How Open is too Open? The Mitigating Role of Appropriation Mechanisms in R&D Cooperation Settings. *R and D Management*, 46(S3), 1113–1128. https://doi.org/10.1111/radm.12232

Veer, T., Yang, P. & Riepe, J. (2022). Ventures' conscious knowledge transfer to close partners, and beyond: A framework of performance, complementarity, knowledge disclosure, and knowledge broadcasting. *Journal of Business Venturing*, 37(3), https://doi.org/10.1016/j.jbusvent.2022.106191

Venkatesh, V., Brown, S. A., & Bala, H. (2013). Bridging the Qualitative-Quantitative Divide: Guidelines for Conducting Mixed Methods Research in Information Systems. *MIS Quarterly*, 37(1), 21–54. https://doi.org/10.25300/MISQ/2013/37.1.02

Verreynne, M.-L., Ho, M., & Linnenluecke, M. (2018). Guest Editorial: Organizational Resilience and the Entrepreneurial Firm. *International Journal of Entrepreneurial Behaviour & Research*, 24(7), 1122-1128. https://doi.org/10.1108/IJEBR-11-2018-533

von Bertalanffy, L. (1968). *General System Theory: Foundations, Development, Applications*. Allen Lane the Penguin Press. (Original work published 1928)

Weber, M. (1968). *Economy and Society*. (G. Roth & C. Wittich, Trans.). Bedminster Press. (Original work published 1921)

Wennberg, K., Wiklund, J., & Wright, M. (2011). The Effectiveness of University Knowledge Spillovers: Performance Differences Between University Spinoffs and Corporate Spinoffs. *Research Policy*, 40(8), 1128–1143. https://doi.org/10.1016/j.respol.2011.05.014

Williams, T. A., Gruber, D. A., Sutcliffe, K. M., Shepherd, D. A., & Zhao, E. Y. (2017). Organizational Response to Adversity: Fusing Crisis Management and Resilience Research Streams. *Academy of Management Annals*, 11(2). https://doi.org/10.5465/annals.2015.0134

Winn, M. (2021). *UK Life Science Open Innovation for Small-to-Medium Enterprise Resilience*. Institute of Small Business and Entrepreneurship Conference, Cardiff, 28-29 October. Cronfa. https://cronfa.swan.ac.uk/Record/cronfa66387/

Wishart, M. (2018). *Business Resilience in an SME Context: A Literature Review*. Enterprise Research Centre, University of Warwick and Aston University. https://www.enterpriseresearch.ac.uk/wp-content/uploads/2018/07/Resilience-review-Final.pdf

Woodward, J. (1965). *Industrial Organisation: Theory and Practice*. Oxford University Press.

Xing, Y., Liu, Y., Boojihawon, D. K., & Tarba, S. (2020). *Entrepreneurial Team and Strategic Agility: A Conceptual Framework and Research Agenda*. Human Resource Management Review, 30(1), 100696–. https://doi.org/10.1016/j.hrmr.2019.100696

Yawson., J. B. (2017). *Effect of Internal Innovation Climate and Strategic Partnerships with Suppliers on Open Innovation in SMEs* [Doctoral Thesis, Capella University]. ProQuest Dissertations Publishing. https://www.proquest.com/docview/1882247788

Zeegers, M., & Barron, D. (2015) *Milestone Moments in Getting your PhD in Qualitative Research* (1st ed.). Amsterdam: Chandos.

Zobel, A.-K., & Hagedoorn, J. (2020). Implications of Open Innovation for Organizational Boundaries and the Governance of Contractual Relations. *Academy of Management Perspectives*, *34*(3), 400–423. https://doi.org/10.5465/amp.2016.0175