FinTech and sustainable development: A systematic thematic analysis using human- and machine-generated processing

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A B S T R A C T

We conducted a systematic literature review (SLR) by integrating FinTech with the the United Nations' (UN) Sustainable Development Goals (SDGs). By focusing on three dimensions (inclusive finance, economy, and environment), we identify how FinTech may influence sustainable development. We innovate using human- and machine-generated processing to develop themes, making systematic literature reviews more objective and advancing replicability and reproducibility. This study demonstrates the contribution of FinTech in expanding the investment opportunity set by including environmental projects and increasing the diversity and participation rates of savers and lenders. Through this process, FinTech increases its market completeness. Accordingly, FinTech can increase economic growth by achieving higher productivity and sustainable growth through diversification, technological upgrades, entrepreneurship, creativity, and innovation. Additionally, FinTech can accelerate investments in poverty eradication and reduce income inequality. These contributions are aligned with specific SDGs and show that FinTech is an appropriate new technology for financial services.

1. Introduction

The United Nations (UN) is dedicated to promoting sustainable development, which strives to balance economic growth, social equity, and environmental protection while addressing pressing issues such as poverty, inequality, climate change, and resource depletion.[1] Furthermore, Lim et al. (2022a) argue that the coalescing of Environmental, Social, and Governance (ESG) and Total Quality Management (TQM) mechanisms can foster sustainable development. ESG principles emphasize organizations' ethical and responsible conduct, aligning values with stakeholders, and data-driven decision-making to measure and improve sustainability performance. With its focus on process optimization, employee engagement, and continuous improvement, TQM can effectively contribute to sustainability goals.

Acquah et al. (2023) show that incorporating green initiatives into TQM ensures that green finance investments are executed effectively and contribute to sustainability goals. Accordingly, integrating ESG principles and TQM is a multifaceted approach that synergizes financial

sustainability with environmental and social responsibilities. Integration promotes transparency through robust reporting practices, aligns strategic objectives with ESG and green finance goals, and fosters a resilient and competitive organization committed to a sustainable and responsible future for companies and society.

Potential catalysts for advancing sustainability and fostering the UN's sustainable development goals (SDGs) have emerged in FinTech and Industry 4.0.[2] These innovations enable streamlined financing for sustainable practices, establish transparent and traceable supply chains through blockchain, and automate sustainability commitments through smart contracts. Furthermore, these innovations provide real-time data analytics for informed decisions, optimize energy and resource allocation, fortify resilience against climate-related risks, foster continuous improvement, and bolster reporting and accountability mechanisms. According to Soni et al. (2022), FinTech and Industry 4.0 can be used by small and medium-sized firms to enhance their functioning and investment capability, particularly in supply chain financing.

FinTech can act as a catalyst for achieving sustainable development.

This technology can innovate and improve financial services, which, if applied prudently, can foster, facilitate, and promote sustainable development. Additionally, FinTech can increase accessibility, speed, and security, while reducing costs and promoting greater inclusion. This is particularly important in regions where education levels and financial literacy are low, and limited banking facilities exist. By leveraging FinTech solutions, the UN can facilitate sustainable investment, reduce carbon emissions, increase financial literacy, and promote sustainable development.

Given the ubiquitous nature of FinTech, researchers have focused on systematic literature reviews on the application and use of FinTech. Cai (2018) examines a niche element of FinTech through crowdfunding and blockchain. Similarly, Ahmad et al. (2020) show the relationship between mobile payments and inclusive financial development. Alkhowaiter (2020) presents a global perspective focusing on the determinants and factors of FinTech in GCC countries, and Bollaert et al. (2021) address how FinTech influences access to finance (inclusive finance) from the perspective of investors and firms. Kara et al. (2021) demonstrate how access to finance supports sustainable development goals through inclusive financial development. However, their study only covers access to finance and is limited to individuals' demographic and socioeconomic characteristics (such as gender, race, income, and education) with credit aspects. Therefore, the basic dimension of the existing systematic FinTech literature reviews includes inclusive financial development.

While inclusive financial development is an important indicator of sustainable development, economic and environmental impacts have been omitted. To increase the completeness of FinTech for sustainable development, we proceed with the research question, "*In which dimensions can FinTech influence and promote sustainable development?*"

Examining specific SDGs led to the identification of three dimensions targeting financial and innovative financial services. These are SDG 1 (end poverty), SDG 8 (promote sustained, inclusive, and sustainable economic growth, full and productive employment), SDG 9 (build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation), SDG 10 (reduce inequality within and among countries), SDG 11 (inclusive, safe, resilient, and sustainable cities and human settlements), and SDG 13 (take urgent action to combat climate change). After identifying specific SDG targets, we identified three dimensions in which FinTech can influence sustainable development.

The first dimension discusses the significance of access to finance (inclusive finance or financial inclusion), innovative financial services, affordable credit services, and other financial issues. The second dimension discusses how innovative financial services influence the economy, particularly in terms of poverty alleviation, income inequality reduction, and economic growth. Finally, the third dimension considers environmental quality improvement, particularly carbon emission reduction, as a critical environmental issue that determines sustainable development.

We expand the systematic literature review by integrating FinTech with the SDG. Kumar et al. (2022a, 2022b, 2023) use 'technology-empowered' and machine-learning approaches to conduct a systematic literature review. Goodell et al. (2021) use artificial intelligence and machine learning to identify themes and research clusters. Kumar et al. (2023) argue that artificial intelligence can complement operations and tasks that require human intelligence. Similarly, Ciasullo and Lim (2022)[3] envision the coexistence of machines and humans when executing tasks.

While the PRISMA model is employed, we innovate using human- and machine-generated processing to develop themes. Martin and Waldman (2022) examine machine-generated decisions, and Pethig and Kroenung (2022) compare human- and machine-generated decisions.

We use machine-generated concepts to make the systematic literature reviews more objective, thereby advancing replicability and reproducibility.

We principally follow Donthu et al. (2021) and incorporate elements of performance analysis with science mapping. However, we argue that coalescing artificial intelligence and human intelligence processing is iterative. While we commence with human processing followed by machine-generated processing, we reconcile the generated themes and clusters by reverting to human processing to close the feedback loop. This approach ensures that guidelines are formulated to advance both theory and practice.

From a financial perspective, this study finds that FinTech services significantly promote financial inclusion by increasing digital payment services, extending crowdfunding, peer-to-peer (P2P) lending, student microlending, motivating personal deposit accounts, integrating FinTech and e-commerce, and facilitating faster and easier lending processes.

In the economic dimension, FinTech promotes the economy by expanding market competition, increasing service sector employment opportunities, expanding financial activities, and encouraging sustainable agribusiness development. FinTech alleviates poverty by assisting households in managing budgets, motivating household savings, promoting entrepreneurial activities, and enabling the more efficient administration of new/existing businesses. FinTech reduces income inequality by promoting financial and economic activities through digital connectivity. However, FinTech can only reduce income inequality through the formal financial sector when education levels and skills are high and public policies are supportive.

In the environmental dimension, FinTech promotes renewable energy production and consumption, increases green financing in environmentally supportive projects, and fosters investment in low-carbon-emitting production technologies. FinTech reduces carbon emissions and improves environmental quality by promoting and motivating forestation initiatives and encouraging low-carbon behaviors among users to reduce carbon emissions.

This study demonstrates the contribution of FinTech in expanding the investment opportunity set by including environmental projects and increasing the diversity and participation rates of savers and lenders. This is particularly pertinent in developing countries where savers and lenders cannot access traditional banking systems. Through this process, FinTech increases market completeness in both developed and developing countries. Accordingly, FinTech can increase economic growth by achieving higher productivity and sustainable growth through diversification, technological upgrades, entrepreneurship, creativity, and innovation. Additionally, FinTech can accelerate investments in poverty eradication and reduce income inequality.

These contributions are aligned with specific SDGs for sustainable development and show that FinTech is an appropriate new technology for financial services. This strengthens the domestic financial institutions' ability to expand and encourage access to banking, insurance, and financial assistance. It also demonstrates how emerging FinTech technologies satisfy the environmental quality protection criteria of the SDGs, thereby reducing the per capita adverse environmental impact. The findings have important practical implications for FinTech consumers, service providers, policymakers, governments, and academics. In brief, the outcome of this study implies that if a bank provides consumer-friendly and cost-effective services by overcoming the challenges of supportive policies from regulators, access to FinTech will be promoted. In addition, there will be significant positive implications for overall financial, economic, and environmental aspects.

This paper is structured as follows. The first section discusses the literature review matrix, the second discusses systematic approaches to the study method, the third describes the conceptual framework, and the fourth presents our findings. Sections five and six discuss how FinTech connects with sustainable development and the challenges of FinTech access. Finally, implications, conclusions, and future research directions

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[3] Ciasullo et al. (2023) consider social innovation and resilience.

are presented in the eighth and ninth sections.

2. Systematic methodology

The methodology is presented in two sections: (i) methods for human-specified theme mapping and (ii) methods for machine-generated theme mapping. In this study, "human-specified thematic mapping" involved manually specifying themes and their mapping through human effort. In contrast, "machine-generated" refers to utilizing various bibliometric research tools that employ pre-defined machine-learning algorithms. These two approaches are discussed sequentially.

2.1. Methods for human specified themes

2.1.1. Setting the study scope

To clarify the scope and objectives of the research, we initially use the term "FinTech" to designate the research field. Since FinTech is an all-inclusive term, the scope of this study includes different FinTech services, such as mobile payment, mobile money, digital payment, alternative financing, and others.

Given FinTech's recency, we include an additional step in the systematic literature review process. The additional step previews the existing literature, ensures that the words and terms used for the subsequent systematic literature review are optimal, and identifies the gaps in the literature. The preview step and systematic literature review use identical screening procedures to maintain consistency and coherence.

2.1.2. Preview pilot step

As FinTech is an emerging research area, almost all articles were published between 2020 and 2022. Accordingly, the screening process was based on quality rather than quantity. First, we identify research papers published in *the Financial Times's top 50 journals (FT50)*, with an initial focus on papers from specific finance and economics journals included in the FT50 list. Subsequently, we extend our search to include all FT50 journals. Table 1 shows how leading journals, academics, and

Table 1
Relevant research published in elite journals.

Financial Time 50 Journal (FT50)	Count	ABDC	ABS
FT50 Finance and Economics domain			
Review of Financial Studies	32	A*	4*
Journal of Financial and Quantitative Analysis	11	A*	4
Review of Economic Studies	4	A*	4*
Journal of Financial Economics	3	A*	4*
Journal of Finance	2	A*	4*
Review of Finance	2	A*	4
FT50 Others domain			
Harvard Business Review	15	A	3
Journal of Management Information Systems	9	A*	4
Entrepreneurship Theory and Practice	7	A*	4
Research Policy	6	A*	4*
Management Science	5	A*	4*
Sloan Management Review	5	A	3
The Accounting Review	3	A*	4*
Production and Operations Management	2	A*	4
Information Systems Research	1	A*	4*
Journal of Operations Management	1	A*	4*
MIS Quarterly	1	A*	4*
Organization Science	1	A*	4*
Strategic Management Journal	1	A*	4*

Notes: FT50 refers to the Financial Times' top 50 journals in the greater business domain. ABS Rank refers to the journal ranking by the *Chartered Association of Business Schools (CABS)*. There are four ranks: 4*, 4, 3, 2, and 1. ABDC Journal Quality List refers to the journal listed by the *Australian Business Deans Council*. The ABDC list ranks the journal in four categories: A*, A, B, and C. See Joshi et al. (2023) also follow journal categories such as ABDC and CABS (ABS Ranking).

editors consider the different facets of FinTech. Therefore, previous systematic literature reviews have not fully captured the impact of FinTech.

2.1.3. Specifying study gaps and aims

Similar to Kara et al. (2021), our criteria specify that the article must be from a peer-reviewed academic journal, and the language must be English. Based on the previous pilot step, we extend our study scope to include "FinTech" and "sustainable development.". Thus, the systematic literature review incorporates inclusive finance, poverty reduction, income inequality reduction, economic growth, and CO_2 emissions reduction. These extensions are connected to the UN Sustainable Development Goals (SDGs).

Specifically, our study examines the impact of FinTech products/services on sustainable development, which the UN SDGs primarily measure. After specifying the specific sections of sustainable development that FinTech can influence, we segment the three dimensions in which FinTech may have a significant influence. These are the financial, economic, and environmental dimensions. In particular, access to financing through formal banking and FinTech is considered a financial dimension. Poverty alleviation, income inequality reduction, and economic growth are regarded as economic dimensions, while reducing adverse environmental impacts is considered as environmental dimension.

2.1.4. Searching the extended focus with specific keywords

After specifying the focus of the study, we search for articles on the Web of Science (WoS) platform. We limit our search to the Social Science Citation Index (SSCI) and Science Citation Index Expanded (SCIE), which are the most reliable and extensive indices for science and social science publications. In this stage, we use specific financial keywords as search words: *FinTech OR financial technology OR mobile money OR digital payment OR mobile payment OR digital finance OR internet finance OR digital financial service OR digital financial inclusion OR digital money*.

2.1.5. Data inclusion, exclusion, and segmentation

After collecting data from different sources, we begain the data inclusion and exclusion processes and group-wise segmentation. The PRISMA framework concept (Page et al., 2021) is used in the initial data screening process. A detailed PRISMA diagram of this study is shown in Fig. 1. Using the specified keywords, we find a total of 1944 papers; among these, we identified 371 papers that are eligible for the study. We divide our papers into financial, economic, and environmental groups. After group-wise inclusion, we peruse the abstract and methods and limit our literature to empirical research. Therefore, review-based qualitative studies are excluded from the analysis. After the exclusion of 253 studies, 118 are included. After data inclusion, exclusion, and segmentation, we review the literature on financial, economic, and environmental groups.

2.1.6. Manual searching

We follow four manual search steps. First, we search for two or more keywords in Google Scholar that reflected the existing literature. Second, we inspect the reference lists of the included articles. We use a citation tracking system for the articles included in the third step. Usually, citation tracking systems are available on indexing platforms such as the Web of Science and Scopus. The fourth manual search technique is commonly used for manually identifying relevant literature. A manual search involves searching for the title of a relevant article, and the search engine displays the relevant articles.

2.2. Methods for machine-generated themes

In the second stage, the 118 studies reported in Fig. 1 are used to obtain bibliometric data from the Web of Science database. After collecting the data, we employ different bibliometric research tools based
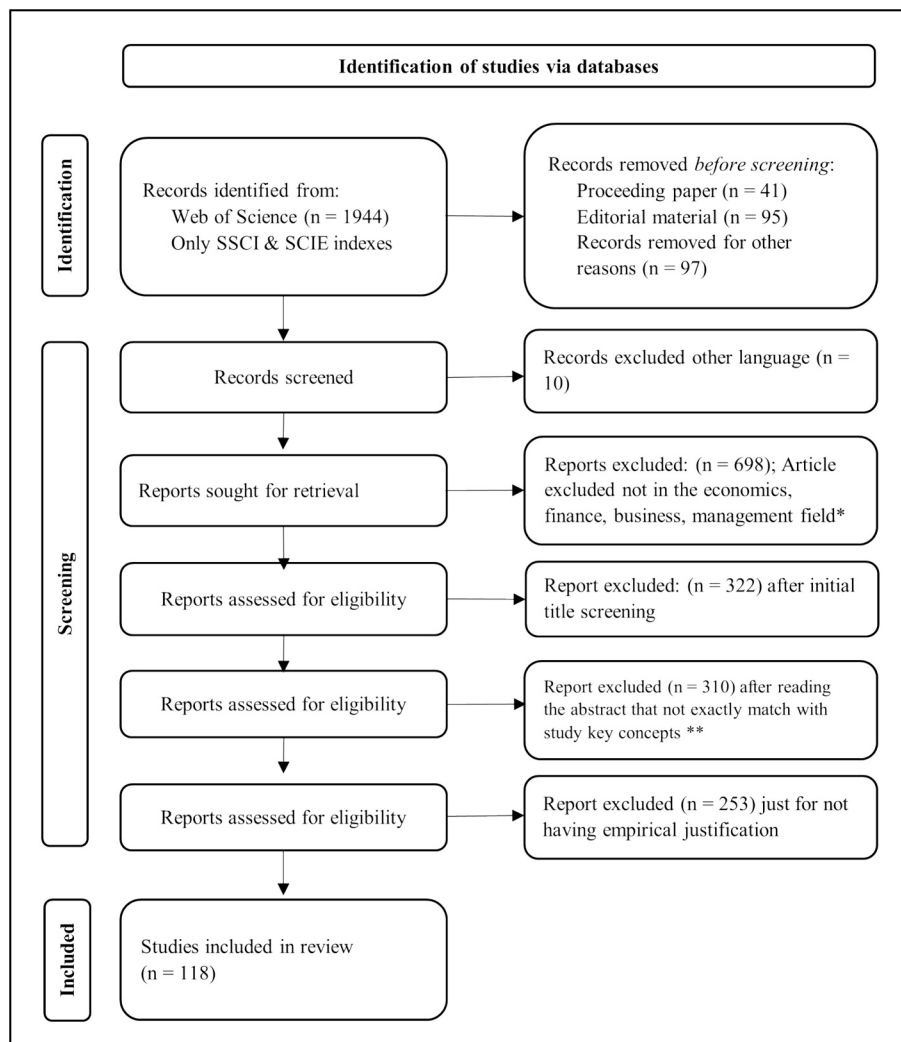
Fig. 1. PRISMA diagram of this study.

Source: Authors explanation from PRISMA guideline (Page et al., 2021) (Note: * Management, Economics, Communication, Sustainability Science, Telecommunications, Economic Theory, Supply Chain & Logistics, Knowledge Engineering & Representation, Agricultural Policy, Political Science, Climate Change, Energy & Fuels, Environmental Sciences, Operations Research & Management Science, Hospitality, Leisure, Sport & Tourism, and Social Reform, ** refers to the existence of the mentioned words but in a different place and ultimately not related to FinTech. For example, a paper published on **Entrepreneurship Theory and Practice** on **Financial** Management Competence of Founding Teams and Growth of New **Technology**-Based Firms has both "financial' and 'Technology' in the title; however, this is not related to financial technology. Therefore, we must exclude those studies.)

on machine-generated algorithms to generate clusters and themes. Cluster and network analyses are performed using graphical user interface-based software, VOSviewer (Perianes-Rodriguez et al., 2016; van Eck and Waltman, 2010; Waltman et al., 2010), and WordCloud analysis and thematic analysis visualizations are performed using the Bibliometrix package in R Studio (Aria and Cuccurullo, 2017), a command-based software.

3. Descriptive statistics and themes development

Table 2 describes the study areas highlighted in the FinTech research. China has the highest number of publications on specific research themes. Surprisingly, the US and Europe rank at the bottom of this list. Plausibly, developed nations are more concerned about FinTech's impacts on environmental issues than on financial inclusion, poverty alleviation, income inequality reduction, and economic expansion. Therefore, researchers are focusing on FinTech's contribution to sustainable development in developing nations.

Table 3 presents the descriptive statistics of the different financial services regarded as FinTech in previous studies. In the beginning stage

of FinTech research, many studies considered information and communication technology (ICT) infrastructure variables as a proxy of FinTech factors. An important logic behind considering ICT forces is that most FinTech services use ICT devices.

Table 4 details the specified themes of this study and the number of yearly publications. This study identifies three dimensions (financial, economic, and environmental) on which FinTech influences sustainable development. The total number of publications (empirical and case studies) used in this thematic classification is 78. In some cases, a single study discusses multiple themes. Thereby, the number of total themes is 82, which is higher than the number of publications. The number of publications on environmental concern is also rapidly increasing after 2021. In 2021, it was six publications; however, it rose to 14 in 2022.

4. Thematic interaction of human and machine themes

This study uses human intelligence and three machine-generated processes to identify themes and clusters. The overall results for the human-specified and machine-specified themes are presented in Table 5. The innovation of using machine-generated processing facilitates

Table 2
Descriptive statistics (study area focus).

Area	Economic status	Count	Share (%)
China	Developing	29	39.7
Worldwide*	Mixed	8	11.0
Ghana	Developing	7	9.6
African**	Developing	4	5.5
Belt and Road Initiative (BRI)***	Mixed	3	4.1
Sub-Saharan	Developing	3	4.1
Kenya	Developing	3	4.1
OECD	Mixed (majority developed)	2	2.7
Bangladesh	Developing	2	2.7
India	Developing	2	2.7
Uganda	Developing	2	2.7
Brazil, Burkina Faso, Cameroon, E7 countries, South Asia, USA, Europe, ASEAN	Mixed	8	10.7
Total study areas		73	100

Notes: *The number of countries examined in those study are 60, 87, 93, 105, 197, and 140 (2 studies). **51 African countries belong to the list of developing economies; thereby, we categorize "Africa" as developing nations. *** In BRI countries, 34 high-income countries, 42 upper middle-income countries, 41 lower-middle-income countries, and 30 low-income countries.

replication and reproducibility and increases confidence in the objectivity of the systematic literature review process.

In the first correlation analysis, human-specified themes and WordCloud, this study finds that only two themes are correlated with WordCloud mapping out of all human-specified themes. The two themes correlated between human-specified themes and WordCloud are *FinTech and inclusive finance/financial inclusion* and *FinTech and promoting economic growth.* Fig. 2 presents the WordCloud of the authors' keywords used in the selected publications for this study. According to Fig. 2, the ten most highlighted and frequent keywords are FinTech (35), financial inclusion (33), mobile money (12), digital finance (9), economic growth (9), digital financial inclusion (8), ICT (7), mobile payment (5), blockchain (), and crowdfunding (4).

In the second correlation analysis of human-specified and network clustering, we find concurrence between human-specified themes and network clustering. Fig. 3. a illustrates the general clustering links. Of the 337 keywords, 59 met the threshold when the minimum number of occurrences was 2. There are ten significant clusters and 241 total link strengths.

Cluster links can be isolated using this approach, as shown in Fig. 3.b. Specific themes can be examined using the correlations between machine-clustering links and human-specified themes.

In the third correlation analysis of human-specific and thematic mapping themes, we find that all human-specific themes and thematic mapping themes are correlated. Four broad themes are identified through a co-occurrence cluster analysis. Motor themes represent core concepts; similarly, basic themes reveal fundamental or underlying concepts. Niche themes characterize specialized concepts and provide a more nuanced understanding of the broader topic. In contrast, the emerging themes uncover new insights and directions. The roles of FinTech in sustainable development can be better understood by identifying the motor, basic, niche, and emerging themes. As one can readily discern, the core tenets of motor themes revolve around the pivotal role of information and communication technology (ICT) and the imperative of fostering financial literacy and inclusion to achieve financial development—a matter of paramount importance for developing nations. Similarly, the basic themes underscore the significance of FinTech, financial growth, and digital inclusion. The harmonious integration of these themes acts as a catalyst for economic growth. Within the niche theme, poverty alleviation, addressing inequality, and promoting renewable energy consumption are domains in which the digital economy can exert a substantial impact. Notably, among emerging themes,

Table 3
FinTech products and services.

FinTech product and service	Variables	Count	Share (%)
ICT Infrastructure	ICT infrastructure/ mobile cellular subscription/ internet penetration/ Internet usage/ fixed broadband subscribers/ fixed telephone/ telephone subscribers	22	21.2
FinTech	FinTech/ FinTech access/ access to digital finance/ FinTech-based financial services/ proxies of FinTech (such as depth of usage, coverage, and digitalization level)/ digital payment/ mobile money/ mobile payment/ mobile money accounts/ mobile money adoption/ mobile money savings/ mobile payment technology/ mobile banking/ dummy of mobile payment usage/ usage of digital financial products/ usage of FinTech innovations	21	20.2
Digital Financial Inclusion	Digital financial inclusion index/ digital financial development level/ digital financial integration/ global FinTech index/ global FinTech index city ranking/ FinTech-based financial inclusion index/ digital finance/ digital finance index (DFI)/ DFI at the city level/ FinTech progress at the city level/ FinTech development index	18	17.3
ATM Penetration	ATM penetration/ number of ATMs/ debit card penetration	6	5.8
FinTech lending	Lending through FinTech/ alternative finance (crowdfunding and P2P lending)/ P2P loan applications/ third-party payment and credit/ FinTech credit through community-based organizations	6	5.8
Applied FinTech applications	Application of technology/AI operations such as chat box, fraud detection, cyber security, and so on/ big data-based technologically innovative financial products/ blockchain-enhanced emissions-trading systems/ FinTech innovations	5	4.8
Financial Literacy	Financial literacy/ digital literacy	4	3.9
Digital Economy	Digital economy/ digital economic development index/ digital economy index	4	3.9
FinTech usage characteristics	Mobile money perceived cost/ high transaction costs/ FinTech service cost/ mobile money perceived usage intention/ mobile money relative advantages	5	4.8
FinTech for other services	A mobile phone used to pay a bill/ recharged credit in their mobile through mobile money/ mobile phone users to pay the bill	3	2.9
Remittance	Remittance/remittance recipients	2	1.9
FinTech industry development	Financial industry development scale/ FinTech industries' market-cap weighted index	2	1.9
Others	E-commerce usage & payment, a FinTech start-up formation, mobile agents, digital infrastructure quality, uncertainty of new technologies, Regtech *	6	5.8
Total		104	100

Notes: * refers to each count as 1.

the prominence of Industry 4.0, which encompasses blockchain, digital finance, and crowdfunding, is unmistakable. In this context, the overarching view suggests that FinTech can enhance market efficiency for both unserved and underserved populations.

This study identifies 12 themes from the thematic mapping analysis, as depicted in Fig. 4.a. A summary of the interplay between human-

Table 4
Specified dimensions and publications.

Themes	Count	Total count	Share (%)
Dimension 1: Finance			
FinTech and inclusive finance/ financial Inclusion	31	31	37.8
Dimension 2: Economic			
FinTech and poverty reduction	9	30	36.6
FinTech and income inequality reduction	8		
FinTech and promoting economic growth	13		
Dimension 3: Environment			
FinTech and carbon emissions reduction	21	21	25.6
Total	82	82	100
Year	**Dimension-1**	**Dimension-2**	**Dimension-3**
2018	0	1	0
2019	1	2	1
2020	8	5	0
2021	11	10	6
2022	11	10	14
Total publications	31	28	21

Table 5
Comparison of Human specified themes with machine-generated themes.

Dimension	Human specified themes	WordCloud (top 10 words)	Clustering	Thematic Map
Dimension 1: FinTech and inclusive finance	Inclusive finance/ financial Inclusion	✓	✓	✓
Dimension 2: FinTech and economy	FinTech and poverty reduction		✓	✓
	FinTech and income inequality reduction		✓	✓
	FinTech and promoting economic growth	✓	✓	✓
Dimension 3: FinTech and environment	FinTech and carbon emissions reduction		✓	✓

Notes: (i) The top 10 frequent words (please see following Fig. 2). (ii) There are 10 clusters according to network and cluster analysis (please see Figs. 3.a and 3. b). (iii) There are 12 themes according to the thematic map (please see following Figs. 4. a and 4. b).

specific themes and thematic mapping is shown in Fig. 4. b.

5. Dimension and thematic findings

The applications and effects of FinTech are related to three dimensions of sustainable development: finance, economy, and the environment. These dimensions ultimately represent the human-specific themes of FinTech's impact on sustainable development. Each theme has specific links to sustainable development. Because machine-generated themes support human-specified themes, this study discusses human-specified themes as findings in the following sections.

5.1. Dimension 1 - FinTech and inclusive finance

The first dimension of this study discusses how and in what ways FinTech promotes inclusive finance, particularly access to it. The findings for Dimension 1 are discussed in the following section, and a brief literature matrix is presented in Table 6. It is apparent that FinTech products/services have a positive role in increasing financial inclusion (IF), as seen in the column entitled "Effect".

5.1.1. FinTech and direct financial access

FinTech influences financial inclusion by (i) reducing the costs of financial services, (ii) increasing financial transaction opportunities for nontraditional financial market clients, (iii) promoting small businesses through e-commerce transactions, (iv) offering financial transaction facilities in remote locations distant from formal financial institutions, (v) improving bank efficiency, and (vi) providing affordable loans and investment opportunities (Hasan et al., 2022a; Hasan et al., 2020; Joia and Cordeiro, 2021; Lee et al., 2021; Morgan, 2022; Zhao et al., 2022b).

The use of digital finance products/services is a crucial factor in formal financial inclusion (Ozili, 2018). FinTech supports financial inclusion by including the maximum number of unbanked firms in its formal system (Kanga et al., 2021). Mobile money payments and savings are the most popular services for access to financing (Coffie et al., 2021; Demir et al., 2020; Kim, 2022). Mobile money for bank deposits also boosts access to finance, indicating that positive usage behavior significantly promotes financial inclusion through savings in formal banking (Ndassi Teutio et al., 2021).

FinTech has significantly increased bank accounts in formal economic systems and motivated rural dwellers to save and borrow more from financial institutions (Demir et al., 2020). The global impact of FinTech is apparent. However, this is more evident in remote and poor regions than in developed regions (Luo et al., 2022a), particularly in African and Asia-Pacific countries (Khera et al., 2022). Thus, FinTech promotes regional financial efficiency and contributes to sustainable financial inclusion.

5.1.2. ICT, FinTech, and access to finance

ICT progress is closely related to FinTech services and financial inclusion. ICT products such as mobile telephony have increased cellular subscription penetration and significantly increased the usage of loan and deposit accounts, which are considered a proxy for financial inclusion (Ghosh, 2016). Higher mobile phone penetration motivates people to access traditional banking and microfinance services (Mushtaq and Bruneau, 2019). Moreover, Shen et al. (2020) and Coffie et al. (2021) suggest that mobile and internet usage influence financial inclusion by promoting FinTech products and services, mainly benefiting households and SMEs (Small and medium-sized enterprises) in rural areas. However, although mobile money usage promotes financial inclusion, almost 75% of mobile money users still have no bank accounts (Hamdan et al., 2022).

5.1.3. Financial literacy and FinTech access

Better knowledge regarding P2P transactions, application use, e-commerce dealing, and FinTech training significantly motivates rural people to gain financial access to FinTech products and services (Hasan et al., 2022a). Respondents' knowledge about sending and withdrawing money from mobile money accounts is the most critical factor influencing access to FinTech (Hasan et al., 2021). Thus, previous experience with FinTech product usage promotes access to digital finance (Shen et al., 2020). Combining financial literacy with digital literacy improvement is essential for promoting financial inclusion (Joia and Cordeiro, 2021). However, financial inclusion does not ensure financial fragility. Baker et al. (2023) reveal the importance of financial fragility on well-being in the US context but note that financial literacy is not a

Fig. 2. WordCloud (Word occurrence by frequency).

significant moderator in this relationship.[4]

5.1.4. FinTech and lending opportunities

FinTech creates significant opportunities to challenge traditional banking. Numerous ethnic minorities, immigrants, social entrepreneurs, and students have insufficient personal assets and appropriate collateral to satisfy traditional banking credit-scoring metrics (Gomber et al., 2018; Leong et al., 2017). By contrast, FinTech payment methods make lending faster and easier than traditional lending, promote financial inclusion, and mitigate household shocks (Suri et al., 2021). FinTech also provides solutions to the equity market and lending with increasing funding accessibility to marginal firms. Interestingly, Xie and Zhu (2022) find that FinTech lending growth reduces the capital available to more efficient firms. Integrating FinTech services with e-commerce platforms supports rural financial inclusion by extending lending to rural areas (Kong and Loubere, 2021; Kowalewski and Pisany, 2022). Furthermore, FinTech provides affordable lending and investment opportunities, boosting small businesses through e-commerce transactions (Morgan, 2022). FinTech also mitigates rural household shocks by offering small loans with quick delivery services through payment technology to small rural borrowers to meet their emergency needs and their children's schooling.

5.1.5. FinTech, remittances, and access to lending

FinTech development for remittances offers significantly lower costs, more accessible services for transferring funds from one country to another for family maintenance, payback of family and community debts, and sharing of expenditures for international tourism and education (Gomber et al., 2018). Guermond (2022) reveals a positive relationship between domestic remittance recipients and credit lending, as those who receive domestic remittances are better able to repay their

loans. Crowd funders obtain information about how remittance recipients receive, use, and manage funds. Thus, lenders provide information on borrowers' loan suitability.

5.1.6. FinTech, trust, and access to finance

Trust substantially influences the adoption and use of mobile payments. Customer confidence in digital finance services ensures that they use FinTech (Okello Candiya Bongomin and Ntayi, 2020). In particular, high trust in digital services motivates mobile money users (Senyo and Osabutey, 2020). Conversely, individuals' distrust of banks is likely to drive them to direct their funds via crowdsourcing rather than through bank deposits (Saiedi et al., 2020). Joia and Cordeiro (2021) recommend trustworthy environmental implementation for clients as a public policy mechanism for promoting FinTech-based financial inclusion.

5.1.7. FinTech, supportive policies, and access to finance

Senyo et al. (2022) reveal three interlinked practices that significantly shape inclusive finance. These are (i) introducing new and innovative FinTech products and blending innovative FinTech products and services with collaborative models to promote financial inclusion; (ii) implementing supportive policies and developing the controlling infrastructure of FinTech products and services to promote financial inclusion; and (iii) empowering policies for financial education, strengthening cyber security, developing agent-based networking, and encouraging shadow branches to promote financial inclusion.

The institutional-level factors that reduce the financial exclusion gap include government incentives (Agwu, 2020), institutional quality (Banna et al., 2022), more supportive telecom sector regulations (Lashitew et al., 2019), and improved local financial regulatory capacity (Chen et al., 2022). According to Chen et al. (2022), local governments should invest more in financial regulations to reduce regulatory information asymmetry, increase financial resources to monitor credit quality, minimize credit risk, and strengthen FinTech activities. Policies and regulations should assist digital financial services and traditional financial institutions to promote financial inclusion.

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[4] Using Portuguese data, Tavares et al. (2023) examine financial literacy in business-trained individuals and show a disconnect between financial literacy perception and financial literacy reality. Furthermore, She et al. (2023) consider young adults financial well-being.
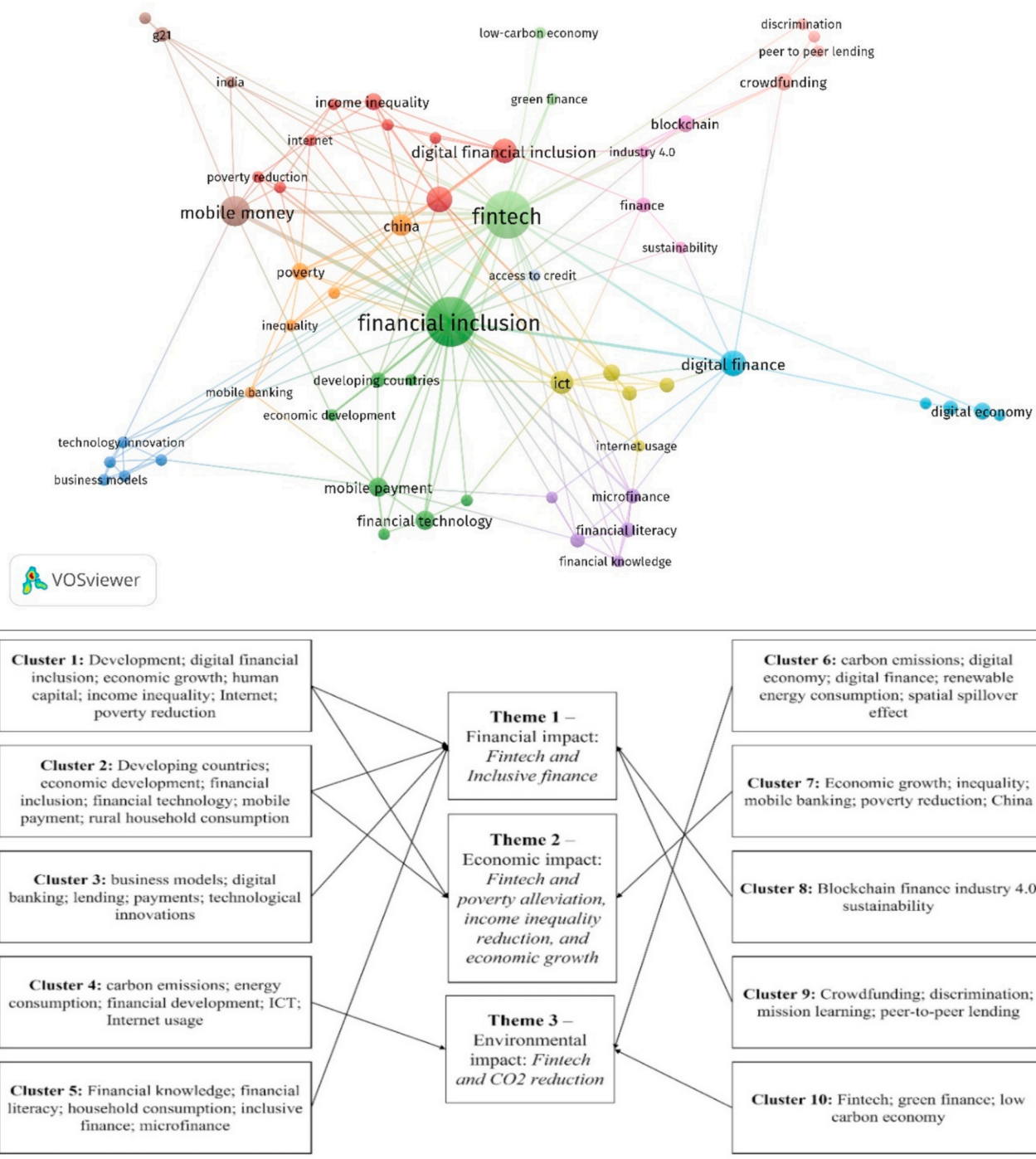
Fig. 3. a: Machine-generated clustering and co-occurrence networking (association strength clustering).
b: Interaction with Human specified themes and machine clustering.

5.2. Dimension 2 - FinTech and economy

The second dimension discusses how and in what ways FinTech impacts sustainable economic development, particularly by alleviating poverty, reducing income inequalities, and promoting economic growth. The findings of dimension 2 are discussed in Table 7, and the impact on the economy is shown in the column entitled "Effects." As can be seen, FinTech leads to improvements in poverty alleviation (PA), income inequality reduction (IIR), and economic growth (EG).

5.2.1. FinTech and poverty alleviation

Progress in mobile communication and Internet infrastructure are essential factors driving FinTech advancement (Appiah-Otoo and Song, 2021). The higher penetration of mobile cellular subscriptions, Internet users, and fixed-line subscribers significantly alleviates poverty by promoting the informal economy, which is highly correlated with poverty reduction (Ikechukwu Kelikume, 2021; Lechman and Popowska, 2022; Mushtaq and Bruneau, 2019) and significantly improves respondents' health, living standards, and knowledge (Asongu and Le Roux, 2017). Mobile banking assists rural households in managing budgets during poverty-related shocks, mitigates transaction- and
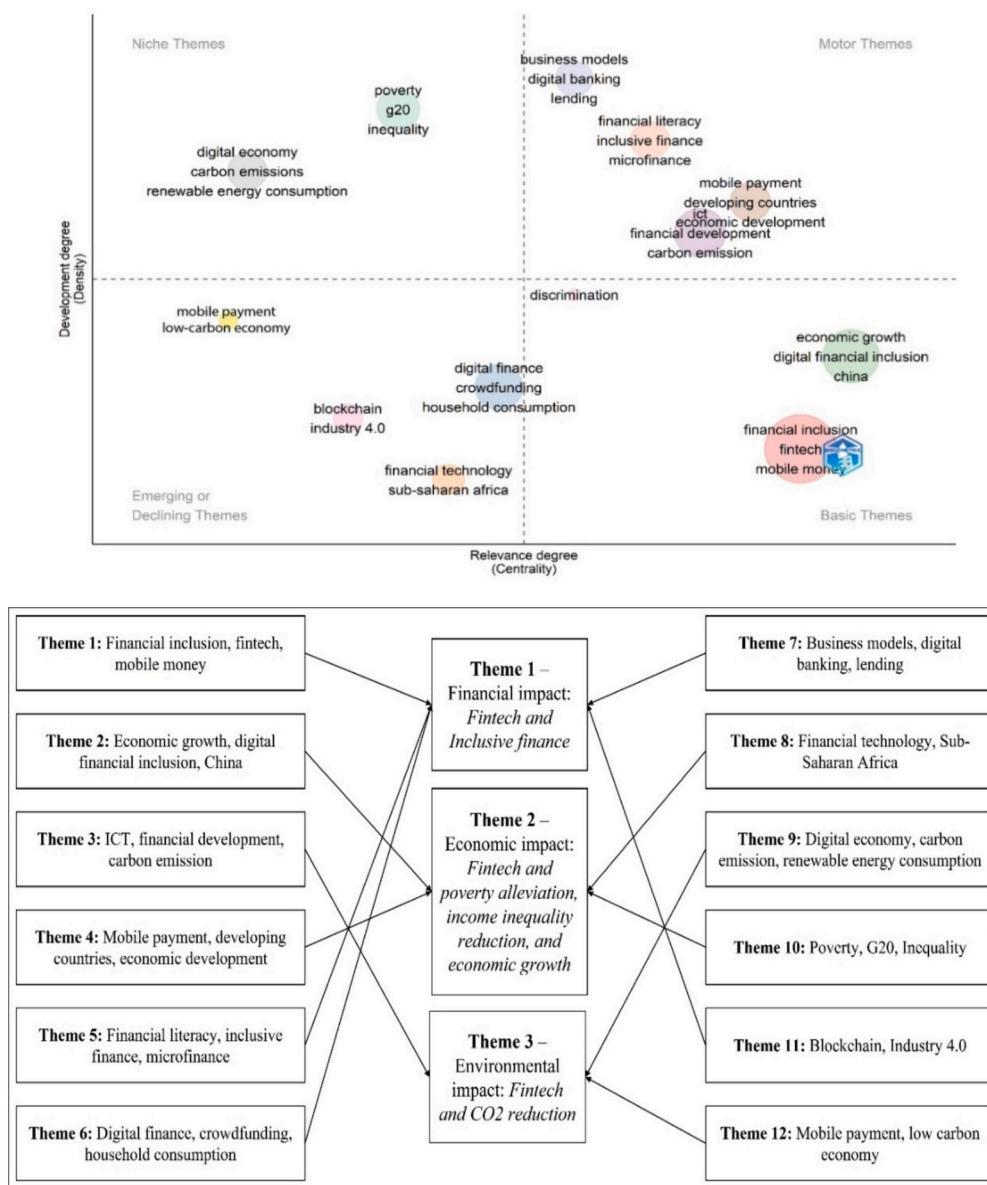
Fig. 4. a: Machine-generated thematic mapping.
b: Interaction with Human specified themes and machine-generated themes (Thematic mapping).

transportation-related costs during formal banking operations, inspires household savings, and enables women to run new and existing businesses more efficiently (Asongu and Nwachukwu, 2018). Also, increasing access to finance with FinTech payments reduces welfare poverty at the individual level, particularly the lack of nutrition, healthcare, and education (N'dri and Kakinaka, 2020).

Chen and Zhao (2021) mention four absolute and relative poverty reduction mechanisms in rural areas through FinTech innovations. These are as follows: (i) FinTech access alleviates rural households' credit constraints to reduce poverty; (ii) FinTech access increases rural households' attention to financial and economic information and increases mobile payments to reduce poverty; (iii) FinTech access accumulates rural households' social capital to reduce poverty; and (iv) FinTech access promotes entrepreneurial activities to reduce poverty. Finally, FinTech, especially third-party payments and online credit, improves living standards and facilitates financial development and economic growth, ultimately alleviating poverty (Appiah-Otoo and Song, 2021; Kanga et al., 2021).

5.2.2. FinTech and income inequality

Promoting access to FinTech products and services can reduce income inequality (Asongu and Nwachukwu, 2018; Demir et al., 2020; Xuan and Trung, 2022). FinTech progress reduces income inequality by increasing rural household income growth through diversified digital financial services. FinTech makes it easier for people to borrow, decreases entrepreneurs' financing barriers, and boosts income (Luo et al., 2022b; Zhang et al., 2020). Xuan and Trung (2022) mention digital payment as the most important financial service compared to other financial services to reduce income inequality. It is also noted that the impact of FinTech on income inequality is more substantial in developing countries. Higher FinTech access penetration increases financial and economic activity, increases per capita income in the longer term, and reduces income inequality (Kanga et al., 2021).

5.2.3. FinTech and economic growth

A significant Internet threshold effect on access to digital financial products/services on economic growth indicates that a higher level of Internet development substantially affects access to digital finance on

Table 6
Dimension - FinTech and inclusive finance (IF).

Author	Themes (IF)	Country	Period	FinTech products and services	Dependent variables	Effects
						IF
Lashitew et al. (2019)	Mobile money diffusion on financial inclusion	Kenya	2010–2014	bank account, ATM penetration, banking sector concentration	mobile money accounts, sending money (last 12 months) and receiving money	↑
Agwu (2020)	Technology impact of reducing financial exclusion gap	Multiple African countries	2012–2016	application of technology	access to finance	↑
Amoah et al. (2020)	Influencing forces of mobile money-based inclusive finance	Ghana	2019	recharged credit in their mobile through mobile money	probability of using mobile money	↑
Demir et al. (2020)	FinTech on financial inclusion	140 countries	2011, 2014, 2017	a mobile phone used to pay a bill	access to finance (account, savings, and borrowing)	↑
Mhlanga (2020)	Artificial intelligence on digital financial inclusion	–	–	AI operations such as chat box, fraud detection, cyber security, and so on	digital finance access	↑
Myeni et al. (2020)	Examine the mobile money usage impact on accelerating financial inclusion	Eswatini	2014	demographic characteristics, educational attainment, and geographical variables	probability of using mobile money	↑
Okello Candiya Bongomin and Ntayi (2020)	Moderating the impact of trust on the relationship between the adoption of mobile money and inclusive finance	Uganda	2018	mobile money adoption	access to bank	↑
Senyo and Osabutey (2020)	Usage of FinTech innovations on financial inclusion	Ghana	2017–2018	usage of FinTech innovations	access to bank	↑
Shen et al. (2020)	Usage of digital technology on financial inclusion	China		financial literacy, Internet usage, usage of digital financial products	financial inclusion	↑
Coffie et al. (2021)	FinTech payment promotes SMEs	Ghana	2018	mobile money savings, mobile phone penetration	online payments, mobile money, and card payments	↑
Hasan et al. (2021)	Financial and digital literacy and inclusive finance	Bangladesh	2019–2020	financial literacy	access to the bank, access to FinTech, access to microfinance	↑
Kanga et al. (2021)	Access to FinTech promotes access to finance	Worldwide	1991–2015	ATMs, mobile penetration	financial inclusion index	↑
Kong and Loubere (2021)	FinTech and e-commerce on access to finance	China		FinTech access and e-commerce usage	access to rural credit	↑
Maskara et al. (2021)	P2P platforms in improving financial inclusion	United States	2008–2019	P2P loan applications	access to bank, short-term financing	↑
Ndassi Teutio et al. (2021)	Mobile money savings promote access to finance	Cameroon	2019–2020	mobile money perceived cost, relative advantages, perceived usage intention	financial inclusion	↑
Strangio, 2021	FinTech challenges and financial inclusion	Africa	2019	high transaction costs, the uncertainty of new technologies, poor digital infrastructure	financial inclusion	↓
Senyo et al. (2021)	Mobile finance impact on inclusive finance	Ghana	2017–2018	mobile money	access to finance	
Sheng (2021)	FinTech promotes banks' ability to offer credit to SMEs	China	2011–2018	FinTech, bank size (small, medium, and large)	banks' credit supply to SMEs	↑
Suri et al. (2021)	Digital loans and household resilience to shocks	Kenya	2016–2017	FinTech access	digital lending	↑
Banna et al. (2022)	FinTech-based financial inclusion on microfinance risk-taking behavior	Sub-Saharan African		FinTech-based financial inclusion index	microfinance risk-taking	↑
Chen et al. (2022)	FinTech on the digital economy	China	2012–2018	digital economic development index	FinTech development index	↑
Guermond (2022)	Remittance digitalization, FinTech, and the progress of digital financial inclusion	Ghana	2017	remittance recipients	credit lending	↑
Hamdan et al. (2022)	Mobile payment and access to banking	Uganda	2019	socio-demographic attributes, availability of financial services, and business characteristics	maximum likelihood of access to banking	↑
Hasan et al. (2022a)	Financial literacy impact on financial inclusion	Bangladesh	2019–2020	knowledge regarding P2P transactions, service transactions, FinTech applications, e-commerce dealing, FinTech training, basic banking knowledge, and microfinancing knowledge	access to FinTech	↑
Khera et al. (2022)	FinTech products on expanding financial inclusion	52 African and Asian countries	2014–2017	mobile money accounts	access to bank	↑
Kim (2022)	Mobile money on women's financial inclusion	Kenya	2015–2016	mobile money	access to bank	↑
Lai et al. (2022)	Digital financial inclusion on illegal fundraising	China	2013–2019	DFI at the city level	money invested in illegal fundraising	↑

Table 6 (*continued*)

Author	Themes (IF)	Country	Period	FinTech products and services	Dependent variables	Effects
						IF
Luo et al. (2022a)	Digital financial services on economic efficiency	China	2011–2019	DFI index	financial efficiency level	↑
Morgan (2022)	FinTech contribution to inclusive finance	ASEAN countries and India	2012–2019	digital payments, alternative finance (crowdfunding and P2P lending), remittance	access to FinTech	↑
Senyo et al. (2022)	FinTech ecosystem impact on inclusive finance	Ghana	2019–2020	mobile money	access to banking	↑

Note: Author names are mentioned chronologically and then alphabetically. Effects ↑ refers to promoting and ↓ refers to demoting inclusive finance.

economic growth (Liu et al., 2021). Digital financial integration promotes economic growth by expanding market competition, increasing service sector employment opportunities, expanding financial activities, increasing investment, and rising income levels (Cheng et al., 2023b; Emara and El Said, 2021; Kurantin and Osei-Hwedie, 2019). Chen, Kumara, & Sivakumar, 2021 suggest that information and communication technologies significantly influence access to digital financial services, leading to positive economic growth. In addition, greater access to FinTech at the regional level improves regional economic development. Increased access to FinTech creates the right digital financial environment to facilitate and expand service penetration by financial institutions and reduce barriers to accessing finance (Ahmad et al., 2021). FinTech increases economic growth by reducing the size of the shadow economy; however, in some cases, it increases financial instability by raising non-performing loans (Syed et al., 2021). In this aspect, Wang et al. (2023) support that fintech significantly helps reduce non-performing loan risk by improving the performance of formal financial institutions. Fintech also increases the stability and efficiency of national banks, particularly in the regions where fintech development is more advanced. Still its influences on stability and efficiency are less evident in the case of less profitable banks, local banks, and other local financial institutions situated in region, where FinTech is yet to be developed (Chen and Shen, 2024).

Shen et al. (2021) reveal that access to financial development through mobile and digital Internet transactions has substantially promoted a country's economic growth by enabling financial institutions to attract more savings and deposits from rural and urban consumers. FinTech also plays an essential role in agribusiness financing by providing mobile remittance transfer services to smallholders and farmers (Hinson et al., 2019). Higher access to digital financial services, increased ATMs, and debit card penetration stabilizes the economic sector by attracting innovative financial products and services (Ozturk and Ullah, 2022). Additionally, Dong and Yu (2023) imply that firms' innovation through fintech enhances sustainable economic development. The synergy between FinTech service providers and conventional banking increased the pool of savers and lenders (Muganyi et al., 2022).

5.3. Dimension 3 - FinTech and environment

The third dimension discusses how FinTech affects the environment, especially the reduction of carbon emissions through different FinTech products and services such as green finance, investment in green technology, and investment in innovative green products, influencing human behavior toward eco-friendliness. The findings for Dimension 3 are discussed in the following section, and a brief description of the literature matrix is provided in Table 8. As can be seen, almost universally, the adoption of FinTech leads to CO_2 reduction.

5.3.1. FinTech, green finance, CO_2 emissions
The FinTech sector offers new risk management tools, such as big data analytics and new strategies to encourage renewable energy production and consumption. Access to more complete, improved, and unbiased financial information means that funding for renewable energy projects is possible, eventually increasing per capita renewable energy consumption. Thus, increasing the per capita use of renewable energy reduces carbon emissions and increases energy efficiency (Ganda, 2019; Liu et al., 2022; Yu et al., 2022; Zeng et al., 2024). The renewable energy industry can grow in developed economies (Croutzet and Dabbous, 2021).

FinTech also encourages renewable energy production and consumption through financing in rural areas and underdeveloped countries through community-based organizations. Community-based financing has grown, especially in areas in which traditional banks must pay more attention to project financing. Individuals, groups, and SMEs use mobile payment services to facilitate community-based renewable energy financing projects (Butu et al., 2021). Both FinTech and green finance improve the quality of the environment through effective green finance regulations and FinTech product policies, which help avoid information asymmetry and solve moral environmental threats (Nenavath, 2022). Finally, the integration of FinTech, green finance, and technological progress promotes energy efficiency and reduces adverse ecological impacts.

5.3.2. FinTech, behavioural intention, and CO_2 reduction
FinTech companies reduce carbon emissions by promoting and motivating tree-plantation initiatives. Planted trees absorb carbon and reduce adverse environmental impacts (Zhang et al., 2021). Zhang (2022) also mentions that a model is highly effective for green finance development in this era of technological innovation. The process was conducted on a big data platform using cloud computing, artificial intelligence, and blockchain technology.

5.3.3. FinTech, energy-efficient technologies, and CO_2 emissions
Greater access to digital finance has resulted in economic growth owing to technological advances. Technological advances have reduced inefficient energy use owing to low-grade technology usage. Energy-efficient technologies promote environmental quality and reduce carbon emissions (Tao et al., 2022; Zhao et al., 2021). Additionally, promoting access to digital finance significantly reduces carbon intensity by fostering green technological innovations and industrial structures. Green technologies are always energy efficient and have fewer adverse environmental impacts than traditional technologies. Additionally, higher investments in science and technology significantly reduce carbon emissions (Lee and Wang, 2022). FinTech also improves corporate green innovation by increasing the number of green patents to reduce adverse effects on the environment. It also increases corporate transparency, strengthens information sharing between enterprises and stakeholders, reduces internal and external information asymmetry, and enables barrier-free transmission of green innovation both inside and outside the enterprise (Rao et al., 2022).

5.3.4. FinTech, digital economy, and CO_2 emission
Owing to the development of the digital economy, carbon emissions have gradually decreased, particularly in coal-based energy economies (Li et al., 2021). Zhang et al. (2022b) extend the impact of digital economy mechanisms on carbon emissions performance. The digital

Table 7
Dimension - FinTech and economy {poverty alleviation (PA), income inequality reduction (IIR), and economic growth (EG)}.

Author	Themes (PA, IIR, and EG)	Country	Period	FinTech products and services	Dependent variables	Effects PA	IIR	EG
Asongu and Nwachukwu (2018)	Mobile banking and inclusive growth	93 countries	1990–2011	mobile banking and human development	poverty rate (living below 1 USD), and inequality index (measured by the GINI Index)	↓	↓	
Hinson et al. (2019)	FinTech impacts the transformation of agribusiness toward sustainable development	–	–	FinTech-based financial services	agribusiness			↑
Kurantin and Osei-Hwedie (2019)	Digital financial integration and economic growth	Ghana	1986–2016	digital financial integration (cellular subscription, mobile penetration, and increasing mobile agents)	GDP growth rate			↑
Canh et al. (2020)	Technological development impact on income inequality	87 countries	2002–2014	mobile, fixed telephone, and internet usage	Gini index		↓	
Demir et al. (2020)	FinTech and income inequality	140 countries	2011, 2014, 2017	mobile phone users to pay the bill	income inequality		↓	
N'dri and Kakinaka (2020)	Mobile money access to improve individual welfare	Burkina Faso		mobile money	poverty reduction	↓		
Pal et al. (2020)	Mobile payment technologies on sustainable human-centric development and human empowerment	India	2015	mobile payment technology	human empowerment			↑
Zhang et al. (2020)	FinTech development to explore the impact of FinTech on income growth and income disparities	China	–	FinTech development index	per capita household income		↓	
Ahmad et al. (2021)	Access to digital finance on China's provincial-level economic growth	China	2011–2018	digital finance index, proxies of FinTech, such as depth of usage, coverage, and digitalization level	GDP growth			↑
Appiah-Otoo and Song (2021)	FinTech on poverty reduction	China	2011–2017	third-party payment and credit	household consumption per capita	↓		
Chen and Zhao (2021)	FinTech in reducing poverty	China	2017	digital finance	poverty at the city level (dummy variable)	↓		
Chen, Kumara, & Sivakumar, 2021	Access to digital finance on economic growth	China	–	information and communication technologies	per capita income	↓		↑
Ikechukwu Kelikume (2021)	Access to digital finance impacts poverty reduction	42 African countries	1995–2017	mobile phone penetration and internet usage penetration	poverty index	↓		
Kanga et al. (2021)	FinTech diffusion on living standards	137 countries	1991–2015	FinTech (ATMs and mobile phone subscriptions)	per capita income		↓	
Liu et al. (2021)	Digital financial products and services on economic growth	China	2011–2019	digital financial index	GDP per capita			↑
Shen et al. (2021)	Access to digital finance and economic growth	105 countries'	2016	digital financial inclusion index	per capita GDP			↑
Syed et al. (2021)	FinTech influenced financial stability and economic growth	South Asian countries	2004–2018	digital payment and the number of ATMs	financial instability			↑
Luo et al. (2022b)	Digital finance inclusion on reducing household consumption inequality	China	2015–2017	DFI level	Kakwani index		↓	
Luo et al. (2022c)	FinTech innovation on household consumption	China	2011–2020	FinTech innovations	household consumption	↓		
Muganyi et al. (2022)	FinTech and regtech on economic sector developments	China	2011–2018	FinTech progress at the city level; regtech	loan balance, rural and urban savings, level of institutional financial deposit			↑
Ozturk and Ullah (2022)	Digital finance on economic growth	42 one-belt road countries'	2007–2019	access to digital finance	GDP			↑
Odhiambo (2022)	ICT and economic growth	Sub-Saharan African	2004–2014	mobile phone penetration rate, internet penetration, and fixed broadband subscription	GDP growth rate			↑
Wang et al. (2022)	Digital financial inclusion on CO_2 emissions	China	2011–2017	digital financial inclusion index	Carbon emissions			↑
Xuan and Trung (2022)	Digital payment and FinTech credit on income inequality	60 countries'	2017	mobile payment and lending through FinTech	Gini coefficient		↓	
Youxue and Shimei. (2022)	Access to FinTech and income distribution	China	2011–2020	digital financial development level	GINI coefficient		↑	
Zhang et al. (2022a)	Mobile payment technology on household consumption	China	2017	a dummy of mobile payment usage	per capita household consumption	↓		
Zhao et al. (2022a)	Mobile payments on rural household consumption	China	2017	mobile payment	household consumption	↓		

Note: Author names are mentioned chronologically and then alphabetically. Effect ↑ refers to increasing poverty, income inequality, and promoting economic growth. And ↓ refers to reducing poverty, income inequality, and demoting economic growth.

Table 8
Dimension – FinTech and environment.

Author	Themes (CO2)	Country	Period	FinTech products and services	Dependent variables	Effects
						CO2
Ganda (2019)	Innovation and green technology investments in carbon emission reduction	26 OECD countries	2000–2014	number of patents (innovation), green energy use (measured by renewable energy consumption)	carbon emissions	↓
Anser et al. (2021)	Information technology factors and carbon emissions	26 European countries	2000–2017	telephone subscriptions, mobile subscriptions, and internet penetration	carbon emissions	↓
Butu et al. (2021)	FinTech and community organizations influence renewable energy financing	sub-Saharan Africa	1985 and 2020	FinTech credit through community-based organizations	renewable energy financing	↓
Croutzet and Dabbous (2021)	Significance of FinTech on the usage of renewable energy	21 OECD countries	2005–2018	FinTech start-up formation	renewable energy use	↓
Li et al. (2021)	Digital economy and technology on CO_2 emissions	China	2011–2017	digital economy index	per capita carbon emissions	↓
Zhang et al. (2021)	The environmental and socio-economic impact of Ant Forest	China	–	Mobile payment	Carbon emissions	↓
Zhao et al. (2021)	Impact of digital finance on carbon emissions	China	2011–2018	digital finance index (DFI)	carbon emissions	↓
Lee and Wang (2022)	Access to digital finance on reducing carbon intensity	China	2011–2017	China's digital inclusive finance development index	carbon intensity	↓
Li and Wang (2022)	Digital economy and carbon emission reduction	China	2011–2018	digital economy	carbon emissions	↓
Liu et al. (2022)	FinTech, financial inclusion, and green financing on energy efficiency	E7 economies'	2016–2020	global FinTech index, green finance	energy efficiency level	↓
Nenavath (2022)	Green finance and FinTech on environmental quality	India	2010–2020	Indian FinTech industries' market-cap weighted index	industrial gas releases, smoke releases, and sulphur dioxide emissions	↓
Ozturk and Ullah (2022)	Access to digital finance and environmental sustainability	42 Belt and Road Initiative countries	2007–2019	ATMs and debit card penetration	co_2 emissions	↑
Rao et al. (2022)	Digital finance on improving corporate green innovation	China	2011–2017	DFI	green innovation	↓
Shu et al. (2022)	Blockchain-enhanced emissions-trading systems	–	–	blockchain-enhanced emissions-trading systems	carbon emissions	↓
Tao et al. (2022)	FinTech development and greenhouse gas emissions	Worldwide	2019	global FinTech index city ranking	greenhouse gas emissions	↓
Wang and Yi (2022)	Financial industry development scale and carbon emission reduction	China	2009–2018	financial industry development scale	carbon emissions intensity	↑
Wang et al. (2022)	Digital financial inclusion on CO_2 emissions	China	2011–2017	digital financial inclusion index	carbon emissions	↓
Weili et al. (2022)	ICT on carbon emissions	Belt and Road Initiative (BRI) countries	2000–2019	telephone subscribers, fixed broadband subscribers, internet use, and mobile cellular subscription	carbon emissions	↑
Yu et al. (2022)	Digital finance access and renewable energy consumption	China	2011–2017	DFI	per capita renewable energy consumption	↓
Zhang (2022)	FinTech usage on reducing carbon emissions through green finance	China	–	mobile payment and big data-based technologically innovative financial products	carbon emissions and environmental problems	↓
Zhang et al. (2022b)	Digital economy mechanisms and carbon emission	China	2011–2019	digital economy	carbon emissions performance	↓

Note: Author names are mentioned chronologically and then alphabetically. Effects ↑ refers to increasing and ↓ refers to reducing CO_2 emissions.

economy primarily affects carbon emissions by reducing energy intensity, improving green technologies, promoting digital innovation, and increasing urban reforestation. Successful technological transformation in the digital economy promotes the growth of low-carbon production equipment, improves energy utilization, and reduces per-unit carbon emissions. However, the digital economy is expected to increase and reduce carbon emissions (Li and Wang, 2022).

5.3.5. FinTech, social and economic activities, and increased CO_2 emissions

Financial digitization enables individuals and companies to pay on-line, use mobile accounts, pay debits and credit cards, and withdraw money from ATMs. Therefore, an increase in the number of ATMs and the popularity of debit cards has significantly increased carbon emissions (Ozturk and Ullah, 2022). FinTech access considerably improves economic levels, promoting local infrastructure and creating higher employment opportunities. These factors encourage internal migration from neighboring cities. This internal in-migration from neighboring

cities significantly increases carbon emissions in local towns. However, out-migration from neighboring cities reduces carbon emissions in neighboring cities (Cheng et al., 2023a; Wang et al., 2022; Yan et al., 2023).

6. FinTech and sustainable development dimensions

6.1. Conceptual framework of FinTech and SDGs

Lim (2022) and Lim (2023) integrate a meta-perspective and multi-stage approach, and Lim et al. (2022, 2022b) use bibliometric and thematic analyses to provide theoretical and practical insights. Mukherjee et al. (2022) advocate that bibliometric research informs

theory and practice.[5] Thus, we show that the current research has specific significance for socioeconomic and environmental aspects in response to the research gaps and objectives. To assess sustainable development in the financial, economic, and environmental dimensions of FinTech, we build the conceptual framework shown in Fig. 5, in which we align the significance of FinTech to specific SDGs. Considering the existing literature and the SDGs, we show three specific SDGs dimensions of the relationship between FinTech and sustainable development. Achieving these goals results in long-term development through financial sustainability.

6.2. Dimension 1 - FinTech → inclusive finance → sustainable development

The *first dimension* describes the relationship between FinTech and sustainable development through inclusive financing. SDG *Target 1.4* emphasizes access to basic services, particularly appropriate new technologies and financial services, including microfinance. FinTech is an emerging financial product that ensures and boosts financial services with new technologies. Buckley et al. (2021) relate "FinTech" and "sustainable development" through "financial inclusion," which encompasses broader access to financial services. Access to financial services positively affects sustainable development; however, financial literacy, infrastructure development, and institutional quality also play pivotal roles (Yap et al., 2023). FinTech has emerged as a key catalyst for expanding access to financial services, ultimately fostering a more equitable and sustainable development trajectory. This transformation is driven by a multifaceted approach encompassing alterations in business models, creation of incentives, formulation of policies, and implementation of regulations. These strategies are geared toward channeling financial resources both globally and within individual nations to bolster sustainable development initiatives, as posited by (Arner et al., 2020).

Target 8.3 focuses on access to financial services to promote development-oriented policies to support productive activities, entrepreneurship, creativity, and innovation and inspire the formalization and growth of micro-, small-, and medium-sized enterprises. In this aspect, FinTech offers different financial services to promote entrepreneurship and innovation, boost SMEs in rural areas through higher financing, and improve lending technologies. Research has firmly established the connection between this phenomenon and sustainable development. Notably, Bayram et al. (2022) posit that FinTech significantly enhances financial inclusion for underbanked individuals and medium-sized enterprises (SMEs) through innovative mechanisms such as contactless payments, digital contracts, and mobile-based microfinance. This contribution strengthens the financial landscape and aligns it with the sustainable development objectives.

Further, FinTech contributes to sustainable development by augmenting payment systems with educational content focused on responsible consumption, thereby promoting informed financial choices. Additionally, it fosters rural socio-economic development by cultivating robust rural e-commerce ecosystems and empowering traditionally underserved communities to participate in economic growth. FinTech companies are introducing new services to help SMEs overcome barriers to adopting business models (Kong and Loubere, 2021). Moreover, FinTech's potential extends to facilitate SMEs' transition toward more sustainable business models and enhance their integration of circular economy practices, as articulated by (Pizzi et al., 2021). Sheng (2021) argues that FinTech promotes sustainable development by extending credit to SMEs.

These discussions also support the SGD *Target 8.10*, which emphasizes strengthening the capacity of domestic financial institutions to expand and encourage access to banking, insurance, and financial

services. In this context, greater FinTech access helps more people integrate into the formal financial system, which eventually drives the formal financial system, especially banks, insurance companies, and other financial service institutions. *Target 9.3* emphasizes developing the financial services of developing countries, particularly affordable credit services. In this context, FinTech substantially boosts commercial bank lending by reducing lending default risks (Berg et al., 2020; Cheng and Qu, 2020; Croux et al., 2020) and lending disparity (Bartlett et al., 2022). Remarkably, FinTech has more potent effects on lending in developing countries (Bharadwaj and Suri, 2020), with fewer lending opportunities and less access to banking (Saiedi et al., 2020). Rizwan and Mustafa (2022) suggest that nations have a significant opportunity to enhance their financial inclusion by utilizing FinTech tools, such as crowdfunding and blockchain. These tools can disrupt and introduce novel roles that traditionally rely on intermediaries. This transformative impact is particularly conspicuous in developing economies, where momentum is gaining rapidly. Nevertheless, it is essential to acknowledge that further infrastructure and financial system improvements are imperative to fully realize these benefits. Deng et al. (2019) support the impact of FinTech, particularly P2P lending, on sustainable development. Hence, FinTech plays a multifaceted role in reshaping the financial landscape and fostering economic sustainability.

Target 10.C of the Sustainable Development Goals (SDGs) considers the promotion of remittances by reducing costs associated with cross-border payments. A critical enabler of this goal is access to FinTech, an essential financial product that plays a transformative role in reducing transaction expenses for cross-border remittances. Gomber et al. (2018), Gozman et al. (2018), and Guermond (2022) demonstrate that cost-effective cross-border remittances significantly promote access to finance and FinTech. Hahm et al. (2021) note that access to FinTech provides diversified financial services for the unbanked, accelerates economic and social growth through digital remittances, and achieves sustainable development. Buckley et al. (2021) advocate that FinTech, and financial inclusion tools should be used together to ensure future sustainable development.

6.3. Dimension 2 - FinTech → economy boosting → sustainable development

The *second dimension* describes the relationship between FinTech and sustainable development through the promotion of economic development. In the economic section, SDG 1 (specific *Target 1.1*) aims to eradicate extreme poverty by 2030. *Target 1B* emphasizes accelerating investments in poverty eradication actions. In this context, FinTech, especially digital payments, significantly increases per capita income and strongly supports poverty reduction in least-developed countries (LDCs) toward sustainable development (Chen, Kumara, & Sivakumar, 2021; Kanga et al., 2021; Yu et al., 2022). *Target 8.1* of SDG 8 focuses on sustainable economic growth (at least 7% gross domestic product growth per year), particularly in the least developed countries.

The progress of digital financial integration has expanded market competition, increased service sector employment opportunities, expanded financial activities, encouraged sustainable agribusiness development, and promoted economic growth.[6] FinTech assumes a multifaceted function in addressing the financing gap critical to sustainable development. First, it catalyzes infrastructure development and fosters economic expansion, as highlighted by (Michael and Latkovska, 2021). Aryusmar (2020) reinforces this notion by emphasizing how

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[5] Kraus et al. (2022) show the role of literature reviews in developing advanced understanding.

[6] See the following references for how the progress of digital financial integration expands market competition, increases service sector employment opportunities, expands financial activities, encourages sustainable agribusiness development, and finally promotes the economy's growth (Adu et al., 2023; Kanga et al., 2021; Kurantin and Osei-Hwedie, 2019; Lashitew et al., 2019; Lechman and Popowska, 2022).
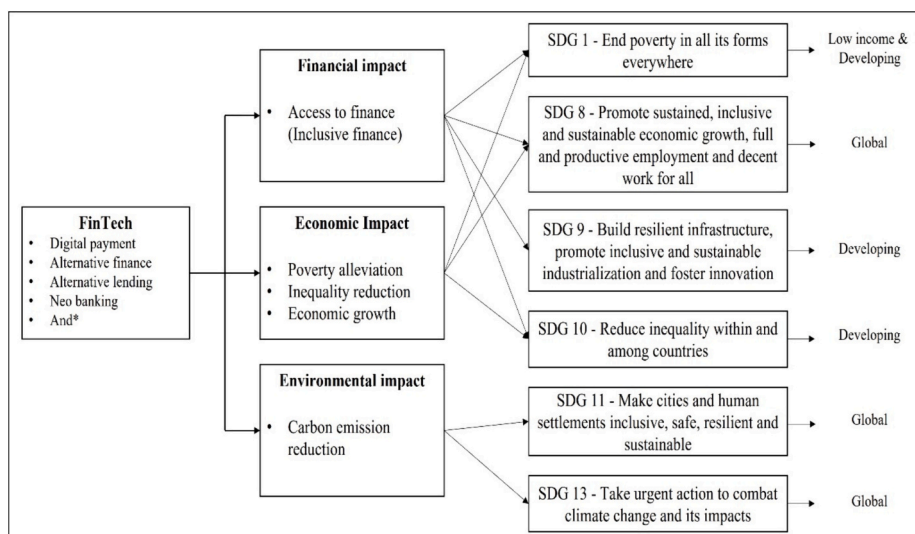
Fig. 5. Dimension of FinTech and SDGs.

Note: * refers to different FinTech products and services such as mobile payment, mobile savings, mobile banking, internet banking for other services, financial innovations (innovative patents), mobile money for bill payments, alternative finance (crowdfunding and P2P lending), business lending, consumer lending, student microlending, ATM usage, e-commerce transaction, AI-based financial applications, FinTech startup formation, online lending through community-based organizations, remittance, blockchain-enhanced emissions-trading systems, debit and credit card usage, big data-based technologically innovative financial products.

FinTech can invigorate economies, curtail corruption and illicit fees, bolster state revenue streams, and ultimately contribute to sustainable development, thereby enhancing living standards.

Furthermore, applying FinTech methodologies to manage vast datasets and using tools to actualize green economy principles holds the potential to render green businesses more appealing to investors. Simultaneously, this fosters smooth interactions between governments and businesses, culminating in a green economy that fosters sustainable economic development, as expounded by (Ignatyuk et al., 2020). Razletovskaia (2020) concludes that effective cross-border and cross-sectoral financial coordination promotes global financial and investment strategies, thereby boosting sustainable development. Through inclusive financing, FinTech significantly promotes sustainable development through the circular flow of the economy (Begum et al., 2023).

FinTech also supports economic development by achieving higher economic productivity through diversification, technological upgrades, and innovation (*Target 8.2*). Integrating new digital financial services also reduces income inequality by offering higher banking access and improving digital connectivity, which promotes financial and economic activities and makes household financial activities convenient. The role of FinTech in mitigating individual and societal income inequality aligns closely with the objectives outlined in SDGs *Target 10.3*. This explicitly underscores the importance of fostering equal opportunities and diminishing disparities in outcomes. In support of this perspective, Buckley et al. (2021) reveal that access to finance indirectly promotes sustainable development by creating quality employment opportunities, economic expansion, industrial infrastructure development, and reducing disparities in income and wealth. Access to FinTech also reduces gender discrimination and promotes women's empowerment, leading to sustainable development (Esmaeilpour Moghadam and Karami, 2023).

In addition to *Target 10.3 and Target 10.4* focus on adopting fiscal, wage, and social protection policies and progressively achieving greater equality. Countries that adopt favorable policies supporting access to finance and FinTech, especially mobile payments and savings, play a pivotal role in advancing the Sustainable Development Goals (SDGs) (Michael and Latkovska, 2021). However, it is essential to recognize that, in addition to these supportive policies, enacting and enforcing comprehensive FinTech laws holds significant importance in shaping and enhancing SDG funding (Michael and Latkovska, 2021).

6.4. Dimension 3 - FinTech → environment quality → sustainable development

The *third dimension* describes the relationship between FinTech and sustainable development through improving environmental quality, mainly by reducing carbon emissions. Considering the SDGs targets, *Target 11.6* emphasizes reducing the per capita adverse environmental impact by 2030. FinTech significantly reduces per capita carbon emissions by promoting and motivating low-carbon behavior among FinTech users. Both Zhang (2022) and Zhang et al. (2021) discover that Ant Forest, a mobile payment technology-based app, has many potential roles in attaining the SDGs. The impact of forests extends across a spectrum of vital areas, including land restoration, carbon emission reduction, poverty alleviation, and human health enhancement. Ant Forest effectively incentivizes positive behavior among mobile payment users, fostering a sense of responsibility toward sustainability.

Restoration projects facilitated by FinTech, exemplified by Ant Forest, have substantial scalability potential. However, continuous platform refinement is imperative for maximizing this impact. This refinement should align with current users' aspirations and objectives, while actively recruiting new users to join the cause. This dynamic approach ensures that Ant Forest is a powerful force in advancing sustainability and SDGs.

SDG 13 focuses on climate action and aligns with the UN's Paris Agreement (UNFCCC, 2016). This study focuses on *Target 13.2* "integrate climate change measures into national policies, strategies, and planning indicators." *Target 13.2.2* focuses on annual gas emissions. In this regard, a country's FinTech innovation encourages the development of technologies such as information technology, nanotechnology, and biotechnology, which have substantial beneficial spillover effects on promoting environmental quality and reducing greenhouse gas emissions (Tao et al., 2022). According to Lisha et al. (2023), FinTech plays a crucial role in advancing environmental conservation efforts, particularly in carbon emissions reduction through the integration of green and innovative technologies. However, the transition to these sustainable environmental technologies is gradual, necessitating both time and concerted efforts.

Besides, *Target 13.A* focuses on green climate funds from the perspective of transparency and mitigation actions to implement and fully operationalize the United Nations Framework Convention on

Climate Change (UNFCCC). The UN Paris Agreement provides a framework to show how countries support one another, particularly focusing on financial, technological, and capacity-building support (UNFCCC, 2016). In this regard, FinTech promotes green finance (Liu et al., 2022; Nenavath, 2022), and encourages renewable energy production and consumption (Butu et al., 2021; Croutzet and Dabbous, 2021) to reduce adverse impacts on the environment. Nenavath and Mishra (2023) show how green finance shapes the development of financial structures, enhances financial efficiency, and safeguards environmental quality, a triumvirate that collectively fosters high-quality economic growth. FinTech enhances the synergy between green finance and economic success, amplifying the profound impact of green finance on the financial system and preserving environmental quality.

Furthermore, FinTech has emerged as a potent force propelling sustainable economic development by introducing new business models, innovative business processes, and cutting-edge financial products. These novel services will pave the way for improved access to energy funding and active promotion of sustainable economic growth (Awais et al., 2023). FinTech also enhances the sustainability of renewable energy businesses by increasing investment efficiency. Specifically, adopting eco-friendly credit policies and enhancing the quality of information disclosure contribute to FinTech's positive influence on the sustainable growth of renewable energy enterprises (Jiang, 2023).

Additional literature supports the vital nexus between access to finance, FinTech, and the advancement of development goals. Ullah et al. (2023) find that FinTech significantly promotes sustainable development by increasing energy efficiency and promoting a positive energy transition. Ozili (2022) further substantiates this connection by revealing that enhanced access to finance is correlated with increased electricity production from various renewable sources. Moreover, service recipients' perceptions play a pivotal role in shaping the impact of FinTech on sustainable development. Campanella et al. (2023) illustrate this by highlighting how customers exhibit preferences for service providers with strong environmentally conscious images, particularly those that prioritize green strategies to foster environmental sustainability.

7. Challenges of access to FinTech

Several challenges reduce FinTech-based sustainable development. The high costs of FinTech services and overhead costs of ICT create significant barriers to accessing FinTech products and services (Hamdan et al., 2022; Murinde et al., 2022; Mushtaq and Bruneau, 2019; Ndassi Teutio et al., 2021; Ozili, 2018). In addition, security concerns related to online banking and cyberattacks (Agwu, 2020; Hajek et al., 2022; Yang, Abedin, & Hajek, 2023), poor data quality (Mhlanga, 2020), and low adoption rates of ICT products and services (Khera et al., 2022) limit FinTech acceptance. Furthermore, the uncertainty of new technologies, poor digital infrastructure (Strangio, 2021), weak regulations, and a lack of data ethics (Abedin et al., 2021; Hinson et al., 2019) influence rural residents to keep money at home and motivate them to be excluded from using FinTech products and services. Additionally, respondents' poor knowledge of banking services is a significant barrier to accessing FinTech services (Hamdan et al., 2022). Hasan et al. (2021) and Hasan et al. (2022b) point out that poor knowledge regarding specific FinTech services is a significant obstacle to FinTech-based inclusive development. There are also some challenges, such as the perceived risk, that reduce confidence in digital financial services and mobile money agents and demotivate users from using FinTech products (Senyo and Osabutey, 2020).

The major concern is that potential income and wealth disparities increase because higher-income countries adopt more FinTech than lower-income countries. Differences in adoption even exist within a country based on educational level and income (Morgan, 2022). In addition, the development of information and communication technologies fuels illicit financial activity, ultimately fuelling the shadow economy (Lai et al., 2022). A relatively high shadow economy ultimately reduces financial inclusion as financial transactions occur outside the mainstream financial system (Kanga et al., 2021). However, although people are becoming more familiar with using FinTech products, there is still a drawback, as evidenced by 66% of women who had mobile payment accounts but did not use them to keep or save money (Kim, 2022).

8. Implications of the study

Our study has implications for FinTech consumers, service providers, policymakers, governments, and academics. *First*, considering the FinTech consumer dimension, consumers will be much more positive when they realize the importance of FinTech in reducing the individual level of poverty, improving financial conditions, enhancing economic well-being, and eliminating social inequality in FinTech access. Financial literacy, especially FinTech and digital literacy, is one of the most important factors in their realization. *Second*, FinTech progress reduces the size of the informal economy. In this case, banks try to expand their FinTech products and services to expand the size of their formal economy. Particularly, data privacy, data security, service availability, and cost-effective banking services make consumers more interested in being included in formal financial systems. Thus, banks and financial institutions consider the significance of FinTech access and include more financially excluded users. *Third*, this study shows how, and to what extent, access to FinTech plays an important role in alleviating poverty, reducing inequality, accelerating the economy, and improving the quality of the country's environment. Our research also shows that greater use of technology and a strong regulatory response to institutional-level factors can close the financial exclusion gap. Therefore, policymakers should prioritize developing supportive policies to narrow the financial exclusion gap and the gap between consumers and financial institutions so that more consumers can be integrated into the formal financial system. In some cases, the government is involved and responsible, especially in underdeveloped and developing countries, where the development of most public services depends on the government. Thus, if governments develop ICT and digital infrastructure, these developments will positively affect the economy. Additionally, consumers will benefit if the government enacts strict laws to combat cybercrime, thereby facilitating access to FinTech more actively. Simultaneously, almost all countries face severe environmental risks. Our research shows that FinTech plays many direct and indirect roles in improving environmental quality, and policymakers consider FinTech to be an important factor in carbon neutrality. Particularly in areas where rural consumers do not have access to credit facilities, FinTech plays an important role in ensuring a sustainable environment by increasing credit facilities for environment-supportive projects.

Additionally, our study suggests that policymakers should formulate different climate change-related policies to address the greenhouse effect caused by financial inclusion. It is essential to focus on how FinTech addresses various climate-related challenges. FinTech directly affects the environment by promoting renewable energy production and consumption, green financing, and other green incentives. Therefore, if policymakers formulate support policies for FinTech start-ups and support policies for traditional financial institutions, more FinTech start-ups will be developed to promote green investment and improve environmental quality.

9. Conclusion and future research direction

This study aims to identify the dimensions of FinTech's impact on sustainable development through a systematic review. FinTech for sustainable development begins by providing access to FinTech to accelerate consumers' daily financial and household activities that guide their individual development. Individual development also leads to inclusion at the rural level and overall financial and economic

development. Financial and economic development includes eradicating poverty, reducing inequalities at the individual and societal levels, and playing a more significant role in overall economic growth.

Most studies have highlighted only mobile payments as a measure of FinTech. FinTech is in its nascent stage but with growing services. Other FinTech services will become prevalent, including alternative financing for SMEs, crowdfunding (reward-based), crowd investing (equity-based crowdfunding), alternative lending to individual consumers, online business lending, branchless banking (neobanking), Robo-advising, and FinTech-based asset management. These FinTech innovations can provide niche research avenues for the future.

Focusing on all FinTech tools, it is crucial to research how FinTech applications may support sustainable consumer choices and improve financial literacy. This could include budgeting tools based on sustainability standards or apps that provide information on product sustainability.

It is crucial to examine FinTech's potential to facilitate cross-border payments, reduce transaction costs, and enhance the transparency of international charitable organizations, disaster relief initiatives, and sustainable development projects. Future research should focus on the development of FinTech solutions that streamline and promote sustainable investments. This could involve the creation of user-friendly platforms for green bonds and sustainable funding. Another valuable research avenue is evaluating the impact of such investments on achieving sustainability objectives. Additionally, research is required to explore how blockchain technology can be leveraged to establish transparent and traceable supply chains and ensure the ethical and sustainable sourcing of products.

FinTech resources can be used to evaluate and manage financial risks related to climate change. Research can investigate the development of algorithms, machine-learning models, and tools to determine how climate change affects financial portfolios and create risk-reduction plans. It is also possible to research how blockchain technology and smart contracts can improve the market efficiency and transparency of carbon credits. Research should concentrate on how FinTech can enhance the insurance sector's capacity to manage risks related to climate change. This includes IoT (Internet of Things) data used for risk assessment and parametric insurance products triggered by climate events.

FinTech resources present a valuable opportunity to assess and mitigate the financial risks associated with climate change. Research endeavors may explore the development of advanced algorithms, machine learning models, and analytical tools dedicated to forecasting the impact of climate change on financial portfolios and crafting effective risk-mitigation strategies. In addition, there is a promising avenue of research for applying blockchain technology and smart contracts to enhance market efficiency and transparency concerning carbon credits. A focused research effort can also be directed toward strengthening the insurance sector's capacity to manage climate-related risks. This entails harnessing IoT data for precise risk assessment and designing parametric insurance products activated by climate-related events.

This study also focuses on study methods for future research. Although multiple review methods exist, the two most prominent are PRISMA and SPAR-4-SLR.[7] With the proliferation of open-source software that automates literature reviews, human processing must provide a sound basis for both theoretical and practical applications. Therefore, a circular or iterative approach was adopted.

Economic development influences the environment both directly and indirectly. Since FinTech affects the environment positively and negatively with the development of the economy, it is necessary to research how to reduce the negative impact of FinTech on the environment by promoting the economy and reducing the negative impact of economic development on the environment. Thus, this study provides a deeper understanding of the role played and challenges faced by FinTech and underlines its potential contribution to sustainable development.

Data availability

Data will be made available on request.

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[7] Refer to Paul et al. (2021), and Ciasullo et al. (2022)

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