An investigation into aspects of market behaviour in UK financial futures markets.

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An investigation into aspects of market behaviour in UK financial futures markets

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Thesis
submitted to the University of Wales in candidature for the degree of

PHILOSOPHIÆ DOCTOR

European Business Management School
University of Wales Swansea
Swansea SA2 8PP
United Kingdom
December 2003

To my family.

Declaration

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

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Pornsawan Evans

December 2003

Statement

This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by footnotes giving explicit references. A bibliography is appended.

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Pornsawan Evans

December 2003

Statement

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December 2003

Summary

This thesis investigates a number of features of UK financial futures markets: (i) market microstructure through the context of the volume-maturity relationship of FTSE100 futures (stock index futures), Long Gilt (bond futures) and Short Sterling (interest rate futures), (ii) domestic market linkages through the impact of macroeconomic announcements on the lead/lag relationship between the stock index futures and its equity index, (iii) international market linkages through the transmission of arbitrage information, measured by the mispricing errors, of stock index futures across the UK, US and Australian market, and (iv) the market efficiency of the three UK financial futures contracts, including the impact of the introduction of an electronic trading on the efficiency. We found an inverse relationship between the maturity and traded volume of these futures contracts. However, observation of the relationship for various maturity horizons (the near, middle and far contract) reveals that the inverse relationship is contributed mainly by the middle contract trading. The study of the lead/lag relationship reveals a futures lead over the cash market of 50 minutes for the FTSE100. UK macroeconomic announcements are found to strengthen the futures lead by up to 5 minutes. The impact from bad news created by the announcements appears to strengthen the futures lead whereas good news causes a price lead from the cash market to the futures market instead. The study of the international market linkages reveals the existence of bi-directional transmission of mispricing errors of stock index futures across the countries under investigation. We found a spillover from the US market to the Australian market, but not to the UK market, and from the Australian market to the US market. Finally, the study of market efficiency indicates that all three UK futures markets under investigation are weak-form efficient.

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Chapter 1

Introduction

This thesis investigates a number of features of UK financial futures markets, including market microstructure, domestic market linkages, international market linkages and market efficiency. Although there has been extensive research published on the above topics, this study has however investigated aspects of these topics that have never been previously examined. The results contribute completely new findings to the existing literature.

This study investigates an aspect of market microstructure of UK financial futures markets through the context of the volume-maturity relationship of financial futures contracts; the domestic market linkages through the impact of macroeconomic announcements on the lead/lag relationship of a stock index futures contract and its underlying equity index, including the impact of asymmetric responses to good and bad news generated by macroeconomic announcements on such a relationship; the international market linkages through the transmission of arbitrage information across international boundaries. Finally, the study examines the market efficiency of UK financial futures contracts.

Here, the study on the volume-maturity relationship of financial futures contracts is the first research work to identify the factors contributing to the negative maturity effect on traded volume of futures contracts (or an inverse volume-maturity relationship) as widely reported by previous studies. This is done by examining the relationship for three maturity groups, the near, the middle and the far contracts. This approach helps to identify the maturity group, which makes the major contribution towards the inverse relationship. In addition to this, it is the first study to undertake a comparative study of three financial futures contracts, all of which have distinctive characteristics. The overall findings provide more conclusive empirical evidence on the volume-maturity relationship of futures contracts. Previous work reports the findings of a negative maturity effect on traded volume acquired from the analysis using the pooled data of futures contracts irrespective of their maturity horizons.

In this study, a new measure is also devised to identify the degree of hedging and speculative demand of futures contracts. The timing of rollover from the nearest maturity contracts to the second-nearest maturity contracts is examined. This finding is very important to traders who wish to accurately identify the time window of high liquidity of a particular futures contract in order to achieve successful trade executions.

Next, the study investigates the impact of macroeconomic announcements on the lead/lag relationship between the stock index futures and its underlying equity index. The few studies that have previously looked at this relationship for the UK stock index market have all used low frequency data of an hour interval. This is the first study to employ high frequency data for such analysis, the result of which can be used to more accurately identify the timing of the lead and lag effect in the market. This is also the first study to examine whether asymmetric responses to good and bad news created by UK macroeconomic announcements strengthen or weaken the lead/lag relationship of the index futures with its underlying equity index. The finding of the asymmetric impact from the announcements will enable traders to produce more efficient forecasts of the equity price, based on the results of the lead/lag relationship.

Next, the study investigates the international market linkages through the transmission of arbitrage information across international boundaries. A great number of studies have been undertaken on international spillovers among financial markets. However, previous research has only focused on the spot equity markets. The spot and futures markets are closely related and futures markets are regarded as the markets for price discovery mechanism. The lower transaction (trading) cost in the futures markets is considered to be an important factor to induce informed traders to act there first, resulting in the price adjustment in the futures markets. The information of newly adjusted prices of the futures markets could then be used by traders in the spot markets. This is the first study to investigate the international spillovers of financial futures markets. The mispricings of futures contracts of the US, UK and Australia are examined and compared, the approach of which has never been previously taken. If the information spillovers exist, the inclusion of this finding in the analysis can help to forecast the pricing of spot indices more effectively. The three countries under investigation are chosen on the criteria of having strong historical, political and economical bond between them, i.e. US-UK, UK-Australia.

Finally, the study investigates the market efficiency of three UK financial futures markets. This is the first study to examine the market efficiency of UK stock index futures market (FTSE100 futures), UK bond futures market (Long Gilt) and UK interest rate futures market (Short Sterling). The study employs the concept of weak-form informational market efficiency as in the Efficient Market Hypotheses (EMH). The analysis aims to prove the randomness of futures price fluctuation, which signifies evidence of market efficiency. Traders can exploit the information of market inefficiency (or efficiency) of the financial futures instruments for more efficient forecasting of the financial instrument prices.

The investigations are presented in four chapters as follows. First, Chapter 2 investigates the microstructure of the UK financial futures markets via the context of the volume-maturity relationship. Unlike option traders, all futures contract traders have a settlement obligation to fulfil if they still have a position at contract expiration. It is observed that most traders focus their trading on the shortest-maturity contracts. To maintain a long term hedging position, traders normally avoid delivery obligation by rolling over to the second-nearest maturity (or middle) contracts. That is when the contract maturity has played a significant role in determining the market behaviour.

This research has undertaken a comparative study of the volume-maturity relationship of FTSE100 futures, Long Gilt and Short Sterling contracts. The three classes of UK futures contracts under investigation all have distinctive specifications. The analysis results could therefore yield more conclusive evidence of the maturity effect on traded volume of the financial futures contracts. The study aims to examine whether these contracts have a negative volume-maturity relationship as widely documented by previous research work and whether the relationship has been affected by the unique characteristics of the contract. A measure for the level of speculative and hedging demand for the futures contracts is devised. This helps to examine whether different level and type of demand for different classes of futures contracts has any significant effect on their volume-maturity relationships. The trading patterns of the futures contracts are also observed.

Financial futures contracts usually have three maturities available for trading, called nearest, middle and far contracts. The original feature of this study is to examine the volume-maturity relationship of each maturity group. This helps to identify the actual factors contributing to the magnitude and sign of the volume-maturity relationship.

The study also examines the timing of rollover, the situation whereby traders sell the futures contracts, usually of the shortest-maturity, and buy the second-nearest futures (or middle) contracts when approaching the expiration time of the contracts currently held. This information is crucial not only to traders who need to be able to accurately identify the timing of high liquidity to help facilitate successful trade executions but also to researchers who employ time series of price, volume and open interest for statistical analysis.

The effect of recent market deregulations, on the volume-maturity relationships is also examined, including the Long Gilt decimalisation, a change in tick size of FTSE100 futures contracts and the introduction of electronic trading at Euronext.liffe.

Chapter 3 investigates the existence of domestic market linkages between the financial futures contracts and the underlying equity index through the observation of its lead/lag relationship. A great deal of previous research reports a futures lead over the spot market, which implies that lagged changes in the futures price can help to predict changes in the spot prices. One of the primary uses of futures contracts is for price discovery. Lower transaction (or trading) costs and high liquidity in the futures markets helps facilitate successful trade executions more quickly than the spot markets.

To investigate the lead/lag relationship, the study employs the methodology of Fleming et al (1996), which includes an error correction term to account for cointegration which is induced by the arbitrage relationship between a security and its derivatives.

The original part of this investigation is to examine the impact of UK announcements on the lead/lag relationship, i.e. whether the relationship is strengthened or weakened around the announcements. According to the EMH, markets are sensitive to news arrival, either firm-specific or macroeconomic releases. As the macroeconomic announcement typically incorporates a high content of unexpected news, the study therefore investigates the impact of unexpected news (or news surprise) and the asymmetric news response on the lead/lag relationship. The type of news generated by the macroeconomic announcements is also examined in some detail. Chapter 4 examines the information spillovers of futures mispricing of one market across international boundaries. Previous research has investigated the international spillovers through equity markets. This is the first study to extend the analysis to futures markets.

An extensive literature review has reported the existence of mispricing in the financial futures markets. This study examines whether deviations from a domestic spot-futures relation, as identified through mispricing series in stock index futures, spill over international boundaries. The Cost-of-Carry model is employed to calculate the mispricing errors. Such spillovers suggest that information from a mispricing series in one market convey a signal of similar mispricing in another market. In the presence of arbitrage traders and in the absence of market frictions, mispricing series should be independent across international boundaries. The study employs a vector autoregressive analysis (VAR) of stock index futures mispricing across Australia, UK and the US. Using time zone differences, tests are conducted for the daily transmission of arbitrage information. The results reveal the relationship between mispricing series is bi-directional. Based on this finding, a trading strategy is employed to examine the economic significance of apparent profits.

Chapter 5 examines the market efficiency of the three UK financial futures markets; FTSE100 futures (stock index futures), Long Gilt (bond futures) and Short Sterling (interest rate futures), both before and after the introduction of electronic trading system.

This study is based on weak-form informational efficiency of the Efficient Market Hypotheses (EMH). As the Random Walk Hypothesis and the Efficient Market Hypotheses (EMH) have become closely related, the confirmation of a random walk is considered to be a sufficient condition of the market efficiency, although the rejection of a random walk does not necessarily imply market inefficiency. The study has therefore used the randomness of the price series as an indicator of the market efficiency of the futures contracts under investigation. To identify the randomness, the study examines whether the futures price series is non-stationary. For robustness, the analysis employs three different testing methods; the Augmented Dickey-Fuller unit root (ADF) test, the KPSS test by Kwiatkowski, Phillips, Schmidt and Shin (1992) and the Variance Ratio test by Lo and MacKinlay (1989). The study initially performs the efficiency test by using the ADF unit root method. To counter for the shortcoming of the ADF method for failing to distinguish between a unit root and a weakly stationary series, the study employs a further test by using the KPSS method. In contrast to the ADF unit root test, the KPSS test has stationarity of the price series as the null hypothesis and nonstationarity as the alternative. The combined results from both the ADF test and KPSS test, which is the acceptance of the ADF unit root null hypothesis and the rejection of stationarity from the KPSS test, will provide firmer evidence of the nonstationarity of the futures price series under investigation. If found, this will signify that the futures price series follows a random walk process, and that the futures contract is weak-form market efficient. However, as unit root tests also fail to detect certain important departures from the random walk, the study has also undertaken the Variance-Ratio test, as considered to be a better alternative for random walk test. To examine whether the introduction of electronic trading system has had any impact on market efficiency, the observation data are divided into two sub-periods, before and after the introduction of an electronic trading system. The results from applying the Variance-Ratio test to both sub-samples can therefore be used to indicate the impact, if it exists, of the change in trading system on the market efficiency of the futures contracts under investigation.

Finally, the summary and conclusions of this thesis are presented in Chapter 6.

Chapter 2

The volume-maturity relationship for stock index, interest rate and bond futures contracts

2.1 Introduction

It is generally observed by market traders that the majority of trading in futures contracts is concentrated in the front-month contract, i.e. that which has the shortest time to maturity. Trading in stock index futures tends to remain in the front-month contract right up to maturity, while other types of futures contract tend to exhibit rollover of trading volume and open interest into the second nearest contract some days or weeks before maturity. This study is unique in examining and quantifying the volume-maturity relationship across different classes of futures contracts.

The time pattern of traded volume and open interest over the life of a futures contract is crucial to traders who wish to deal in a liquid market. It is important for traders to know in which contracts volume is concentrated, and to understand issues relating to the timing of volume rollover and the levels of volume and open interest in longer maturity contracts. Additionally, the concentration of trading is an important factor for exchanges in the design of new contracts, and in achieving and maintaining adequate liquidity in existing contracts.

Detailed understanding of volume-maturity relationships is also highly relevant for market analysts and researchers, when employing time series of prices, volume and open interest for trading, risk management and market microstructure applications. The splicing of prices from different maturities has been shown to have a significant impact on most statistical tests (see Geiss (1995); Rougier (1996)). Hence, inferences are sensitive to the selection of the timing and form of rollover when constructing continuous series.

This chapter offers a unique contribution in highlighting and quantifying differing volume-maturity relationships for different classes of futures contract traded at the London International Financial Futures and Options Exchange (LIFFE). In anticipation of our findings, we generally report a significant inverse volume-maturity relationship, but find that this relationship is predominantly driven by the second-nearest contract to maturity. However, there are important differences in the relationship across stock index, interest rate and bond futures which are driven by different levels of hedging and speculative demand for the different classes of contract, and by differences in the timing and pattern of the rollover of volume and open interest as maturity approaches. A closer look during the periods of some major events such as the introduction of electronic trading system, the decimalisation of bond futures contracts and use of new tick size of the stock index futures is also undertaken to identify any significant impact on the market behaviour.

The remainder of this chapter is organised as follows. The next section discusses theory and previous empirical evidence of volatility-volume-maturity relationships. Section 2.3 describes the data and methodology used in this study. Section 2.4 presents the empirical results on hedging versus speculative demand, timing of rollover, trading patterns, and econometric analysis of the volume-maturity relationship. The findings are summarized in section 2.5.

2.2 Theoretical Background and Previous Evidence

The primary uses of futures contracts are hedging, speculation and arbitrage. Speculators will be most active in liquid contracts that allow them to close out positions as necessary. Arbitrage should have no impact on delivery schedules since it is based on price discrepancies. Therefore, hedging considerations are likely to be the main determinant of the choice of delivery schedule. Hedgers need to roll over their futures contracts, should their commitment of the underlying products exceed the current futures contract maturity. If transaction costs exist in the rollover of contracts from one maturity to another, this will lead to a preference for contracts with long maturity as this will reduce the number of times the position must be rolled over. Rolling a position forwards will involve rollover risk arising from the possibility of mispricing of the two related contracts at the time of the rollover. This increases the cost of rolling over a position, so favouring long maturity contracts. However, there is empirical evidence, for example, Chen et al (1999), to support the proposition that mispricing risk reduces as maturity approaches thus leading to a preference for short maturity contracts.

Sutcliffe (1997) presents some theoretical reasons for the choice of delivery schedule for stock index futures contracts, and the following discussion draws on his analysis. If there is no dividend or interest rate risk and the no-arbitrage condition applies at all times, the choice of contract maturity for use in a hedge is arbitrary. For any contract maturity, the hedge is then riskless and, if there are no costs in rolling over a position, there is no reason to prefer one maturity over another. Grant (1982) shows that in this situation, there need only be one maturity available at a time and the actual maturity date is irrelevant.

A number of factors (i.e. basis risks, dividend risk, interest rate risk as explained below) favour the use of short maturity stock index futures contracts for hedging and therefore induce a negative volume-maturity relationship. Both dividend risk and interest rate risk are likely to fall as the maturity date approaches. As a consequence, basis risk will be lower for contracts with a short maturity. Castelino and Francis (1982) show empirically that the volatility of the basis declines as the maturity of the contract shortens.

Although there appears to be a conflict between factors favouring a long contract maturity (roll-over transactions costs and roll-over risk), and factors favouring a short maturity (basis risk), the existing empirical evidence suggests a preference for short-term contracts. Also, if most hedgers have a short horizon, then roll-over costs and risk (even for a futures contract with a short maturity) will be zero, and hedgers will favour a short maturity contract.

The issue of designing contracts with appropriate maturities could be solved by the existence of a very large number of contracts with different maturities, but this raises the issue of liquidity. Traders prefer to use a liquid market with low bid-ask spreads and minimal price impact for large trades. If many different contracts were traded, each with a different maturity, the liquidity of each of these contracts would tend to be reduced. In order to maintain liquidity, exchanges list only a limited number of delivery dates at any given time. The higher the total volume in the market, the larger the number of outstanding maturities that can be supported.

Bamberg and Dorfleitner (2000) employ a stochastic model to establish a connection between the volume concentration on short maturity futures contracts and a high level of early unwinding. Their model demonstrates that the short maturity contract is favoured over the next nearest to maturity because of the early unwinding option. This holds as long as the early unwinding process has three properties; (i) day trading is not a dominant type of trading; (ii) holding a position to expiration is not the dominant trading behaviour; and (iii) the early unwinding propensity is regular. Bamberg and Dorfleitner (1998) report very high early unwinding ratios (proportion of all individual contracts closed before expiration) for the German DAX market, ranging from 90 to 98%.

When analysing futures contracts with various maturities trading simultaneously, it is necessary to establish the timing of the rollover. When analysing a long time series, due to the limited life of an individual futures contract, researchers construct longer time series either by discrete rollover or by splicing prices from contracts with different maturities. In the case of rollover, there are typically four choices for the switch from using the front-month to the second nearest contract: (a) the time of volume crossover; (b) the time of open interest crossover; (c) the time when volume in the second nearest contract exceeds a certain threshold; or (d) a fixed number of days from the expiry of the front month contract.

The splicing process can potentially generate biases in the time series properties. Ma et al (1992) showed that typical statistical tests of futures price series can be very sensitive to the choice of rollover date and the method used for linking prices across contracts when splicing. Their evidence suggests that the expiry date should not be chosen as the rollover date as it is subject to excessive price volatility. Geiss (1995) and Rougier (1996) discuss splicing rules whereby weighted averages of prices on outstanding futures contracts are used instead of a discrete switch from the front month to the second nearest contract. Geiss (1995) reported that both the method of splicing and the form of price variable have a significant impact on most statistical tests. Hence, inferences will be sensitive to the selection of the timing of rollover when constructing continuous series.

2.2.1 Volatility-Volume Relationship

There is some evidence that price volatility in futures markets increases both as delivery approaches and as volume increases, which implies that volume may increase as delivery approaches. Samuelson (1965) hypothesised that the volatility of futures prices should increase as expiry approaches. This 'maturity effect' occurs because the model assumes that market competition forces the spot and futures prices to converge at maturity. Thus, prices of futures contracts close to maturity react more strongly to new information about the underlying asset than do prices of long maturity contracts. For longer-maturity contracts, relatively little is known about the future spot price at the delivery date. Galloway and Kolb (1996) survey the literature testing this hypothesis, and present new evidence on this volatility-maturity relationship for 45 commodities over the period 1969-1992. Overall, the evidence is not conclusively in support of the Samuelson hypothesis.

In terms of the volatility-volume relationship, a number of theoretical models of asset markets predict its direction. The leading theories are the 'mixture of distributions' hypothesis and the 'sequential information arrival' model, both of which predict a positive relationship between daily volume and volatility. Under the first theory, Clark (1973) proposes that volatility measured over time periods is a positive function of a directing (or mixing) variable, and that this variable is information arrival. If volume per time period is a proxy for the rate of information arrival, this would imply a positive correlation between volume and volatility. Tauchen and Pitts (1983) argue that information arrival causes traders to revise their asset valuations. If there is agreement on the new asset value, the price will change but, apart from some portfolio rebalancing, little trading will occur. A larger discrepancy of traders' opinion will normally generate higher traded volumes. Thus, both volatility and volume per time period are functions of the rate of information arrival.

Copeland (1976) proposed the sequential information arrival model, which makes the assumption that a piece of information is received by one trader at a time, and each recipient trades on this information before it becomes known to anyone else. A sequence of temporary market equilibrium is suggested, which ends when every trader is aware of the information. A positive correlation is demonstrated between volatility and volume measured over the time period of a full response to information arrival.

The majority of empirical studies of the volatility-volume relationship have found a positive relationship (see Clark (1973); Grammatikos and Saunders (1986); Tauchen and Pitts (1983)). For the FTSE100 stock index futures, Board and Sutcliffe (1990) report that after controlling for maturity and weekend effects, a positive correlation exists between volume and volatility on a daily basis. Chen et al (1999) also find a positive relationship between Nikkei futures price volatility and maturity. Using intraday data on the same three LIFFE futures contracts as those examined in this paper (FTSE100, Short Sterling and Long Gilt), ap Gwilym et al (1999) find significant contemporaneous correlation between volume and volatility, and strong evidence of bi-directional Granger causality which is robust to a variety of temporal horizons and to adjustment for the impact of macroeconomic news announcements. A few studies have found evidence of a negative relationship between volume and volatility, e.g. Kawaller et al (2001) found such a relationship during the period around formal exchange re-designation of the lead S&P500 futures contract from the nearest to the next nearest maturity.

2.2.2 Previous Evidence on the Volume-Maturity Relationship

Grammatikos and Saunders (1986) examine the volume-maturity relationship for several currency futures and find strong negative relationships. For Eurodollars and U.S. dollar futures, Chamberlain (1989) finds a positive relationship, but shows that the relationship was not monotonic as volume increased initially and then decreased close to maturity and this may have induced the positive relationship. The data set included the days immediately prior to delivery when volume for most futures (except stock index futures) tends to have fallen dramatically, i.e. rollover has occurred to the next maturity contract.

Chamberlain (1989) also examines daily high-low data for the FTSE100 stock index futures contract, and finds a negative volume-maturity relationship for the two delivery months during March and June 1985. Board and Sutcliffe (1990) use transaction data for the FTSE100 stock index futures contract during the period from May 1984 to July 1989 to estimate the daily volume-maturity relationship and find it to be strongly negative.Sutcliffe (1997) uses data from 1984 to 1989 on the FTSE100 stock index futures contract, and disaggregates trades in the near, middle and far contracts. He finds that 81.3% of contracts traded are for the near month, with only 2.9% in the far contract. He states that the pattern was stable across the five years of data, indicating a clear preference for the nearest contract. The data were also disaggregated into the number of months to maturity. This showed that the volume of the nearest contract is evenly spread over its three-months of trading. The middle contract only has substantial volume when the nearest contract is in its delivery month. Sutcliffe (1997) also provides a brief comparison of this relationship against other U.K. futures. The primary difference between the FTSE100 contract and the five others examined is that there is little trading in the final month before delivery in all other contracts. For the FTSE100 futures, volume in the delivery month is over 25% of the total, with around 11% of trading when there are four months to delivery. For the other five contracts, the average volume share is 2.5% in the delivery month and 29% at four months before maturity.

2.3 Data and Methodology

2.3.1 Details of Data

The contracts examined have differing trading hours, settlement and trading features. The total observations are from 1 January 1990 to 19 September 2002 (Latest date for data subscription from LIFFE). During the second half of the1990's, there have been changes in regulations and trading system of the derivatives markets, some of which may have a significant impact on the market behaviour. We have therefore included three major events into our investigation; that is, the introduction of the electronic trading system, the decimalisation of the Long Gilt contracts and a change in tick size of FTSE100 futures contracts. In doing so, the trading behaviour is examined over the three sub-periods, called Period1, Period2 and Period3. Period1 covers from 1 January 1990 up to the commencing of the decimalisation of Long Gilt contracts and the introduction of the new tick size of the FTSE100 futures contracts whereas Period2 covers from then up to the introduction of the electronic trading system. Meanwhile, Period3 covers from the introduction of the electronic trading system onwards. As for the Short Sterling contracts, Period1 covers the time before the introduction of the electronic trading whereas the time beyond that is defined as Period3. The use of the electronic trading system for the FTSE100 futures, Long Gilt and Short Sterling market commences on 10 May 1999, 12 April 1999 and 6 September 1999 respectively. The decimalisation of the Long Gilt contracts is introduced on 11 May

1998. A sharp rise in daily traded volume, as shown in Table 12, Appendix 1, indicates that the impact of the new tick size for FTSE100 futures trading takes effect from 20 March 1998, or the March-1998 expiry.

a). Decimalisation of Long Gilt Contracts

With effect from 11 May 1998, the Long Gilt June 1998 contract was traded with a decimal (£0.01) rather than fractional (£1/32) minimum price movement. Up to and including the contract for June 1998 delivery, the unit of trading was £50,000 nominal. Subsequently, it became £100,000 nominal. Prices are quoted per £100 nominal value. Prior to decimalisation, the minimum price movement was £1/32, which had a value of £15.625. Following the decimalisation, the minimum price movement is £0.01, which had a value of £10. Thus, although the price grid became approximately three times finer, the tick value was reduced to approximately two-thirds rather than one-third of its pre-decimalisation level.

b). Change in Tick Size of FTSE100 Futures Contracts

As for the FTSE100 futures contract, the new tick size is reduced from £12.50 to £5 tick value (with unchanged tick size of 0.5 index points). The first contract with the new unit of trading was the June 1998 contract (with notice to the market issued in December 1997), which would be the 'Near1' contract from mid-March 1998. The change reflected the gains made by the underlying index over time, which resulted in an increase in the nominal value of the contract.

2.3.2 Futures Contract Specifications

a). FTSE100 Futures Contracts

The FTSE100 stock index futures contract is based on an index of the top 100 U.K. companies by market capitalization. During the sample period (1990-2002), trading in this market was by open outcry from 0835-1610 GMT, and by Automated Pit Trading (APT) from 1632-1730 GMT. The minimum price movement is 0.5 index point, which had a value of £12.50. The contract is cash settled based on the Exchange Delivery Settlement Price (EDSP), which is calculated from the average level of the FTSE100 index between 1010 and 1030GMT on the last trading day. Delivery day is the first business day after the last trading day. Delivery months are March, June, September and December, with the nearest three available for trading.

b). Long Gilt Contracts

Trading in the Long Gilt contract was by open outcry from 0830-1615 GMT for the period up to 31 July 1994 and from 0800-1615 GMT thereafter, and by APT from 1630-1800 GMT. During the sample period, prices were quoted per £100 nominal value and the minimum price movement was £1/32, which has a value of £15.625. Delivery may be made of any Gilt on the List of Deliverable Gilts and delivery can occur on any business day in the delivery month (at the seller's discretion). Delivery months are March, June, September and December, with the nearest three delivery months trading at any given time.

c). Short Sterling Contracts

Floor trading in the Short Sterling 3-month interest rate futures contract over the sample period was from 0805-1605 GMT, with APT trading from 1622-1757 GMT. Prices are quoted as 100.00 minus the rate of interest and the minimum price movement is 0.01. The contract is cash-settled based on the Exchange Delivery Settlement Price (EDSP), which uses the British Bankers' Association Interest Settlement Rate (BBAISR) for three-month sterling deposits at 11.00 on the Last Trading Day. The settlement price is then 100.00 minus the BBAISR (rounded accordingly). Delivery day is the first business day after the last trading day. Delivery months are March, June, September and December, with the nearest twelve available for trading.

Regulations on contract expiry and delivery of the underlying asset are likely to affect trading behaviour, in particular, the timing of rollover. For example, whereas both the FTSE100 and Short Sterling contracts are cash settled, the Long Gilt contract can be settled by sellers delivering gilts to holders of a long position at any time during the delivery month. The seller can initiate the delivery time schedule whereby the buyer will be legally obliged to accept. The physical delivery can be as early as the first business day of the delivery month. Buyers who do not wish to take up actual delivery are forced to close out their positions before the start of the delivery month. This possibility of delivery at the seller's discretion deters much speculative trading during the delivery month.

2.3.3 Methodology

Data are obtained from LIFFE-online information service supplied by the exchange (Euronext.liffe). We use daily observations for the above three UK futures contracts, over the period from 1 January 1990 to 12 September 2002. The total number of daily observations is 9690, 9405 and 44256 for the FTSE100 futures, Long Gilt and Short Sterling respectively. Data on volume, open interest, settlement (or closing) price and the contract delivery/expiry date are utilized. Time-to-maturity, hereafter termed expiry days, is the number of calendar days before maturity.

The relationship is initially observed via the scatter diagram plotting. Figure 1a-1c demonstrate a linear relationship between the traded volume and time-to-maturity of the three futures contracts. Estimation of the volume-maturity relationship is thus based on the following model:

$$V_t = \alpha + \beta M_t + \varepsilon_t \qquad \text{.........(1)}$$

where V represents the unadjusted traded volume and M is the number of calendar days remaining until futures contract expiration. The β represents the regression coefficient of the relationship whereas ε is an error term. The t subscript denotes the calendar date.

On each trading day, several futures contracts of the same type but different maturities are traded simultaneously. We categorise these as Near1, Near2 and Near3 (and additionally Near4 etc. for Short Sterling). To gain additional insights, we investigate the volume-maturity relationship using both pooled observations and observations for the sub-groups (Near1, Near2 and Near3). The pooled estimations investigate the volume-maturity relation for each contract in the sample from the contract's inception to its expiry day. The sub-group estimations investigate the relationship for the period where a contract falls into one of the sub-group categories of Near1, Near2, etc. Figure 2-4 display the scatter diagrams of the sub-groups Near1, Near2 and Near3 of the three futures contracts.

From OLS estimations, Durbin-Watson (D-W) test results indicate the existence of significant positive autocorrelation of the residuals for all three contracts. To address this, Generalized Method of Moments (GMM) is used for the estimation of the regression model. This method can provide a consistent estimator by the use of the weighting matrix that is robust to heteroscedasticity and autocorrelation of unknown form. The Newey-West's fixed bandwidth selection and Bartlette Kernel option are used during the estimation process. The Prewhitening method is used by running a preliminary VAR (1) prior the estimation.

Figure 1a
FTSE100 Futures Volume v.s. Expiry days

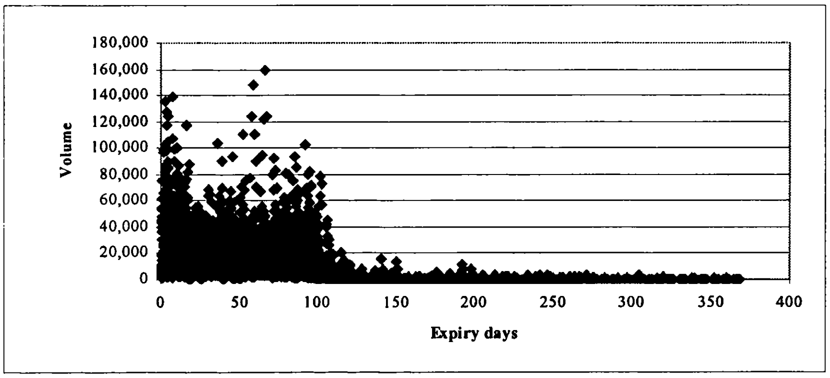


Figure 1b
Long Gilt Volume v.s. Expiry days

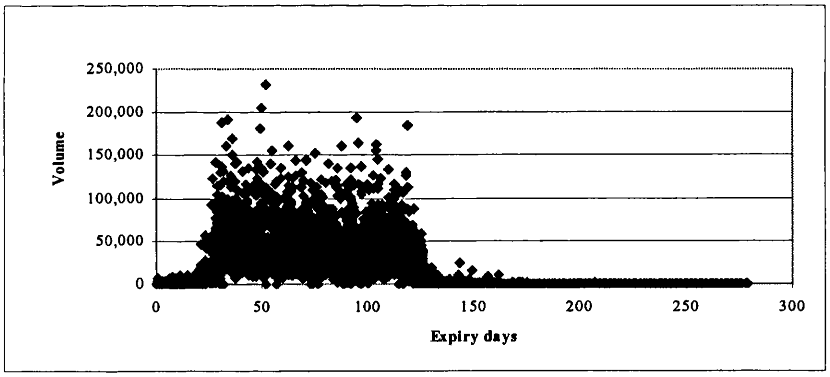


Figure 1c
Short Sterling Volume v.s. Expiry days

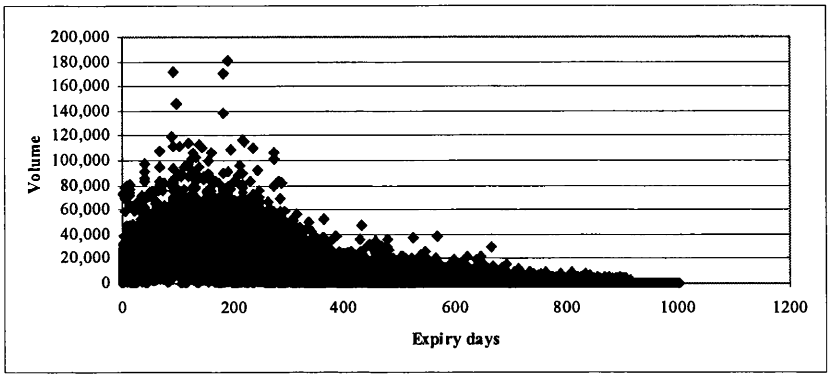


Figure 2a
FTSE100 Futures Volume v.s. Expiry days – Near1

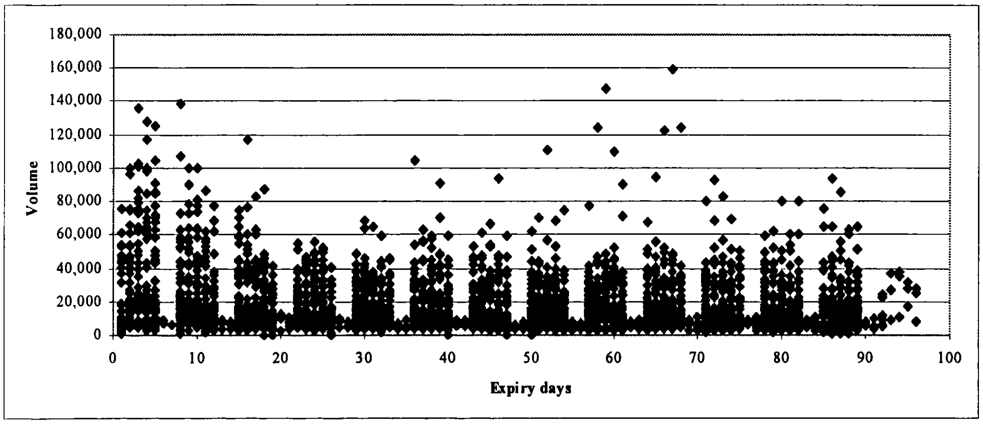


Figure 2b
FTSE100 Futures Volume v.s. Expiry days – Near2

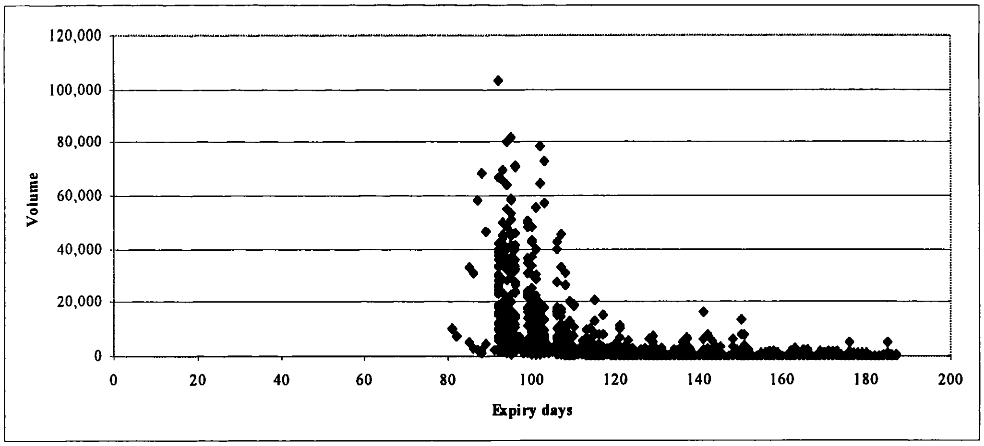


Figure 2c
FTSE100 Futures Volume v.s. Expiry days – Near3

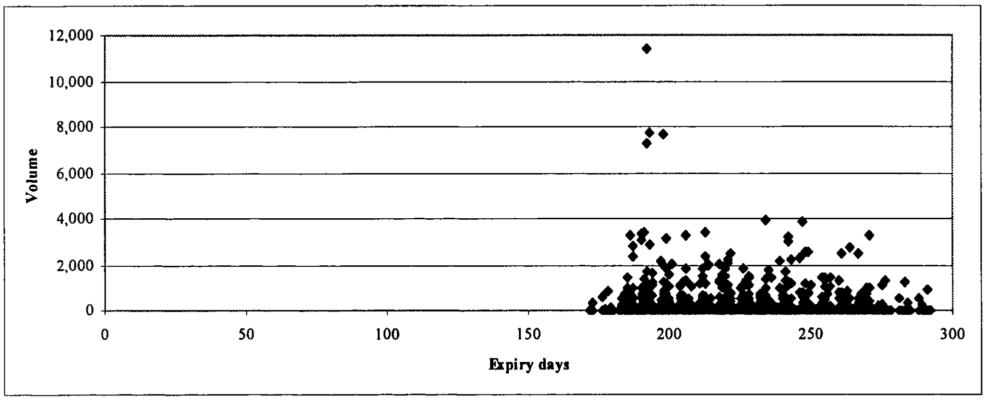


Figure 3a
Long Gilt Volume v.s. Expiry days – Near1

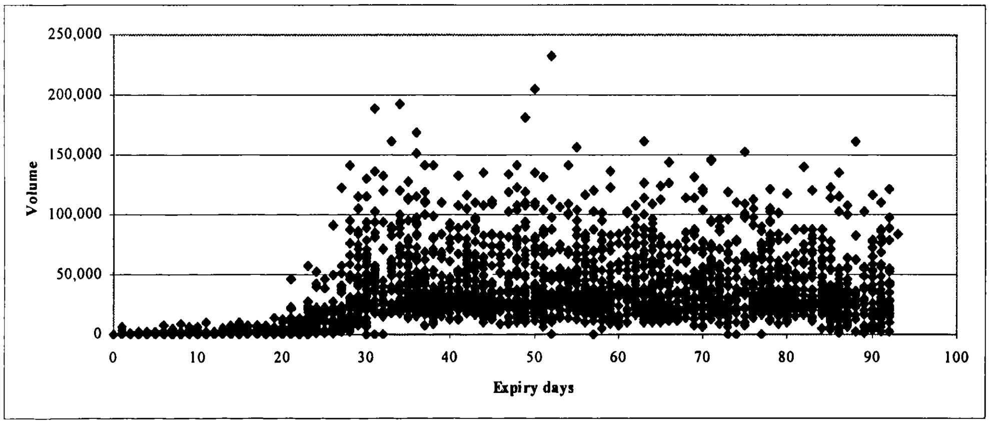


Figure 3b
Long Gilt Volume v.s. Expiry days – Near2

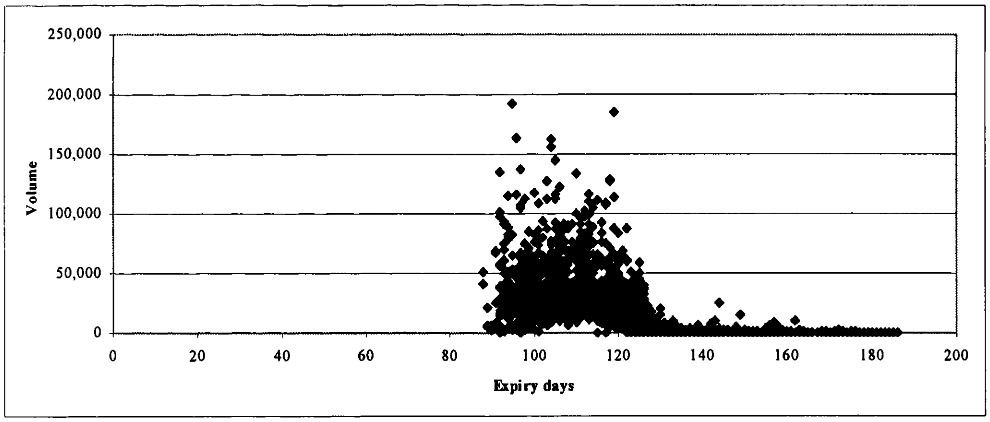


Figure 3c
Long Gilt Volume v.s. Expiry days – Near3

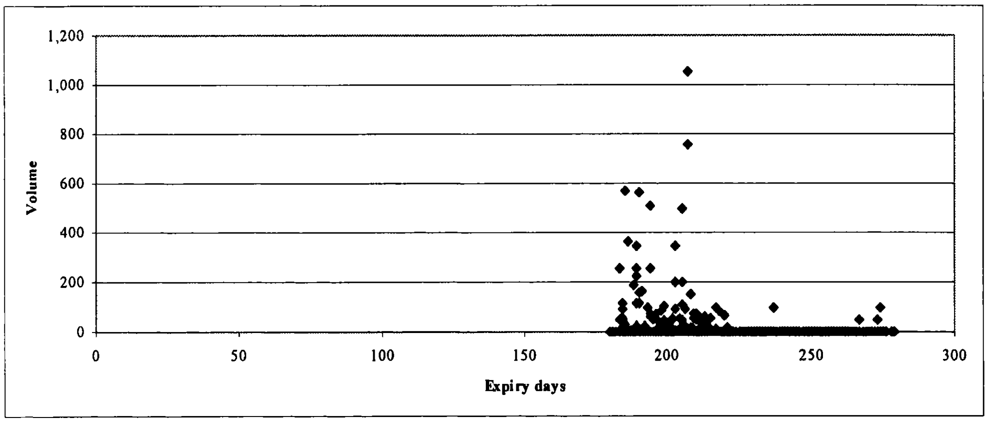


Figure 4a
Short Sterling Volume v.s. Expiry days – Near1

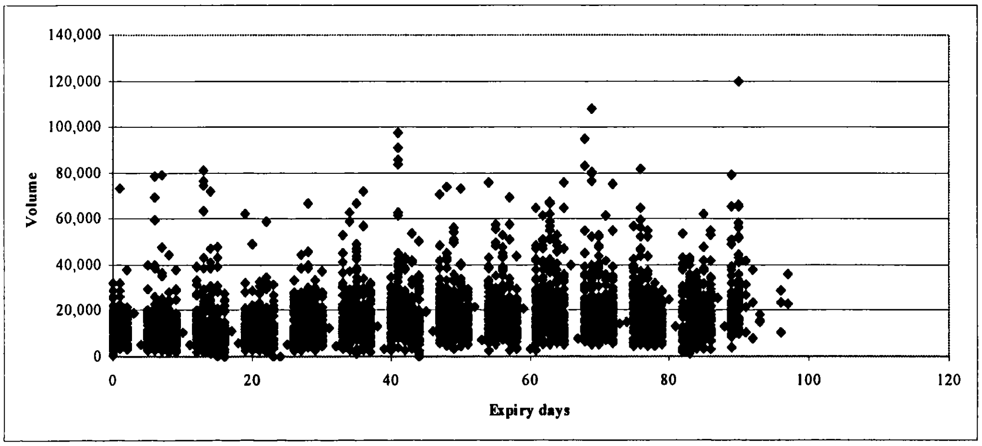


Figure 4b
Short Sterling Volume v.s. Expiry days – Near2

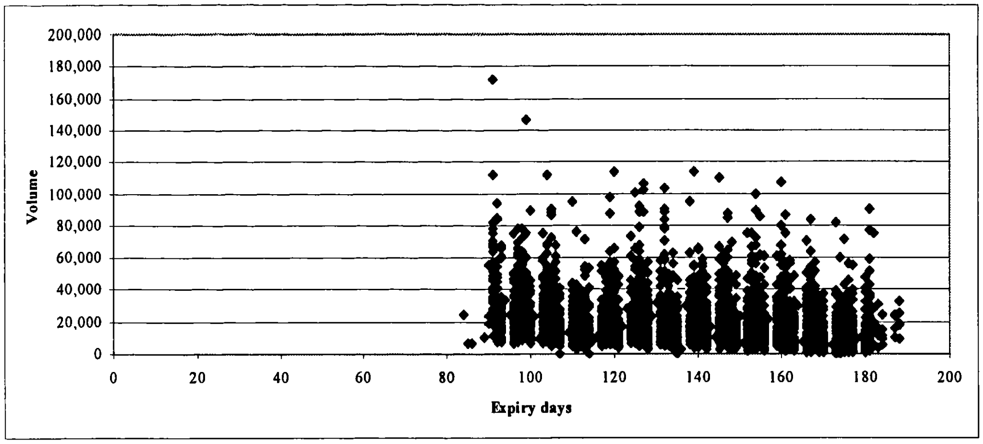
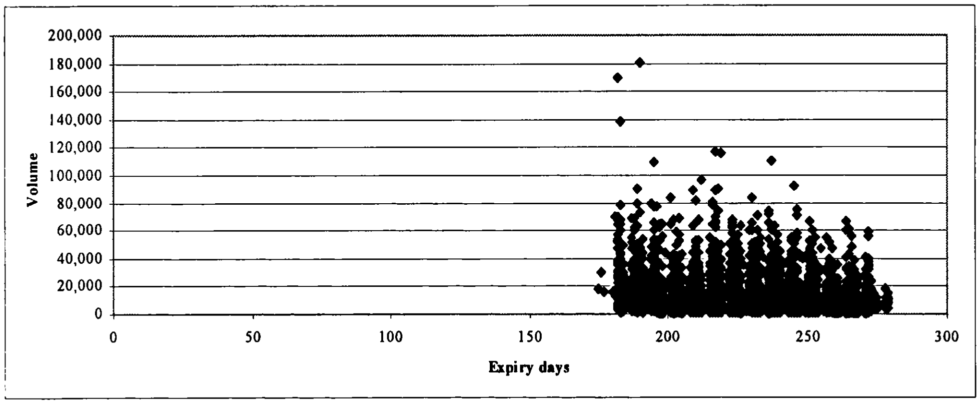


Figure 4c
Short Sterling Volume v.s. Expiry days – Near3



2.4 Empirical Results

2.4.1 The level of speculative and hedging demand

We begin by analysing daily series of volume and open interest data as an indicator of the levels of speculative and hedging demand for each contract. As most speculators are day traders who do not hold open positions overnight, open interest at the end of each trading day is likely to be a good proxy for the amount of primary hedging activity. Holland and Vila (1997) suggest that the ratio of futures volume to open interest (denoted ratio1 here) can indicate different sources of investor demand. Ratio1 measures the total number of contracts traded in a period relative to the size of open positions at the end of the period. A high ratio implies that traders can open and close their positions with relative ease. Given that open interest primarily reflects hedging demand, a low ratio is likely to indicate high hedging demand while a high ratio indicates high speculative demand. Chang, Pinegar and Schachter (1997) find that the ratio of volume to open interest is high for day traders and low for hedgers.

Ratio1 is calculated for each day during 1990-2002. There appears to be some extreme outliers in the Ratio1s calculated. Although the number of these outliers constitute a very marginal fraction in total observations, or about 0.07%, 0.09% and 0.20% for FTSE100, Long Gilt and Short Sterling respectively, but if included their extreme values can largely distort the average values of the hedging and speculative demand ratios.

Table 1 presents the average value of Ratio1 (without extreme outliers) for the three futures contracts. The results show that the Long Gilt contract has by far the highest level of the ratio, more than double the values observed for FTSE100 and Short Sterling, or 0.252, 0.124 and 0.0.086 respectively. This implies that UK bond futures have relatively much higher speculative demand than the other two futures contracts. These are similar to the results reported by Holland and Vila (1997).

We also calculate Ratio2, based on volume divided by the absolute change in open interest. The change in open interest is a measure of net positions being opened/closed each day and held overnight. This may more accurately reflect the activity of hedgers. The value of Ratio2 is obviously much higher than Ratio1 with daily volume being much greater than daily changes in open interest. The calculations from Ratio2 are consistent with those from Ratio1. Table1 reveals that Long Gilt has the highest value of Ratio2, followed by FTSE100 and Short Sterling (or 11.076, 9.512 and 9.200 respectively). Extreme outliers in Ratio2s, which constitute around 1-3% of total observation, are also excluded from the calculation.

Table 1
Hedging/Speculative Demand Ratios (ex. outliers)

		Ratio1			
		Period1	**Period2**	**Period3**	**Total**
LONG GILT	Near1	0.484	0.370	0.326	0.433
	Near2	0.295	0.263	0.250	0.281
	Near3	0.038	0.000	0.003	0.025
	Total	0.281	0.214	0.193	0.252
FTSE 100	Near1	0.247	0.173	0.170	0.220
	Near2	0.099	0.086	0.096	0.097
	Near3	0.050	0.061	0.074	0.058
	Total	0.132	0.106	0.112	0.124
SHORT STERLING	Near1	0.199		0.122	0.181
	Near2	0.232		0.178	0.219
	Near3	0.162		0.193	0.170
	Near4	0.122		0.145	0.127
	Near5	0.076		0.106	0.083
	Near6	0.066		0.093	0.072
	Near7	0.057		0.078	0.062
	Near8	0.055		0.067	0.058
	Total	0.098		0.063	0.086
		Ratio2			
		Period1	**Period2**	**Period3**	**Total**
LONG GILT	Near1	22.992	19.641	20.732	22.131
	Near2	10.991	14.585	8.617	10.613
	Near3	0.096	0.000	0.003	0.062
	Total	11.623	11.531	9.677	11.076
FTSE 100	Near1	24.202	22.777	24.936	24.271
	Near2	2.321	1.579	7.438	3.591
	Near3	0.307	0.183	3.661	1.213
	Total	8.866	7.946	11.516	9.512
SHORT STERLING	Near1	36.317		55.715	40.966
	Near2	55.895		76.514	60.846
	Near3	50.123		61.202	52.775
	Near4	40.755		60.357	45.449
	Near5	12.100		15.627	12.944
	Near6	9.979		13.312	10.762
	Near7	9.151		10.475	9.460
	Near8	7.438		10.609	8.191
	Total	10.287		7.180	9.200

Investigation of the hedging/speculative demand for the three cross-sectional groups, Near1 to Near3, demonstrates that the shortest-maturity contracts of both FTSE100 and Long Gilt have the highest value of both ratio1 and ratio2 with the Near2 group having a much lower ratio. This suggests that traders use the nearby contracts more for speculative purposes and the middle contracts are primarily employed for hedging. This conclusion does not, however, apply to Short Sterling, where the results suggest a more even spread of hedging demand across maturities. Unlike the other two contracts, the Near2 group of Short Sterling has the highest value of both ratio1 and ratio2 instead of the Near1 group.

Further examination of the hedging demand ratios during the three sub-periods, Period1, Period2 and Period3, displays similar results to those reported earlier, that is, the Long Gilt contracts has the highest speculative demand throughout Period1-3. With the Long Gilt decimalisation and a change in tick size of FTSE100 futures contracts during Period2, the ratio1 of Near1 and Near2 group of both contracts have declined. The average ratio1 of the nearby contracts of both Long Gilt and FTSE100 futures continues to fall despite the introduction of the electronic trading system in Period3. However, unlike Long Gilt, there is an increase in the average ratio1 of the middle contracts of FTSE100 Futures.

We also examine the percentage shares of the positive and negative daily changes in open interest of all futures contracts. A positive change in open interest suggests demand for hedging is strong. Table 2 reveals that the FTSE100 futures contract has a ratio of positive to negative changes of 40:60 for Near1 contracts and 91:7 for Near2 contracts. The Long Gilt contracts also exhibit a smaller ratio of positive to negative changes for Near1 contracts (33:67) whereas the Near2 group has a ratio of 76:23. The ratios for the Short Sterling contracts suggest a similar pattern of trading in the Near1 contracts with a ratio of positive to negative changes of 35:65. The Near2 and Near3 ratios though show a closer relationship of positive to negative changes of 60:40 compared to the FTSE100 and Long Gilt contracts.

Table 2
Positive and Negative Change in Open Interest (%)

	FTSE100 Futures			Long Gilt			Short Sterling		
	Near1	**Near2**	**Near3**	**Near1**	**Near2**	**Near3**	**Near1**	**Near2**	**Nea3**
Pos	40.2	90.9	88.6	32.6	75.7	72.1	34.7	59.6	59.7
Neg	0.1	2.21	2.9	0.6	1.0	0.9	0	0	0
Zero	59.7	6.9	8.5	66.8	23.3	27.0	65.3	40.0	40.3
Total	100	100	100	100	100	100	100	100	100

2.4.2 Timing of Rollover

Table 3 documents the rollover date for each contract and delivery month under investigation. The rollover date (measured in number of days before front month expiry) is defined here as the date from which daily volume/open interest in the second nearest contract is always (i.e. through to expiry) greater than volume/open interest in the front-month contract (i.e. volume crossover). Values of zero indicate rollover occurs on the expiry day.

For the FTSE100 and Long Gilt contracts, this point in time is usually clear-cut in that there is a definite switch from the front-month to the next nearest contract. Short Sterling differs due to periods where the nearest two contracts are quite heavily traded simultaneously. For each contract, rollover of open interest occurs prior to rollover of trading volume. This is because the closing out of positions in a contract as expiry approaches will reduce the level of open interest but maintain volume, all other things being equal. For the three futures contracts examined, rollover occurs closest to expiry for the FTSE100 and occurs furthest from expiry for Short Sterling.

For the FTSE100 contract, the rollover of open interest generally occurs 4-8 calendar days prior to expiry whereas the rollover of volume, except in 1998, is on the expiry day. For the Long Gilt contract, rollover of open interest takes place 23-29 calendar days before expiry, while the rollover of volume occurs 21-28 days from expiry. In contrast, the rollover of the Short Sterling contracts is far less consistent across expiry months. Rollover of open interest occurs between 7 and 82 days from expiry and rollover of volume occurs 21-31 days from expiry. The timing of the rollover of volume and open interest is largely dependent on interest rate volatility in the underlying cash market, i.e. if the market perceives that interest rates are unlikely to change over the next few months rollover may occur a month or so in advance of the expiry of the front month.

Table 3
Timing of rollover into the second-nearest contract

	FTSE100		Long Gilt		Short Sterling	
	Volume	Open Interest	Volume	Open Interest	Volume	Open Interest
Mar-90	0	4	27	28	19	19
Jun-90	0	2	26	27	18	18
Sep-90	0	7	23	24	14	14
Dec-90	0	11	24	25	14	6
Mar-91	0	9	25	26	18	14
Jun-91	1	9	23	24	15	14
Sep-91	0	11	24	25	15	14
Dec-91	0	13	25	26	15	15
Mar-92	0	13	25	26	14	15
Jun-92	0	14	25	26	15	7
Sep-92	0	4	27	28	14	14
Dec-92	0	4	28	29	14	14
Mar-93	0	4	28	29	15	15
Jun-93	0	7	27	28	14	14
Sep-93	0	7	27	28	13	13
Dec-93	0	4	28	29	13	13
Mar-94	0	4	28	29	14	14
Jun-94	0	3	26	28	13	13
Sep-94	0	4	27	28	19	19
Dec-94	0	4	27	28	19	n.a.
Mar-95	0	3	27	29	13	13
Jun-95	0	3	25	27	19	19
Sep-95	0	3	26	27	18	18
Dec-95	0	3	26	27	18	18
Mar-96	0	7	23	27	18	18
Jun-96	0	8	22	24	15	15
Sep-96	0	4	22	25	14	15
Dec-96	0	3	24	26	15	15
Mar-97	0	4	21	23	15	15
Jun-97	0	3	24	25	15	14
Sep-97	0	4	24	26	15	15
Dec-97	0	3	28	29	15	1
Mar-98	10	9	25	26	15	15
Jun-98	**	4	25	26	15	7
Sep-98	**	4	27	28	14	14
Dec-98	**	7	23	24	14	8
Mar-99	**	3	28	29	15	15
Jun-99	**	7	27	28	14	14
Sep-99	**	4	27	28	12	13
Dec-99	**	7	23	24	13	13
Mar-00	**	4	28	29	13	13
Jun-00	**	4	27	28	19	19
Sep-00	**	4	26	27	13	13
Dec-00	**	4	26	27	18	18
Mar-01	**	3	27	28	19	19
Jun-01	0	2	26	27	18	18
Sep-01	0	2	23	24	14	n.a.
Dec-01	0	2	23	25	15	n.a.
Mar-02	0	2	25	26	18	n.a.
Jun-02	0	1	21	23	13	14

2.4.3 Trading Patterns

a). FTSE100 Futures Contracts

Over the sample period, the FTSE100 futures volume, except in 1994, shows a steady increase from approximately 1.4 million in 1990 to 3.7 million in 1997 and a sharp rise to almost 7 million in 1998 and has gone up to 12.7 million in 2001 (see Table 4, page 34). The average annual growth rate during 1990-2002 is around 21%. The vast majority of trading is in the Near1 contracts with an annual percentage share of 86%, followed by the Near2 contracts (12%) and hardly any trading in the Near3 contracts (0.2%).

In Appendix 1, Table 10 shows that almost all trading in the first month of each quarter is in the Near1 contract. This drops slightly in the second month and then reduces to around 70% in the expiry month. The Near2 contract accounts for a very small share of volume traded, generally less than 5%. During the expiry month, trading in the FTSE100 futures switches from the Near1 to Near2 contracts. This is demonstrated by a drop of 20% of the share of Near1 volume in the expiry month coinciding with an increase of the same amount for the Near2 contract. This pattern of trading behaviour has remained fairly consistent throughout the period of 1990-2002 regardless of the absolute change in the FTSE100 traded volume, as displayed in Figure 1.

Figure 5
FTSE100 Futures Monthly Volume Patterns

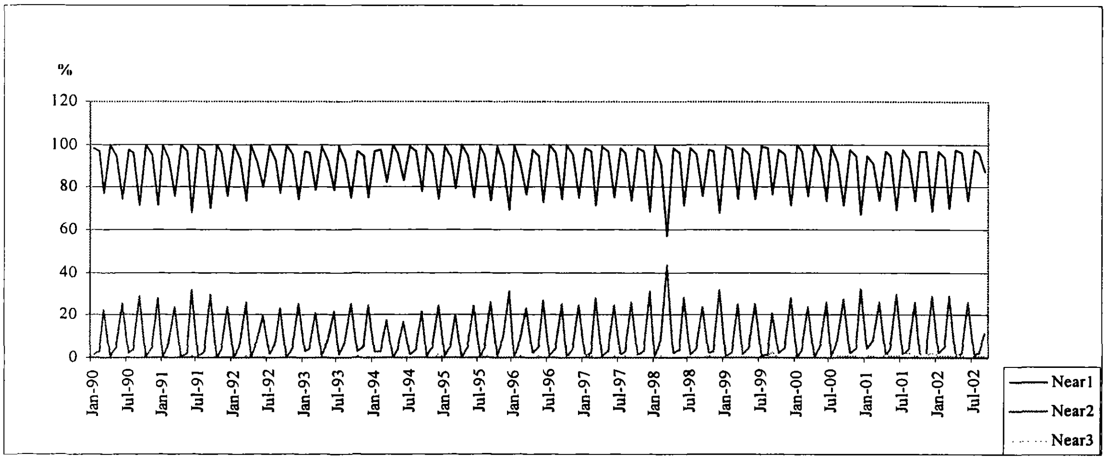


Figure 6
Long Gilt Monthly Volume Patterns

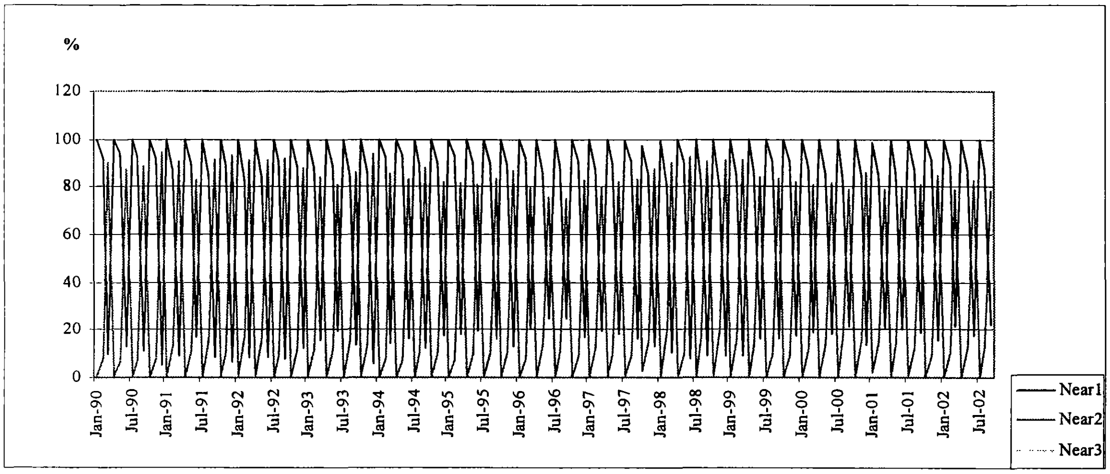


Table 4
FTSE100 Futures Annual Volume, Share and Growth Rate

Year	FTSE100 Futures Annual Volume ('000)				
	Near1	Near2	Near3	Near4	Total
1990	1,279.05	163.37	1.44	0	1,443.86
1991	1,498.85	225.82	2.71	0	1,727.38
1992	2,311.96	303.60	3.07	0	2,618.63
1993	2,752.76	365.30	1.91	0	3,119.97
1994	3,813.80	406.07	7.63	0	4,227.49
1995	2,939.54	426.98	6.75	0	3,373.26
1996	3,176.39	442.26	8.40	0	3,627.04
1997	3,229.81	460.44	8.12	0	3,698.37
1998	5,839.13	1,136.71	12.67	0	6,988.51
1999	7,694.82	1,098.70	46.67	0	8,840.19
2000	8,635.55	1,467.32	26.67	0	10,129.54
2001	10,657.65	1,913.58	139.10	0	12,710.33
2002	9,453.26	1,161.93	84.84	22.76	10,722.79
Total	63,282.55	9,572.06	349.98	22.76	73,227.35

	FTSE 100 Futures Annual Percentage Share (%)				
	Near1	Near2	Near3	Near4	Total
1990	88.59	11.31	0.10	0	100
1991	86.77	13.07	0.16	0	100
1992	88.29	11.59	0.12	0	100
1993	88.23	11.71	0.06	0	100
1994	90.21	9.61	0.18	0	100
1995	87.14	12.66	0.20	0	100
1996	87.58	12.19	0.23	0	100
1997	87.33	12.45	0.22	0	100
1998	83.55	16.27	0.18	0	100
1999	87.04	12.43	0.53	0	100
2000	85.25	14.49	0.26	0	100
2001	83.85	15.06	1.09	0	100
2002	88.16	10.84	0.79	0.21	100

	FTSE 100 Futures Annual Growth Rate (%)				
	Near1	Near2	Near3	Near4	Total
1991	17.19	38.23	87.66	0	19.64
1992	54.25	34.44	13.53	0	51.60
1993	19.07	20.32	-37.83	0	19.15
1994	38.54	11.16	299.42	0	35.50
1995	-22.92	5.15	-11.59	0	-20.21
1996	8.06	3.58	24.49	0	7.52
1997	1.68	4.11	-3.26	0	1.97
1998	80.79	146.88	55.99	0	88.96
1999	31.78	-3.34	268.34	0	26.50
2000	12.23	33.55	-42.85	0	14.59
2001	23.42	30.41	421.52	0	25.48
2002	-11.30	-39.28	-39.01	0	-15.64
Average					
1990-2002	21.06	23.77	86.37	0	21.25
1990-1998	24.58	32.98	53.55	0	25.52
1999-2002	14.03	5.34	152.00	0	12.73

b). Long Gilt Contracts

The annual volume of the Long Gilt futures contract, as shown in Table 5, also exhibits a rising trend over the period 1990-2002. Volume increased to around 16 million in 1998, which is tripled the volume of 1990. There was a large surge in volume in 1994 and 1997, pushing up volume to over 19 million. However, the Long Gilt volume has a sharp drop in 1999, with a volume of only half the previous year and has generally displayed a declining trend ever since.[1] Trading in the Long Gilt concentrates in the Near1 and Near2 contracts, with the ratio 70:30. The far contracts (or Near3) play a very marginal role in UK bond futures trading activity, constituting only 0.01-0.02% of total annual volume. The average annual growth rate over the period 1990-1998 is around 18% (20% when 1994 and 1997 are excluded) and has dropped to only 6% during the period of 1999-2002.

On a monthly basis, 99% of total volume in the first month of each quarter is accounted for by the Near1 contract as shown in Table 11 (Appendix 1). This typically reduces to 90% in the second month and then drops to around 10-15% in the delivery month. In contrast, the Near2 contract's share increases from practically zero in the first month to 10% in the second month and 90% in the delivery month. It can be observed therefore that the Long Gilt trading switches from the Near1 to Near2 contracts at the start of the delivery month. Figure 6 exhibits a very similar trading pattern throughout the period of 1990-2002 regardless of the absolute change in the long Gilt traded volume. This trading behaviour is largely a consequence of the delivery regulation outlined in section 3.

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[1] This is to be expected given the change in nominal value of the Long Gilt contract from £50,000 to £100,000, implying that fewer contracts are needed to gain the same exposure.

Table 5

Long Gilt Annual Volume, Share and Growth Rate

Year	Long Gilt Annual Volume ('000)			
	Near1	Near2	Near3	Total
1990	3,976.39	1,687.98	1.16	5,665.53
1991	3,871.71	1,766.37	1.03	5,639.10
1992	5,715.37	3,085.04	4.24	8,804.64
1993	7,845.57	3,962.39	1.05	11,809.00
1994	13,124.07	5,923.39	0.65	19,048.10
1995	9,264.93	4,529.66	0.46	13,795.05
1996	11,319.93	4,087.85	0.24	15,408.01
1997	13,997.06	5,655.08	1.43	19,653.57
1998	10,770.50	5,279.26	0	16,049.76
1999	5,772.58	2,629.95	0	8,402.53
2000	3,553.43	1,689.25	0	5,242.69
2001	4,700.63	2,025.37	0.05	6,726.05
2002	4,056.81	1,546.87	0.25	5,603.94
Total	97,968.96	43,868.45	10.55	141,847.96

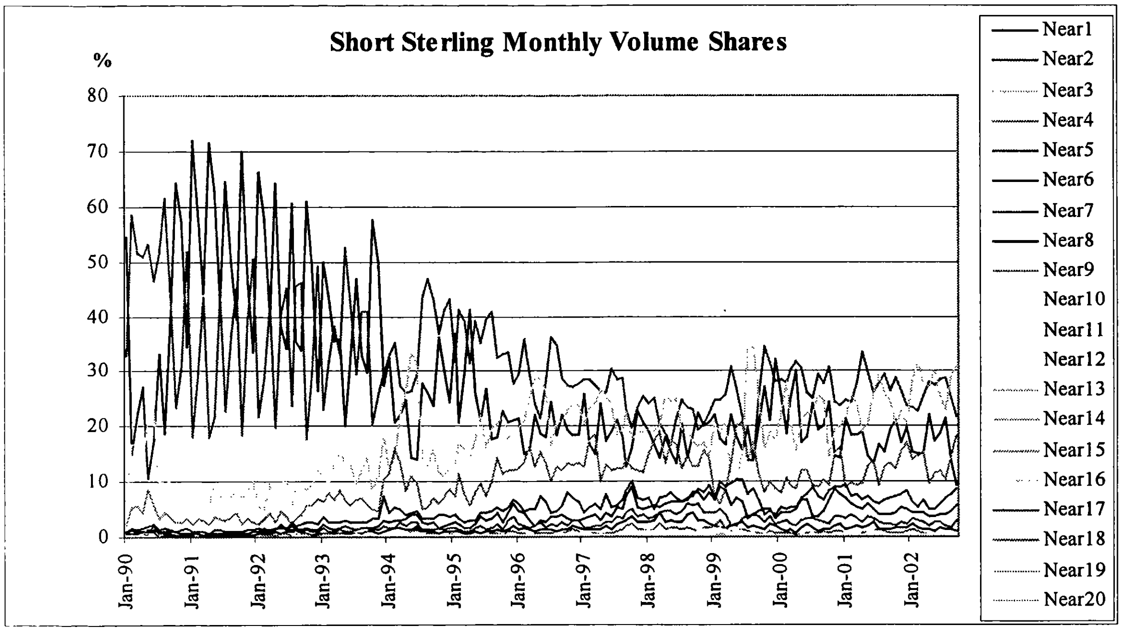
	Long Gilt Annual Percentage Share (%)			
	Near1	Near2	Near3	Total
1990	70.19	29.79	0.020	100
1991	68.66	31.32	0.018	100
1992	64.91	35.04	0.048	100
1993	66.44	33.55	0.009	100
1994	68.90	31.10	0.003	100
1995	67.16	32.84	0.003	100
1996	73.47	26.53	0.002	100
1997	71.22	28.77	0.007	100
1998	67.11	32.89	0	100
1999	68.70	31.30	0	100
2000	67.78	32.22	0	100
2001	69.89	30.11	0.001	100
2002	72.39	27.60	0.005	100

	Long Gilt Annual Growth Rate (%)			
	Near1	Near2	Near3	Total
1991	-2.63	4.64	-11.17	-0.47
1992	47.62	74.65	312.96	56.14
1993	37.27	28.44	-75.29	34.12
1994	67.28	49.49	-38.40	61.30
1995	-29.41	-23.53	-28.06	-27.58
1996	22.18	-9.75	-48.92	11.69
1997	23.65	38.34	502.11	27.55
1998	-23.05	-6.65	-100.00	-18.34
1999	-46.40	-50.18	**	-47.65
2000	-38.44	-35.77	**	-37.61
2001	32.28	19.90	**	28.29
2002	-13.70	-23.63	398.04	-16.68
Average				
1990-2002	6.39	5.50	101.25	5.90
1990-1998	17.86	19.45	64.15	18.05
1999-2002	-16.56	-22.42	398.04	-18.41

c). Short Sterling Contracts

The trading pattern of the Short Sterling futures contract is somewhat different from the FTSE100 futures and Long Gilt contracts as shown in Figure 7. This is partly driven by the availability of twelve delivery months, which results in a three-year horizon for trading activity. The annual volume of Short Sterling futures trades has increased four-fold during the period 1990-1998, rising from just over 8 million in 1990 to 33 million in 1998, with an average annual growth rate of 21% per annum (see Table 6). Very similar to the UK bond futures, the Short Sterling traded volume has also shown a declining trend since 1999. Meanwhile, there appears an interest in trading of much farther expiry contracts, say Near14-16, which is entirely non-existent before 1999 as reported in Table 6.

Figure 7
Short Sterling Monthly Volume Share Patterns



During 1990-1993, trading in Short Sterling interest rate futures focused mainly upon the two nearest contracts, Near1 and Near2, the combined share of which constituted over 80% of total volume. However, this pattern of behaviour has gradually changed since 1994. Despite an increase in their respective volumes, both the Near1 and Near2 contracts experienced a decrease in their share of total volume. From 1994, trading in the Short Sterling contract has spread into the longer-maturity contracts, particularly Near3 to Near8. This is evident from the changing ratio of volume shares between Near1-2 and Near3-8, i.e. 80:20 in 1990 to 40:60 in 1998. In 1998, the Near3 trading share was even higher than the Near1 contracts. Furthermore, the total volume of Near3-8 contracts has, in fact, exceeded the combined volume of Near1 and Near2 since the end of 1997. It should also be noted that the second-nearest contract (Near2) has taken the leading role from the nearby (Near1) contract since 1994. (see Table 6)

Table 6
Short Sterling Annual Volume, Share and Growth Rate

Short Sterling	1990	1991	1992	1993	1994	1995	1996
a. Volume ('000)							
Near 1	2,859.04	4,406.56	5,418.10	4,756.78	4,095.54	3,816.07	3,049.36
Near 2	3,768.65	2,621.68	3,807.75	4,054.09	5,949.78	5,483.26	4,637.90
Near 3	1,020.86	607.99	924.48	1,506.00	3,007.44	2,754.74	3,639.36
Near 4	363.62	247.14	449.07	813.27	1,541.21	1,508.56	2,088.60
Near 5	127.06	87.05	233.86	403.99	692.14	645.28	944.71
Near 6	77.24	46.74	168.25	222.86	478.53	476.56	546.36
Near 7	63.76	21.35	128.54	164.25	300.71	273.23	359.43
Near 8	54.59	16.18	91.63	92.03	212.88	157.00	229.38
Near 9	3.21	4.69	49.99	68.61	120.94	79.77	119.39
Near 10	1.41	2.82	24.66	54.11	101.76	47.25	71.91
Near 11	1.00	1.55	0	0	54.38	40.61	53.97
Near 12	1.20	0.86	0	0	47.85	32.25	53.42
Near 13	0	0	0	0	0	0	0
Near 14	0	0	0	0	0	0	0
Near 15	0	0	0	0	0	0	0
Near 16	0	0	0	0	0	0	0
Near 17	0	0	0	0	0	0	0
Near 18	0	0	0	0	0	0	0
Near 19	0	0	0	0	0	0	0
Near 20	0	0	0	0	0	0	0
Total	8,341.63	8,064.60	11,296.33	12,135.98	16,603.15	15,314.58	15,793.78
b. Percentage Share (%)							
Near 1	34.27	54.64	47.96	39.20	24.67	24.92	19.31
Near 2	45.18	32.51	33.71	33.41	35.84	35.80	29.37
Near 3	12.24	7.54	8.18	12.41	18.11	17.99	23.04
Near 4	4.36	3.06	3.98	6.70	9.28	9.85	13.22
Near 5	1.52	1.08	2.07	3.33	4.17	4.21	5.98
Near 6	0.93	0.58	1.49	1.84	2.88	3.11	3.46
Near 7	0.76	0.26	1.14	1.35	1.81	1.78	2.28
Near 8	0.65	0.20	0.81	0.76	1.28	1.03	1.45
Near 9	0.04	0.06	0.44	0.57	0.73	0.52	0.76
Near 10	0.02	0.03	0.22	0.45	0.61	0.31	0.46
Near 11	0.01	0.02	0	0	0.33	0.27	0.34
Near 12	0.01	0.01	0	0	0.29	0.21	0.34
Near 13	0	0	0	0	0	0	0
Near 14	0	0	0	0	0	0	0
Near 15	0	0	0	0	0	0	0
Near 16	0	0	0	0	0	0	0
Near 17	0	0	0	0	0	0	0
Near 18	0	0	0	0	0	0	0
Near 19	0	0	0	0	0	0	0
Near 20	0	0	0	0	0	0	0
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 6
Short Sterling Annual Volume, Share and Growth Rate (cont.)

Short Sterling	1997	1998	1999	2000	2001	2002	Total
a. Volume ('000)							
Near 1	3,838.06	5,880.89	5,302.35	4,544.03	6,218.48	4,317.57	58,502.82
Near 2	5,307.09	7,269.12	6,664.53	6,154.87	9,586.99	6,657.62	71,963.31
Near 3	4,362.32	6,616.16	5,426.51	4,754.08	8,165.28	7,315.54	50,100.73
Near 4	2,691.31	4,996.67	3,431.38	2,408.29	4,235.55	3,431.40	28,206.06
Near 5	1,361.20	2,441.39	2,255.47	1,544.81	2,544.09	1,629.01	14,910.05
Near 6	1,057.32	2,211.73	1,652.67	1,221.62	1,765.44	1,101.47	11,026.79
Near 7	655.09	1,586.81	945.12	646.59	996.37	669.53	6,810.77
Near 8	449.77	1,081.06	541.39	326.58	604.04	385.45	4,241.97
Near 9	231.66	492.20	359.40	149.07	290.85	184.71	2,154.47
Near 10	184.01	310.10	237.90	83.68	228.33	122.91	1,470.84
Near 11	131.44	270.78	173.92	64.59	144.03	47.30	983.55
Near 12	101.58	194.32	121.92	57.83	74.95	31.39	717.57
Near 13	0	2.35	34.29	6.55	9.27	4.79	57.25
Near 14	0	0.16	12.87	3.75	3.61	1.44	21.83
Near 15	0	1.29	10.56	3.67	2.92	0.15	18.59
Near 16	0	1.55	5.27	3.62	2.28	0.77	13.49
Near 17	0	0	0	1.16	0.05	0.23	1.44
Near 18	0	0	0	0.49	0.07	0.06	0.61
Near 19	0	0	0	0.10	0.01	0.44	0.54
Near 20	0	0	0	0.06	0.01	0.16	0.22
Total	20,370.85	33,356.55	27,175.54	21,975.42	34,872.59	25,901.91	251,202.90
b. Percentage Share (%)							
Near 1	18.84	17.63	19.51	20.68	17.83	16.67	23.29
Near 2	26.05	21.79	24.52	28.01	27.49	25.70	28.65
Near 3	21.41	19.83	19.97	21.63	23.41	28.24	19.94
Near 4	13.21	14.98	12.63	10.96	12.15	13.25	11.23
Near 5	6.68	7.32	8.30	7.03	7.30	6.29	5.94
Near 6	5.19	6.63	6.08	5.56	5.06	4.25	4.39
Near 7	3.22	4.76	3.48	2.94	2.86	2.58	2.71
Near 8	2.21	3.24	1.99	1.49	1.73	1.49	1.69
Near 9	1.14	1.48	1.32	0.68	0.83	0.71	0.86
Near 10	0.90	0.93	0.88	0.38	0.65	0.47	0.59
Near 11	0.65	0.81	0.64	0.29	0.41	0.18	0.39
Near 12	0.50	0.58	0.45	0.26	0.21	0.12	0.29
Near 13	0	0.01	0.13	0.03	0.03	0.02	0.02
Near 14	0	0	0.05	0.02	0.01	0.01	0.01
Near 15	0	0	0.04	0.02	0.01	0	0.01
Near 16	0	0	0.02	0.02	0.01	0	0.01
Near 17	0	0	0	0.01	0	0	0
Near 18	0	0	0	0	0	0	0
Near 19	0	0	0	0	0	0	0
Near 20	0	0	0	0	0	0	0
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 6
Short Sterling Annual Volume, Share and Growth Rate (cont.)

Short Sterling	1991	1992	1993	1994	1995	1996
c. Growth Rate (%)						
Near 1	54.13	22.96	-12.21	-13.90	-6.82	-20.09
Near 2	-30.43	45.24	6.47	46.76	-7.84	-15.42
Near 3	-40.44	52.06	62.90	99.70	-8.40	32.11
Near 4	-32.04	81.71	81.10	89.51	-2.12	38.45
Near 5	-31.49	168.65	72.75	71.33	-6.77	46.40
Near 6	-39.49	259.97	32.45	114.73	-0.41	14.65
Near 7	-66.51	502.01	27.79	83.08	-9.14	31.55
Near 8	-70.37	466.48	0.43	131.31	-26.25	46.10
Near 9	46.33	965.82	37.25	76.27	-34.04	49.67
Near 10	100.64	774.23	119.39	88.07	-53.57	52.20
Near 11	55.12	-100.00	**	**	-25.32	32.89
Near 12	-28.49	-100.00	**	**	-32.59	65.63
Near 13	**	**	**	**	**	**
Near 14	**	**	**	**	**	**
Near 15	**	**	**	**	**	**
Near 16	**	**	**	**	**	**
Near 17	**	**	**	**	**	**
Near 18	**	**	**	**	**	**
Near 19	**	**	**	**	**	**
Near 20	**	**	**	**	**	**
Total	-3.32	40.07	7.43	36.81	-7.76	3.13
	1997	**1998**	**1999**	**2000**	**2001**	**2002**
Near 1	25.86	53.23	-9.84	-14.30	36.85	-30.57
Near 2	14.43	36.97	-8.32	-7.65	55.76	-30.56
Near 3	19.86	51.67	-17.98	-12.39	71.75	-10.41
Near 4	28.86	85.66	-31.33	-29.82	75.87	-18.99
Near 5	44.09	79.35	-7.62	-31.51	64.69	-35.97
Near 6	93.52	109.18	-25.28	-26.08	44.52	-37.61
Near 7	82.26	142.23	-40.44	-31.59	54.10	-32.80
Near 8	96.08	140.36	-49.92	-39.68	84.96	-36.19
Near 9	94.04	112.46	-26.98	-58.52	95.11	-36.49
Near 10	155.88	68.52	-23.28	-64.83	172.86	-46.17
Near 11	143.56	106.01	-35.77	-62.86	123.00	-67.16
Near 12	90.15	91.30	-37.26	-52.57	29.62	-58.13
Near 13	**	**	1360.52	-80.89	41.40	-48.32
Near 14	**	**	7994.97	-70.85	-3.78	-60.08
Near 15	**	**	720.82	-65.27	-20.41	-94.97
Near 16	**	**	239.69	-31.28	-37.12	-66.33
Near 17	**	**	**	**	-95.96	378.72
Near 18	**	**	**	**	-85.98	-14.71
Near 19	**	**	**	**	-94.90	8720.00
Near 20	**	**	**	**	-91.67	3060.00
Total	28.98	63.75	-18.53	-19.14	58.69	-25.72

2.4.4 Regression Analysis Results

a). FTSE100 Futures Contracts

Table 7 presents the results of estimating the volume-maturity model specification (Equation 1, page 20). By using the pooled data, a significant (at the 1% level) negative relationship was found between volume traded and expiry days, with a coefficient of -100.4 on expiry days. A closer look at the sub-samples shows that for both Near1 and Near2 there is a negative maturity effect on volume. However, this negative maturity effect is stronger for contracts in the Near2 phase of their life, as indicated by the higher coefficient of -149.01 (significant at the 1% level), on expiry days compared to -92.01 (significant at the 1% level) for the Near1 contract. The adjusted R^2 statistics confirm this with a lower explanatory power of maturity on volume for Near1 contracts (2%) compared with Near2 contracts (21%). The negative maturity effect on FTSE100 futures volume found for the pooled data is therefore mainly contributed by the Near2 contracts traded rather than the Near1.

When examining the three sub-periods, Period1, Period2 and Period3, or the period with the old tick size and no automation, followed by the period with a change to the new tick size and finally with the introduction of the electronic trading system, the inverse volume-maturity relationship is observed throughout these periods, but at various extents. By using the pooled data, the coefficient value is smallest during Period1, -54.7 (significant at 1% level) and has a sharp rise after using the new tick size, or nearly triple the Period1 value (-148.9). After automation, the negative maturity effect on traded volume of FTSE100 futures contract continue to increase, with the significant coefficient value of -183.9. This indicates that the use of new tick size and electronic trading system appears to have strengthened the negative volume-maturity of the UK stock index futures.

When examining the sub-samples at different time-windows, Table 7 shows that the negative volume-maturity relationship of both nearby and middle contracts has increased by using the new tick size, which is then further enhanced by the automation.

Table 7
Regression Results of FTSE100 Futures Contracts

FTSE 100	Coefficient	Std. Dev	t-statistic	Prob.	Adjusted R^2	N
All						
All	-100.35	6.69	-15.01	0	32.66	9690
Period1	-54.72	2.23	-24.52	0	54.56	6163
Period2	-148.98	18.89	-7.89	0	64.34	851
Period3	-183.87	19.99	-9.20	0	50.81	2676
Near1						
All	-92.01	55.32	-1.66	0.096	1.83	3213
Period1	-31.70	10.00	-3.17	0.002	2.58	2079
Period2	-180.89	52.14	-3.47	0.001	19.79	284
Period3	-198.71	81.04	-2.45	0.014	6.12	850
Near2						
All	-149.01	23.29	-6.40	0	20.84	3212
Period1	-71.59	7.76	-9.23	0	30.19	2077
Period2	-235.07	72.24	-3.25	0.001	39.10	285
Period3	-308.42	56.17	-5.49	0	33.12	850
Near3						
All	-1.30	0.62	-2.09	0.036	0.52	3162
Period1	-0.44	0.11	-4.16	0	1.33	2007
Period2	-0.23	0.59	-0.39	0.695	-0.30	282
Period3	-4.02	1.78	-2.26	0.024	1.70	873
Near4						
All	*	*	*	*		*
Period1	*	*	*	*		*
Period2	*	*	*	*		*
Period3	-4.53	3.10	-1.46	0.148	3.20	103

In summary, our investigation shows that FTSE100 futures volume is significantly and inversely related to maturity. This is mainly due to the rollover effect in that during the delivery month there is a gradual switch in trading from the Near1 to Near2 contracts and the increase in volume of the Near2 contract as delivery of the Near1 contract approaches leads to the negative maturity effect on volume reported. The use of new tick size and electronic trading system has largely strengthened the negative volume-maturity relationship of FTSE100 futures contracts.

b). Long Gilt Contracts

The GMM estimation results shown in Table 8 reveal a significant negative maturity effect on volume, with a coefficient of -151.8 on days to expiry (significant at the 1% level). The Near1 sub-sample reveals a significant positive relationship between volume and maturity (503.7) and the Near2 sub-sample a significant negative relationship (-570.5). The adjusted R^2 for the Near2 sub-sample estimation is twice that for the Near1 estimation (43% and 21% respectively). This implies that the explanatory power of days to maturity on volume is much stronger for the Long Gilt contract when it is in the Near2 phase.

When looking at sub-periods using pooled data, Table 8 shows an inverse relationship between volume and expiry days for the UK bond futures throughout the three periods. Unlike FTSE100 futures, the negative volume-maturity relationship of Long Gilt appears to have decreased after decimalisation and continue falling even after using the electronic trading system, as indicated by the respective significant (at 1% level) coefficient -174.2, -169.4 and -93.4. A clearer picture on the impact of decimalisation and automation can be obtained when observing the relationship of each sub-group, Near1-3, during different periods. The regression results reveal that the positive volume-maturity relationship of the nearby contracts remains positive throughout the three periods, with however, a decrease in the coefficient value after the decimalisation and was nearly halved after employing the automation system, or 592.0, 522.5 and 284.9 during Period1-3 respectively. As for the middle contracts, the decimalisation appears to have strengthened the negative volume-maturity relationship. The negative coefficient has dropped by half after automation.

Table 8
Regression Results of Long Gilt Contracts

Long Gilt	Coefficient	Std. Dev	t-statistic	Prob.	Adjusted R^2	N
All						
All	-151.83	9.73	-15.61	0	21.71	9405
Period1	-174.20	13.03	-13.37	0	22.49	6111
Period2	-169.38	42.44	-3.99	0.0001	22.67	685
Period3	-93.36	8.27	-11.28	0	31.79	2609
Near1						
All	507.31	38.84	13.06	0	19.30	3215
Period1	592.03	50.02	11.83	0	21.66	2113
Period2	522.50	154.44	3.38	0.0008	17.55	232
Period3	284.93	27.72	10.28	0	28.79	870
Near2						
All	-570.51	34.92	-16.34	0	41.29	3215
Period1	-647.16	44.16	-14.66	0	43.54	2113
Period2	-699.05	107.14	-6.52	0	47.82	232
Period3	-344.94	27.09	-12.73	0	53.12	870
Near3						
All	-0.14	0.04	-3.91	0.0001	1.04	2975
Period1	-0.21	0.05	-3.93	0.0001	1.51	1885
Period2	*	*	*	*	*	*
Period3	-0.02	0.01	-1.15	0.2488	0.14	869

In summary, the analysis reveals a significant negative maturity effect on Long Gilt volume when using the pooled data of all contracts under investigation. However, unlike the FTSE100 contract, the analysis on the Near1, Near2 sub-samples reveals a significant positive maturity effect on traded volume for the Long Gilt contract in its Near1 phase whilst in its Near2 phase there is a very strong negative relationship between volume and expiry days. Therefore, we can conclude that the overall negative relation between volume and maturity for the pooled data is contributed mainly by the increase in the volume of a contract in its Near2 phase as the Near1 contract moves into the delivery month. This rollover effect is stronger for the Long Gilt contract compared to the FTSE100 contract because of the exchange regulations relating to delivery of the underlying asset. The decimalisation appears to help strengthen the negative volume-maturity relationship of the middle contracts and, in the meantime, reduced the extent of the positive volume-maturity relationship of the nearby contracts. During Period3, or after automation, the strength of the volume-maturity relationship has reduced by half of both nearby and middle contracts.

c). Short Sterling Contracts

The GMM estimation results using pooled data, as shown in Table 9, demonstrate a significant negative maturity effect on volume, with a coefficient of -12.67 on expiry days (significant at the 1% level). Except for the Near1 (or nearby) contracts, the results for the sub-samples show a significant negative maturity effect on volume for the Near2 to Near8 contracts. Near1-Near8 volumes account for over 95% of total Short Sterling contracts traded. (see Table 6) We also find a significant positive relationship between volume and expiry days for the Near1 contracts. Before the automation, the Near2 group has the highest coefficient value of -126.4. During Period3, or after the introduction of the electronic trading system, Near3 group instead had the highest negative coefficient value, of -195.9.

All the sub-sample regressions have low adjusted R^2 indicating that the maturity effect on volume is not very important during the different phases of the life of the contract. A closer look at each individual Near group reveals that the negative volume-maturity relationship has been largely strengthened for all Near groups, except for the Near2 contracts, the estimate of which was seen to have a drastic drop after automation.

In summary, we find similar results to those for the FTSE100 and Long Gilt contracts, with a negative relationship between volume and maturity for the pooled volume series, which is mainly due to a negative volume-maturity relationship during the Near2 and Near3 phases of the contract. However, we found the maturity effect on the Short Sterling traded volume for the sub-sample of Near2 to be weaker than that found for FTSE100 and Long Gilt futures reflecting a more complex rollover resulting from trading being spread over more contract horizons.

Table 9
Regression Results of Short Sterling Contracts

Short Sterling	Coefficient	Std. Dev	t-statistic	Prob.	Adjusted R^2	N
All						
All	-12.67	0.36	-35.51	0	28.62	44256
Period1	-15.49	0.53	-29.32	0	29.62	28836
Period3	-14.05	0.54	-26.21	0	38.43	15420
Near1						
All	128.55	14.90	8.62	0	7.03	3219
Period1	136.83	17.25	7.93	0	8.02	2449
Period3	104.52	23.71	4.41	0	4.85	770
Near2						
All	-126.35	21.06	-6.00	0	3.95	3220
Period1	-156.07	21.42	-7.29	0	7.36	2449
Period3	-34.84	39.44	-0.88	0.3773	0.13	771
Near3						
All	-95.01	24.66	-3.85	0.0001	2.40	3220
Period1	-64.42	22.57	-2.85	0.0044	1.73	2449
Period3	-195.89	41.74	-4.69	0	7.31	771
Near4						
All	-79.74	16.22	-4.91	0	4.73	3220
Period1	-64.25	18.17	-3.54	0.0004	3.48	2449
Period3	-128.43	23.19	-5.54	0	11.91	771
Near5						
All	-19.66	8.52	-2.31	0.0212	1.01	3220
Period1	-13.63	9.72	-1.40	0.1612	0.53	2449
Period3	-37.27	10.76	-3.46	0.0006	4.08	771
Near6						
All	-16.74	6.96	-2.40	0.0162	1.13	3220
Period1	-13.42	8.52	-1.57	0.1154	0.73	2449
Period3	-25.19	7.43	-3.39	0.0007	3.50	771
Near7						
All	-9.21	4.48	-2.06	0.0396	0.81	3220
Period1	-6.07	5.77	-1.05	0.2933	0.32	2449
Period3	-17.50	4.40	-3.98	0.0001	4.20	771
Near8						
All	-5.86	3.00	-1.95	0.0511	0.69	3220
Period1	-4.12	3.83	-1.08	0.2814	0.30	2449
Period3	-10.29	3.55	-2.90	0.0039	3.00	771

2.5 Conclusion

This study is unique in examining and quantifying the volume-maturity relationship across different classes of futures contracts. We report significant inverse volume-maturity relationships, but find that these relationships are predominantly driven by the second nearest contract to maturity. However, there are important differences in the relationship across stock index, interest rate and bond futures, which are partly driven by different levels of hedging and speculative demand for the different classes of contract. For the stock index and bond futures contracts, speculative demand is high in contracts with relatively short maturity, with hedging demand more dominant in longer maturities. Interest rate futures demonstrate a more even spread of hedging demand.

The index futures contract is characterised by a dominance of trading volume by the front-month contract, with volume rollover typically occurring at its expiry day. The negative volume-maturity relationship is far stronger in the second nearest contract than for the front-month contract. Volume in the bond futures is also heavily concentrated in the front-month contract, but rollover occurs much earlier than for the index futures due to the possibility of delivery at the seller's discretion. In contrast to the index futures, a positive volume-maturity relationship exists for the front-month contract, though the strong negative relationship remains for the second nearest contract.

Market demand for both hedging and speculative purposes sustains volume in a much larger number of simultaneously traded maturities for the short-term interest rate futures. The rollover of volume and open interest is more complex and its timing is much less distinct than is the case for the other classes under analysis. As for the bond futures, the volume-maturity relationship is positive for the front-month contract. For more distant maturities, a strong negative relationship prevails. The new tick size of FTSE100

Futuresand Long Gilt decimalisation appears to have strengthened the negative volume-maturity relationship of the FTSE100 futures and Long Gilt contracts. Likewise, the use of electronic trading system is also seen to have strengthened such relationship of the financial futures contracts.

Appendix 1

Table 10
FTSE100 Futures Monthly Volume and Percentage Shares

	Percentage Share (%)				Total
	Near1	Near2	Near3	Near4	
Jan-90	98.51	1.43	0.06	0	112,761
Feb-90	96.63	3.12	0.25	0	89,172
Mar-90	77.24	22.70	0.07	0	122,363
Apr-90	99.52	0.47	0.01	0	91,620
May-90	94.85	5.01	0.14	0	138,003
Jun-90	74.18	25.60	0.22	0	130,908
Jul-90	97.44	2.49	0.07	0	86,935
Aug-90	96.00	3.91	0.08	0	141,764
Sep-90	71.28	28.72	0.00	0	174,735
Oct-90	99.40	0.60	0.00	0	154,855
Nov-90	95.41	4.46	0.13	0	106,473
Dec-90	71.34	28.40	0.26	0	94,268
Jan-91	99.61	0.33	0.05	0	92,832
Feb-91	93.48	6.49	0.03	0	127,577
Mar-91	76.25	23.67	0.09	0	170,304
Apr-91	99.63	0.27	0.10	0	99,898
May-91	97.14	2.52	0.34	0	94,135
Jun-91	67.65	31.89	0.46	0	168,203
Jul-91	99.34	0.66	0.00	0	133,956
Aug-91	97.22	2.66	0.12	0	116,722
Sep-91	70.14	29.72	0.15	0	205,521
Oct-91	99.64	0.31	0.05	0	137,790
Nov-91	95.97	3.78	0.26	0	176,831
Dec-91	76.04	23.81	0.15	0	203,606
Jan-92	99.71	0.29	0.00	0	173,384
Feb-92	93.52	6.44	0.04	0	150,595
Mar-92	73.64	25.79	0.57	0	237,504
Apr-92	99.70	0.25	0.05	0	184,048
May-92	91.91	8.03	0.06	0	182,295
Jun-92	80.31	19.45	0.24	0	257,790
Jul-92	98.82	1.18	0.00	0	230,601
Aug-92	92.78	7.22	0.00	0	225,971
Sep-92	77.13	22.84	0.03	0	375,820
Oct-92	99.61	0.14	0.25	0	221,430
Nov-92	95.58	4.40	0.02	0	166,081
Dec-92	74.40	25.55	0.05	0	213,110
Jan-93	96.80	3.15	0.05	0	212,473
Feb-93	95.81	4.19	0.00	0	237,726
Mar-93	79.02	20.98	0.00	0	308,463
Apr-93	99.19	0.81	0.00	0	214,711
May-93	92.25	7.73	0.03	0	201,198
Jun-93	78.61	21.39	0.01	0	248,244
Jul-93	98.72	1.16	0.12	0	228,812
Aug-93	92.54	7.42	0.04	0	220,741
Sep-93	74.90	25.04	0.06	0	321,417
Oct-93	96.91	2.72	0.37	0	221,502
Nov-93	94.91	4.98	0.11	0	332,112
Dec-93	75.44	24.55	0.01	0	372,572
Jan-94	96.69	3.19	0.12	0	337,124
Feb-94	97.27	2.69	0.05	0	436,676
Mar-94	82.75	17.17	0.08	0	525,470
Apr-94	99.84	0.07	0.08	0	249,611
May-94	96.48	3.48	0.04	0	301,789
Jun-94	83.47	16.32	0.21	0	440,625

	Percentage Share (%)				Total
	Near1	Near2	Near3	Near4	
Jul-94	98.85	1.15	0.00	0	285,692
Aug-94	96.55	3.45	0.00	0	258,835
Sep-94	78.34	21.44	0.23	0	456,414
Oct-94	99.35	0.62	0.03	0	302,331
Nov-94	95.16	4.75	0.09	0	288,489
Dec-94	74.14	24.72	1.15	0	344,434
Jan-95	98.87	0.94	0.19	0	273,631
Feb-95	94.06	5.83	0.11	0	273,573
Mar-95	79.49	20.25	0.26	0	423,495
Apr-95	99.78	0.12	0.10	0	198,787
May-95	94.50	5.34	0.16	0	263,874
Jun-95	75.39	24.55	0.06	0	404,548
Jul-95	99.31	0.54	0.15	0	219,536
Aug-95	94.80	4.05	1.15	0	199,525
Sep-95	73.84	26.10	0.06	0	347,478
Oct-95	99.18	0.79	0.03	0	262,029
Nov-95	90.63	9.12	0.25	0	225,676
Dec-95	69.07	30.75	0.19	0	281,107
Jan-96	99.85	0.15	0.00	0	231,547
Feb-96	91.08	8.05	0.87	0	277,264
Mar-96	76.70	23.29	0.00	0	385,360
Apr-96	97.78	2.17	0.06	0	219,433
May-96	94.75	4.81	0.44	0	270,430
Jun-96	73.01	26.82	0.17	0	348,176
Jul-96	99.56	0.37	0.07	0	286,125
Aug-96	95.86	4.07	0.07	0	236,834
Sep-96	74.46	25.45	0.10	0	377,971
Oct-96	99.40	0.21	0.38	0	304,982
Nov-96	95.18	4.48	0.35	0	293,301
Dec-96	74.94	24.77	0.29	0	395,621
Jan-97	98.57	0.86	0.57	0	305,761
Feb-97	97.17	2.39	0.44	0	239,079
Mar-97	71.65	28.25	0.10	0	407,610
Apr-97	99.13	0.75	0.12	0	267,640
May-97	97.04	2.83	0.13	0	291,807
Jun-97	75.08	24.49	0.43	0	469,186
Jul-97	98.35	1.61	0.04	0	300,467
Aug-97	96.23	2.90	0.87	0	232,348
Sep-97	73.77	26.21	0.02	0	381,161
Oct-97	98.56	1.44	0.00	0	309,983
Nov-97	97.09	2.91	0.00	0	203,353
Dec-97	68.98	31.01	0.01	0	289,973
Jan-98	99.20	0.80	0.00	0	213,594
Feb-98	90.84	8.21	0.95	0	186,608
Mar-98	56.79	43.08	0.13	0	560,331
Apr-98	97.96	2.00	0.03	0	434,532
May-98	96.29	3.65	0.06	0	396,698
Jun-98	71.50	28.40	0.10	0	869,976
Jul-98	98.08	1.73	0.19	0	516,755
Aug-98	95.73	4.22	0.05	0	626,692
Sep-98	76.17	23.67	0.16	0	1,137,770
Oct-98	97.27	1.89	0.84	0	690,398
Nov-98	96.81	3.19	0.00	0	498,784
Dec-98	67.95	32.05	0.00	0	856,369

Table 10
FTSE100 Futures Monthly Volume and Percentage Shares (cont.)

	Percentage Share (%)				Total
	Near1	Near2	Near3	Near4	
Jan-99	99.00	0.68	0.32	0	559,858
Feb-99	97.75	2.01	0.24	0	559,282
Mar-99	74.52	25.22	0.27	0	1,074,511
Apr-99	98.48	1.18	0.34	0	518,733
May-99	95.48	4.28	0.25	0	597,798
Jun-99	74.57	25.22	0.20	0	1,075,470
Jul-99	98.93	0.92	0.15	0	622,700
Aug-99	98.52	1.20	0.28	0	581,957
Sep-99	76.65	20.74	2.61	0	1,142,573
Oct-99	97.69	2.29	0.03	0	666,789
Nov-99	95.30	4.50	0.20	0	687,387
Dec-99	71.43	28.39	0.17	0	753,132
Jan-00	99.60	0.30	0.09	0	663,275
Feb-00	96.53	3.35	0.12	0	997,173
Mar-00	76.26	23.73	0.02	0	1,311,366
Apr-00	99.69	0.24	0.07	0	592,437
May-00	93.80	6.03	0.17	0	688,981
Jun-00	73.76	26.13	0.11	0	1,179,248
Jul-00	99.19	0.69	0.13	0	515,877
Aug-00	91.56	7.97	0.48	0	558,805
Sep-00	71.88	27.61	0.50	0	1,313,177
Oct-00	97.66	1.87	0.47	0	661,020
Nov-00	94.63	4.36	1.01	0	670,391
Dec-00	67.33	32.48	0.19	0	977,790
Jan-01	95.06	4.29	0.66	0	763,607
Feb-01	91.39	7.86	0.75	0	656,678
Mar-01	73.44	26.29	0.28	0	1,450,561
Apr-01	97.16	1.71	1.12	0	672,950
May-01	94.61	4.54	0.86	0	721,199
Jun-01	69.49	29.86	0.65	0	1,412,220
Jul-01	97.42	1.29	1.29	0	763,928
Aug-01	93.52	4.41	2.07	0	795,327
Sep-01	73.38	25.91	0.71	0	1,871,160
Oct-01	97.06	1.79	1.16	0	1,194,076
Nov-01	96.65	1.61	1.75	0	968,121
Dec-01	68.96	28.83	2.21	0	1,440,499
Jan-02	97.11	2.16	0.73	0	837,502
Feb-02	94.03	5.12	0.84	0	820,119
Mar-02	69.99	29.17	0.77	0.07	1,480,498
Apr-02	97.42	1.06	1.11	0.42	779,190
May-02	96.11	2.31	1.04	0.53	769,481
Jun-02	73.70	25.90	0.33	0.07	1,907,048
Jul-02	97.48	1.77	0.65	0.10	2,103,241
Aug-02	95.95	2.23	0.99	0.83	1,311,216
Sep-02	87.30	11.75	0.95	0	710,359

Table 11
Long Gilt Monthly Volume and Percentage Shares

	Percentage Share (%)			Total
	Near1	Near2	Near3	
Jan-90	99.50	0.50	0.00	454,215
Feb-90	92.03	7.97	0.00	503,790
Mar-90	9.53	90.30	0.18	505,346
Apr-90	99.62	0.38	0.00	409,004
May-90	93.71	6.29	0.00	709,822
Jun-90	12.75	87.24	0.01	567,946
Jul-90	99.96	0.04	0.00	434,245
Aug-90	92.53	7.46	0.01	540,691
Sep-90	10.97	89.01	0.01	379,445
Oct-90	99.69	0.31	0.00	448,586
Nov-90	92.22	7.78	0.00	467,794
Dec-90	5.32	94.66	0.02	244,646
Jan-91	99.88	0.12	0.00	421,901
Feb-91	87.02	12.98	0.00	496,407
Mar-91	9.43	90.57	0.00	402,021
Apr-91	99.99	0.01	0.00	382,564
May-91	89.09	10.91	0.01	444,076
Jun-91	16.89	82.89	0.22	353,516
Jul-91	99.83	0.17	0.00	421,444
Aug-91	84.52	15.48	0.00	527,338
Sep-91	8.69	91.29	0.02	526,452
Oct-91	99.65	0.35	0.00	620,728
Nov-91	89.32	10.67	0.01	656,482
Dec-91	6.60	93.40	0.00	386,172
Jan-92	99.56	0.44	0.00	652,982
Feb-92	82.63	17.36	0.02	665,778
Mar-92	8.26	91.60	0.14	777,004
Apr-92	99.90	0.10	0.00	752,072
May-92	83.82	16.16	0.02	650,297
Jun-92	8.58	91.24	0.18	808,684
Jul-92	99.87	0.13	0.01	842,593
Aug-92	90.61	9.39	0.00	893,585
Sep-92	7.93	91.94	0.13	1,022,569
Oct-92	99.74	0.26	0.00	724,333
Nov-92	88.54	11.44	0.02	663,750
Dec-92	12.22	87.77	0.00	350,992
Jan-93	99.52	0.48	0.00	653,830
Feb-93	88.24	11.76	0.00	798,695
Mar-93	15.70	84.26	0.04	868,109
Apr-93	99.95	0.05	0.00	809,348
May-93	88.47	11.52	0.01	845,389
Jun-93	19.24	80.75	0.01	849,109
Jul-93	99.71	0.29	0.00	838,323
Aug-93	84.68	15.32	0.00	1,189,618
Sep-93	13.62	86.34	0.04	1,257,728
Oct-93	99.51	0.49	0.00	1,271,138
Nov-93	86.99	13.01	0.00	1,490,705
Dec-93	6.12	93.87	0.01	937,006
Jan-94	99.93	0.07	0.00	1,618,457
Feb-94	92.37	7.63	0.00	2,733,630
Mar-94	14.43	85.56	0.01	2,390,769
Apr-94	99.97	0.03	0.00	1,706,493
May-94	93.11	6.89	0.00	1,640,601
Jun-94	16.43	83.54	0.03	1,757,986
Jul-94	99.82	0.18	0.00	1,230,503
Aug-94	89.60	10.40	0.00	1,388,159
Sep-94	12.08	87.92	0.00	1,405,882
Oct-94	99.98	0.02	0.00	1,255,746
Nov-94	89.87	10.13	0.00	1,214,782
Dec-94	17.80	82.20	0.00	705,089
Jan-95	99.71	0.29	0.00	1,028,106
Feb-95	93.15	6.85	0.00	1,305,774
Mar-95	18.37	81.62	0.01	1,370,391
Apr-95	99.80	0.20	0.00	730,816
May-95	90.13	9.87	0.00	1,432,070
Jun-95	19.40	80.58	0.01	1,400,527
Jul-95	99.90	0.10	0.00	963,671
Aug-95	89.69	10.31	0.00	1,005,111
Sep-95	16.30	83.69	0.01	1,309,632
Oct-95	99.90	0.10	0.00	1,164,680
Nov-95	89.54	10.46	0.00	1,261,971
Dec-95	13.24	86.76	0.00	822,301
Jan-96	99.84	0.16	0.00	1,427,205
Feb-96	92.21	7.79	0.00	1,673,428
Mar-96	20.22	79.76	0.02	1,220,101
Apr-96	100.00	0.00	0.00	900,593
May-96	86.17	13.83	0.00	1,252,989
Jun-96	24.61	75.39	0.00	969,227
Jul-96	99.89	0.11	0.00	896,524
Aug-96	88.85	11.15	0.00	1,068,280
Sep-96	24.75	75.25	0.00	1,324,489
Oct-96	99.84	0.16	0.00	1,941,505
Nov-96	90.91	9.09	0.00	1,770,742
Dec-96	17.23	82.77	0.00	962,927
Jan-97	99.95	0.05	0.00	1,465,901
Feb-97	87.60	12.40	0.00	1,989,164
Mar-97	19.49	80.51	0.00	1,425,494
Apr-97	99.47	0.53	0.00	1,128,452
May-97	90.19	9.81	0.00	2,235,106
Jun-97	18.09	81.91	0.00	1,393,103
Jul-97	99.45	0.55	0.00	1,699,084
Aug-97	90.57	9.43	0.00	1,496,176
Sep-97	16.31	83.69	0.00	1,844,839
Oct-97	97.16	2.84	0.00	2,300,305
Nov-97	85.16	14.84	0.00	1,656,594
Dec-97	12.76	87.11	0.14	1,019,347
Jan-98	99.12	0.88	0.00	1,558,107
Feb-98	80.09	19.91	0.00	1,786,343
Mar-98	10.26	89.74	0.00	1,552,504
Apr-98	100.00	0.00	0.00	1,358,714
May-98	90.46	9.54	0.00	1,851,532
Jun-98	7.61	92.39	0.00	1,486,039
Jul-98	99.91	0.09	0.00	1,315,847
Aug-98	82.84	17.16	0.00	1,657,060
Sep-98	9.45	90.55	0.00	1,199,704
Oct-98	100.00	0.00	0.00	857,653
Nov-98	80.45	19.55	0.00	984,596
Dec-98	8.83	91.17	0.00	441,658

Table 11
Long Gilt Monthly Volume and Percentage Shares (cont.)

	Percentage Share (%)			Total
	Near1	Near2	Near3	
Jan-99	99.98	0.02	0.00	727,082
Feb-99	84.61	15.39	0.00	1,109,751
Mar-99	8.88	91.12	0.00	777,634
Apr-99	99.97	0.03	0.00	589,690
May-99	86.19	13.81	0.00	919,475
Jun-99	16.17	83.83	0.00	921,188
Jul-99	100.00	0.00	0.00	724,561
Aug-99	90.45	9.55	0.00	614,591
Sep-99	16.28	83.72	0.00	624,372
Oct-99	100.00	0.00	0.00	478,828
Nov-99	90.81	9.19	0.00	661,207
Dec-99	17.79	82.21	0.00	254,152
Jan-00	100.00	0.00	0.00	402,039
Feb-00	88.33	11.67	0.00	526,704
Mar-00	19.15	80.85	0.00	480,323
Apr-00	99.90	0.10	0.00	283,792
May-00	85.50	14.50	0.00	539,779
Jun-00	18.42	81.58	0.00	417,971
Jul-00	99.97	0.03	0.00	342,743
Aug-00	83.27	16.73	0.00	449,741
Sep-00	21.26	78.74	0.00	476,660
Oct-00	99.95	0.05	0.00	390,952
Nov-00	84.67	15.33	0.00	613,389
Dec-00	13.69	86.31	0.00	318,596
Jan-01	98.24	1.76	0.00	534,311
Feb-01	85.00	15.00	0.00	495,714
Mar-01	20.79	79.21	0.00	544,959
Apr-01	100.00	0.00	0.00	452,664
May-01	85.48	14.52	0.00	658,921
Jun-01	20.31	79.69	0.00	561,704
Jul-01	99.61	0.39	0.00	488,652
Aug-01	87.50	12.50	0.00	662,472
Sep-01	19.11	80.89	0.00	572,758
Oct-01	100.00	0.00	0.00	569,745
Nov-01	91.00	9.00	0.00	771,183
Dec-01	15.43	84.56	0.01	412,971
Jan-02	99.92	0.08	0.00	612,058
Feb-02	89.28	10.72	0.00	665,881
Mar-02	21.32	78.68	0.00	645,605
Apr-02	99.99	0.01	0.00	538,780
May-02	87.46	12.54	0.00	738,497
Jun-02	17.36	82.60	0.04	624,689
Jul-02	100.00	0.00	0.00	671,423
Aug-02	87.09	12.91	0.00	775,754
Sep-02	22.05	77.95	0.00	331,251

Table 12
Average daily futures volumes

a). FTSE100 Futures	Period1	Period2	Period3	Total
Near1	10,366.9	27,550.0	39,889.0	19,695.8
Near2	1,452.0	4,237.3	6,292.4	2,980.1
Near3	21.2	63.7	331.6	110.7
Near4			221.0	221.0
Total	3,993.4	10,634.3	14,785.7	7,557.0

b). Long Gilt	Period1	Period2	Period3	Total
Near1	34,988.6	33,746.7	18,630.8	30,472.5
Near2	15,362.2	18,948.9	8,059.7	13,644.9
Near3	5.4		0.4	3.5
Total	17,411.5	17,847.2	8,900.4	15,082.2

c). Short Sterling	Period1	Period3	Total
Near1	17,156.3	21,411.6	18,174.2
Near2	19,526.4	31,314.2	22,348.9
Near3	11,731.0	27,719.4	15,559.2
Near4	7,178.8	13,781.1	8,759.6
Near5	3,637.0	7,786.2	4,630.5
Near6	2,723.0	5,652.6	3,424.5
Near7	1,763.0	3,233.8	2,115.1
Near8	1,154.3	1,835.3	1,317.4
Near9	639.3	861.7	694.5
Near10	470.6	599.6	504.8
Near11	432.1	358.8	408.6
Near12	342.5	231.5	306.0
Near13	102.1	33.6	53.1
Near14	40.5	12.2	20.3
Near15	37.9	9.0	17.2
Near16	21.2	9.1	12.5
Near17		1.9	1.7
Near18		0.8	0.7
Near19		0.7	0.6
Near20		0.3	0.3
Total	5,641.3	5,741.3	5,676.1

Chapter 3

The impact of macroeconomic announcements on the lead/lag relationship of UK stock index and stock index futures

3.1 Introduction

It is well documented that financial markets are usually sensitive to news arrival, either of firm-specific figure releases or macroeconomic announcements. The market response via price adjustment of the financial instruments conveys the magnitude of trader reaction to the announcements.

This topic has increasingly received a great deal of attention from academic researchers. The firm-specific announcements of earnings, dividends, mergers or acquisitions generally affect the stock prices of individual listed-companies involved whereas the adjustments of portfolio investments can be observed after the announcements of some macroeconomic statistic releases i.e. interest rate, inflation, unemployment, trade deficit etc. Many prior studies concentrate on the impact of announcements on equity or bond prices, particularly on the US markets. Previous research finds that some particular macroeconomic announcements have different levels of significance on the trading of different financial instruments. For example, money supply, interest rate and discount rate information affect bond prices, trade deficits (or balance of trade) and capital flows affect exchange rates whereas inflation rate and unemployment news affect equity prices.

This chapter focuses on an investigation of a lead/lag relationship between stock index financial futures contracts and the underlying equity index. One of the original features of this study is to examine the impact of macroeconomic announcements on the lead/lag relationship. A futures lead over the spot market implies that lagged changes in futures prices can help predict changes in the spot prices. The study uses intraday data at high frequency (5-minute) of the FTSE100 and its futures prices during the two-year period of 1994-1996 and a selection of nine UK macroeconomic announcements. The screening process to identify which announcements have an impact on the stock index is performed by adopting a similar method to that used by Ederington and Lee (1995), with an application of different time horizons in order to obtain a clearer picture of market adjustment responses to the announcements. To investigate the lead/lag relationship, this study employs the multiple regression model as in Fleming et al (1996) which included the error correction term to account for cointegration, which is induced by the arbitrage relationship between a security and its derivatives. The regression estimation is undertaken via the use of Generalized Method of Moments (GMM).

As not having previously been investigated before, the study takes a further step to examine the impact of unexpected news from macroeconomic announcements on the lead/lag relationship. The macroeconomic announcements are usually comprised of a high content of unexpected news. The type of news generated by the announcements can be good, bad or neutral. Asymmetric response on equity prices between good and bad news is widely documented in several studies over the past two decades. For example, Blasco et al (2002) test the impact of economic news on stock volatility and found that the asymmetric behaviour of variance is largely due to the effect of bad news from the announcements. Sentana and Wadhwani (1992) report that responses to bad news lead to greater volatility than do responses to good news. Brown et al (1988) find that unfavourable news tends to produce greater stock price reactions than favourable news. To take this into account, the market forecast and actual announcement figures are examined to specify the type of news generated by the announcements. This information is then incorporated into further investigation of the lead/lag relationship. It is expected that bad news would strengthen the lead/lag relationship more than the good news.

The remainder of this study is structured as follows. Section 3.2 summarizes previous literature relevant to this topic, followed by the data and methodology in Section 3.3. Detail of macroeconomic announcements and the screening process for its significance is also included in Section 3.3. Section 3.4 describes the regression results of the lead/lag relationship. The observation of news type generated by the macroeconomic announcements and the impact of unexpected news on the lead/lag relationship is reported in Section 3.5. Section 3.6 presents the conclusion.

3.2 Review of the Literature

A great deal of research has investigated the interlinkage of financial markets via the context of a lead/lag relationship, mostly between the equity market and its derivatives. Most studies focus on the stock indices of major financial markets. As summarised in ap Gwilym and Sutcliffe (2000), for example, S&P500 (US) by Kawaller et al (1987, 1988, 1993), Herbst et al (1987), Furbush (1989), Kurtner and Sweeny (1991), Stoll and Whaley (1990, 1993), Ghosh (1993), Chan et al (1991), Fleming et al (1996), FTSE100 (UK) by Abhyankar (1998), Ap Gwilym and Buckle (2001), Nikkei (Japan) by Lim (1992), Chung et al (1994), DAX30 (Germany) by Grunbichler et al (1994), Kempf and Korn (1998), CAC30 (France) by Shyy et al (1996), All ordinaries (Australia) by Sim and Zurbreugg (1999). A majority of the studies have reported a similar conclusion; the stock index futures market leads the spot market by approximately 20 minutes, which is due primarily to its relative lower trading cost.

Several studies have investigated the influence of macroeconomic announcements on financial markets, with a focus on the equity price returns, trading volume and volatility. Most studies report a spike in price volatility and traded volume as a result of the macroeconomic news arrival, which occurs in both cash and futures markets. The studies of Becker et al (1995), ap Gwilym et al (1998) and Buckle et al (1998) report an increase in equity price returns and volatility as a result of macroeconomic announcements. Other studies have investigated the effect of macroeconomic announcement on foreign exchange rates, bond prices and interest rates.

Many prior studies find that different types of economic news have different rankings in terms of significant influence on various financial instruments. Almeida, Goodhart, and Payne (1998) examine the effects of 13 U.S. macroeconomic announcements and 9 German macroeconomic announcements on the U.S. Dollar-German Mark exchange rate using high frequency intraday data over the three-year period of 1992-1994. They report that the US news tends to be incorporated in the exchange rates faster than the corresponding German announcements. Furthermore, the announcements associated with capital flows seem to be more significant than announcements that provide information about trade balances. In contrast, Tanner (1997), also using high-frequency intraday data during the period of 1987-1991, found that the trade deficit is the dominant announcement affecting exchange rates but, meanwhile, the dollar exchange rate shows no significant response to news of the money supply, industrial production, the producer price index or the unemployment rate.

However, only a few studies have examined the macro announcement impact on the lead/lag relationship between derivatives and their underlying spot markets. Pioneering work by Chan (1992) reports a stronger lead of the stock index futures market over the spot market on days of market-wide information releases. Later on, Crain and Lee (1995) documents a stronger lead of the futures over the spot in the interest rate (Eurodollar) market on announcement days but found no significant lead of futures in the foreign exchange (Deutsche mark) market. The contradiction in this result has inspired further research by Frino et al (2000), which investigates not only the impact of macroeconomic announcements but also the impact of firm-specific information announcements on the lead/lag relationship between returns of the Australian stock index futures and its underlying spot markets. They test whether a lead of the futures markets over the spot market occurs in the case of macroeconomic announcements and a lead of the spot market over the futures market occurs in the case of firm-specific information releases. They report a lead of futures over the spot market on the macroeconomic announcement days and a weakened lead of futures together with a significant feedback from the spot market to the futures market on the days with the stock-specific information releases.

3.3 Data and Methodology

3.3.1 Stock index and Stock index futures

a). Details of Data

This study uses the intraday data of FTSE100 cash index and its corresponding futures contract, over a two-year period, from 1 January 1994 to 31 December 1996. Stock index futures data are obtained from LIFFEData CDROMs supplied by London International Financial Futures and Options Exchange (LIFFE). The futures prices utilized here are the last prices at a 5-minute interval of the nearby contracts. The observations included are from the market opening at 0835 GMT until 1605 GMT, given a total of 91 intervals per day. The cash index data were provided by ap Gwilym and Buckle (2001). The observation period is limited to 1994-1996 due to the unavailability of the high frequency intraday data of the cash index from non-commercial sources.

b). Stock Index Specifications

FTSE100 Stock Index

The FTSE100 index is a market value weighted index (on the basis of market capitalization) of the top 100 of the UK companies traded at the London Stock Exchange (LSE), during 0800-1630 GMT. FTSE100 futures contracts are traded at LIFFE, using the open outcry system during the floor trading time between 0830-1610 GMT, followed by the Automated Pit trading (APT) system during an-hour period of 1632-1730 GMT (not considered in this study). The APT trading volume is about 5% of the floor trading. The minimum price movement is 0.5 index point, or an equivalent of £12.50, during the period under investigation.

FTSE100 Stock Index Futures

The FTSE 100 Futures is the futures contract of the underlying FTSE 100 index, with four delivery months in March, June, September and December. Unlike Australia, the UK futures contract has a predetermined contract expiry date for each quarter. At any one time, there are three nearest delivery months available for trading.

3.3.2. Macroeconomic Announcements

Macroeconomic announcements are generally scheduled in advance for the specific date and time. The UK announcements included in this study are all released at a set time of 0930 GMT. Table 1 shows the type of announcements, including the frequency and the authorities responsible for the statistic releases. Of the nine individual announcements, there are six statistics released on a monthly basis as follows; Unemployment, Retail Price Index (RPI) or Inflation, Public Sector Borrowing Requirement (PSBR), Production Price Index (PPI), Retail Sales and Money Supply (M0 and M4). Meanwhile, the other three announcements of Balance of Payment (BOP), Gross Domestic Product (GDP) and the Industrial Trends (CBI), take place on a quarterly basis. Table 7 and Table 8 (in Appendix 2) give the information of macroannouncement days used in the analysis.

The study considers not only the trading days with single announcements (category 1-9 in Table 1), but also trading days with multiple announcements, when two or more statistics are announced simultaneously (category 10-21). Of all observations, there are 111 days with single announcement and 30 days with multiple announcements. The latter group comprises of 23 days of two announcements (category 10-16), 6 days of three announcements (category 17-20) and 1 day of four announcements (category 21).

In addition to examine the impact of macroannouncements on the lead/lag relationship, we undertake a further step to capture the market reaction to the unexpected news, which usually constitutes a high content in the macroeconomic announcements. The deviation of the forecast estimate from the official statistic figure is employed here as a proxy for the unexpected news. Thus, both the actual and expected figures of the statistics are required for this calculation. The actual statistics are released from the organisations as shown in Table 1 whereas the expected figures are the median estimates provided by Money Market Services (MMS).[1] The MMS data are based on the median forecast of around 20 leading market analysts. Pearce and Roley (1985), Almeida, Goodhart, and Payne (1998), and Balduzzi, Elton, and Green (2001) find, with few exceptions, that the forecasts provided by MMS are unbiased.

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[1] The data are taken from the weekly Economic Diary tables published in the Financial Times.

Table 1
UK macroeconomic information releases

(a). Single announcements

	Details	Frequency	Source
1. PSBR	Public Sector Borrowing Requirement	Monthly	BOE
2. Unemployment	Unemployed labour figure	Monthly	ONS
3. RPI	Retail Price Index	Monthly	ONS
4. GDP	Gross Domestic Product	Quarterly	ONS
5. BOP	Balance of Payment	Quarterly	ONS
6. Retails Sales	Retails Sales	Monthly	ONS
7. CBI	Industrial Trends	Quarterly	CBI
8. PPI	Production Price Index	Monthly	ONS
9. M0 and M4	Money Supply	Monthly*	BOE

(b). Multiple announcements

10. PBSR + Unemployment	16. GDP + CBI
11. PSBR + RPI	17. PSBR + Unemployment + RPI
12. PSBR + Retail sales	18. PSBR + Unemployment + Retail sales
13. Unemployment + RPI	19. PSBR + RPI + Retail sales
14. Unemployment + Retail sales	20. Unemployment + RPI + Retail sales
15. RPI + Retail sales	21. PSBR + Unemployment + RPI + Retail sales

Notes:

*Except for April, BOE = Bank of England, ONS = Office of National Statistics, CBI =Confederation of British Industry.

3.3.3 Methodology

a). Relative Significance of the Macroeconomic Announcements

Although there are several scheduled macroannouncements made by various authorities, not all of them are expected to have an influence on trading in financial markets. Therefore, we need to have a screening method to determine which announcements have a significant impact on the market. To achieve this, we adopt the same method as used in Ederington and Lee (1993) to examine the impact of the announcements on the futures price volatility by undertaking a regression analysis of the model in Equation 1. The use of time-series data can generally induce a problem of serial correlation, which will inevitably affect the accuracy of the statistical inference of the OLS estimation as this violates one of the standard assumptions of the regression theory. To counter for this, we adopt the Generalized Method of Moments (GMM) for the estimation of the regression model. This method can provide a consistent estimator by the use of the weighting matrix that is robust to heteroscedasticity and autocorrelation of unknown form.

$$\left|R_{i,t} - \overline{R_i}\right| = \alpha_{0i} + \sum_{k=1}^{K} \alpha_{ki} D_{kt} + e_{it} \qquad .....(1)$$

where

$R_{i,t}$	is the log return of the interval i on day t and $P_{i,t}$ is the last futures price at the interval i on day t. $R_{i,t} = ln(P_{i,t}/P_{i-1,t})$,
$\left\|R_{i,t} - \overline{R_i}\right\|$	is the absolute value of the difference between the actual return $R_{,i,t}$ for the 5-minute interval i on day t and the mean return R_i for interval i of all observations,
D_{kt}	is the announcement dummy variable where $D_{kt} = 1$, if announcement k is made on day t, and $D_{kt} = 0$ otherwise. Here, $k = 1, 2,..,1236$. The dummy variable for a multiple announcement is based on the individual announcements made, i.e. D136 represents three simultaneous announcements of PBSR, RPI and PPI (see Table 1, page 64).

Unlike previous studies which examine the impact of the macroannouncements only at or around the immediate statistic release time, we instead observe the market over different time-durations (or horizons) i.e. 5, 10, 15, 20, …minutes after the announcements. For example, the time-duration of 10, 20, 30 minutes will include the observations from time range of 9:30-9:35, 9:30-9:40 or 9:30-9:45GMT respectively. In this study, the market behaviour is examined over various horizons from the announcement time up to midday, 9:30-12:00GMT, giving a total number of 23 time-durations. As a result, not only the extent of the announcement impacts but the speed of price adjustment, when the information is being impounded into the market price, can also be observed.

Table 2 reveals the relative significance of the macroannouncements under investigation which can be summarised as follows. First, all announcements under investigation are statistically significant in explaining the volatility of stock index futures price returns. This is evidently shown by the significant positive coefficients (at 1% level) of all macroannouncements, which mostly appear within the first 25 minutes after the news releases at 0930 GMT. The multiple macroannouncement of GDP and CBI (D47) shows a significant positive coefficient when using the observations during the 45-minute time duration. The relative importance of each announcement is ranked in terms of its significant positive coefficient. According to our findings, the fastest and strongest market response (by impounding information into the market within the first five minutes after the announcement [2] and having relatively much higher coefficient values) can be seen from (1) Inflation or RPI, (2) Unemployment, (3) Production Price Index or PPI, (4) Retail Sales and (5) PSBR. During the first 5-minute duration, the inflation RPI announcement (D3) has the largest significant coefficient of 9.66 followed by 4.54 for the Unemployment, 3.82 for the Production Price Index PPI (D8), 3.68 for the Retail Sales (D6), and 2.31 for the Public Sector Borrowing Requirement PSBR (D1). However, the announcements of Balance of Payment (BOP), Gross Domestic Product (GDP), Money Supply (M0 and M4) and the Industrial Trends (CBI) have individually had relatively less influence on the FTSE100 futures market trading. This is evidenced by a longer time for the market response to the announcements and a much lower extent of the significant coefficients, for example, 1.62 for BOP at 20 minutes, 1.03 for BOP and -0.82 for Money Supply, M0 and M4, at 25 minutes.

A closer look at the regression results of various time-durations reveals that the news of inflation rate (RPI) is impounded into the market the fastest, followed by the news

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[2] Except for the Retails Sales, the largest coefficient of which appears during the 10-minute duration.

of unemployment. This is evidenced by a fast decline in the size of the coefficient in the intervals after the announcement. The coefficients of other announcements reduce at a slower pace. The strongest impact from inflation rate announcement appears within the first 5 minutes after the announcement and is subsequently reduced by half during the next 5-minute period after the figure releases, as shown by its significant (at 1% level) coefficient value of 9.66 and 4.26 during the period of 9:30-9:35 a.m. and 9:30-9:40 a.m. respectively.

Secondly, despite a very much lower number of occurrences, trading days with multiple announcements appear to have higher significant coefficients. This indicates a stronger combined impact from the multiple announcements as compared to the trading days with single announcements. The trading days with three simultaneous announcements, PSBR, RPI and Retail Sales (D126) display a very large significant coefficient value of 28.95, followed by 19.94 for Unemployment and RPI (D23), 16.28 for PSBR and RPI (D13), 16.16 for PSBR, Unemployment and RPI (D123), 13.48 for PSBR, Unemployment and Retail Sales (D126), 10.36 for PSBR and Unemployment (D12) and 11.11 for PSBR, Unemployment, RPI and Retail Sales (D1236).

Thirdly, it is noticed that the highest significant coefficient of each announcement category, either single or multiple, mainly concentrates within the period of 10 minutes after the announcement (9:30-9:40 am). In Table 2, the largest values of significant coefficients for each macroannoucement category using observations over different time-durations are bolded.

Fourth, the announcement news is almost all impounded into the trading decision by midday (12:00). This is evident from the fewer number of significant coefficients obtained from using the observations during longer time-durations and also much smaller values of their coefficients during the corresponding periods. In comparison, Table 2 displays larger number of significant coefficients with higher values during the time-duration of 5, 10, 15 .. up to 30 minutes. Since then, a decline in the number of significant coefficients and an erosion of corresponding coefficient values can be observed. This means the market adjustment response for the announcements news occurs within the first half an hour after the figure releases. After midday, almost all coefficients are insignificant. (Figures are not shown in Table 2.) This implies that the information from macroannouncements is all impounded into the market by approximately midday.

Finally, Table 2 shows that the announcements in this study, either single or multiple, have relevant impact, although to different degrees, on the FTSE100 futures return volatility and therefore would all be included in the next step of our investigation on the lead/lag relationship.

Table 2
The impact of macroeconomic announcements on stock index return volatility

Interval	1212	1213	1214	1215	1216	1217	1218	1219	1220	1221	1222	1223	1224	1225	1226	1227	1228	1229	1230	1233	1236	1239	1242
From 9:30 am to	09:35	09:40	09:45	09:50	09:55	10:00	10:05	10:10	10:15	10:20	10:25	10:30	10:35	10:40	10:45	10:50	10:55	11:00	11:05	11:20	11:35	11:50	12:05
Time since news releas (minutes)	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	110	125	140	160
(1). Single announcements																							
D1 PSBR	**2.31**			1.20	1.07	0.90	1.02		0.45		0.43		0.13		0.20		0.15		0.12		0.04		0.06
D2 Unemployment	**4.54**				0.84		0.42															-0.53	
D3 RPI	**9.66**	4.26	3.59	2.46		2.29		1.85		1.59		1.32		1.05		0.72		0.69		0.44	0.29		0.14
D4 GDP					**1.03**		0.94		1.19	1.17	1.16	0.93	0.75		0.59		0.56		0.55	0.59		0.52	
D5 BOP				**1.62**		1.32			0.76	0.91	1.10	0.90	1.00	1.12		1.15		1.01		0.78		0.70	0.61
D6 Retail sales	3.09	**3.68**	3.10	3.14	2.46	1.87	1.42	0.97			0.47		0.30		0.19		0.15		0.09		0.11		0.13
D7 CBI					**0.54**		0.20		0.11														
D8 PPI	**3.82**	3.74	2.51	2.33		1.71		1.09		0.80		0.65		0.54		0.43							
D9 M0&M4					**-0.82**	-0.78	-0.77	-0.70	-0.63	-0.70	-0.64	-0.58	-0.50	-0.52	-0.31		-0.29						
(2). Multiple announcements																							
D12	**10.36**	5.39	5.28	4.53	2.98	2.17	1.31		1.03		0.51		0.24									1.03	
D13	**16.28**	8.74	9.27	6.54	5.23	4.49		2.96		2.15				2.45		2.02		1.64		1.64	1.50	1.30	1.17
D16					**1.60**		1.40		1.04						1.15		0.82		0.38		0.67		0.60
D23	**19.94**	13.52	11.97	9.56		7.93		7.12		6.07		4.79		4.20		3.69		3.48		3.15		2.85	
D26			2.93	**3.09**	2.39	2.20	2.01	2.07	1.95	1.81	1.69	1.65	1.66	1.61	1.45	1.37	1.35	1.24	1.13	1.03	0.75		0.46
D36					1.56		**1.79**		1.79		1.08		0.58		0.54		0.84		0.72		0.19		
D47									**0.48**														
D123	**16.16**	12.38	11.94	10.05		7.30		5.54		4.69		3.85		2.99		2.89		3.23		2.64		2.46	
D126	**13.48**	13.18	9.84	7.10	7.00	5.60	4.86	4.30	4.03	3.41	3.05	2.65	2.42	1.90	1.84		1.39		1.20		0.44		0.23
D136	**28.95**	19.71	12.16	9.90	8.63	8.61	6.99	6.13	5.47	4.97	4.35	3.85	3.40	3.02	3.01	3.40		2.82		2.24		2.49	
D236			**7.22**	5.68	6.14	6.43	4.71	5.46	5.40	4.34	4.40	4.35	4.39	3.73	3.54	3.81	3.31	3.04	2.64	1.97	1.33		0.94
D1236		**11.11**	7.34		3.90	6.69	6.60	5.08	4.23	3.86	3.62	2.93	2.55		2.19	2.27	1.86		1.79	1.88		1.62	
C Intercept	5.99	6.11	6.06	5.98	5.87	5.81	5.79	5.76	5.70	5.65	5.61	5.58	5.52	5.47	5.44	5.43	5.39	5.35	5.33	5.22	5.14	5.02	4.93

b). Impact of macroannouncements on the lead/lag relationship

There are numerous studies of the lead/lag relationship between the stock index and its futures contracts, most of which are carried out on the US stock indices, S&P500 and MMI. As for the UK, there have been relatively few papers investigating the lead/lag relationship of the FTSE100 and FTSE100 futures. Earlier research by Abhyankar (1995), based on the hourly returns between 0905-1605GMT during 1986-1990, finds the futures market lead up to an hour. This is supported by more recent work by ap Gwilym and Buckle (2001), also using hourly data during 1993-1996, which reports a similar result of the futures market lead up to an hour. The latter paper examines not only the lead/lag relationship between the cash index and its derivatives, futures and options but also between the derivatives themselves. Both studies are constrained by the use of hourly data in the analysis. Further research by Abhyankar (1998), using a higher frequency data of 5-minute intervals, finds bi-directional non-linear leads and lags of the FTSE100. Prior work by Fleming et al (1996) reports that trading of the well-informed investors will generally take place in the derivatives markets earlier than the spot market as a consequence of their leverage and relative lower transactions costs. In addition, Chan (1992) suggests that the futures lead in terms of price movements over the spot market is more likely to be strengthened during the market wide or macroeconomic information releases. Based on these findings, we set up a hypothesis on the lead/lag relationship as follows:

H_1: The futures market lead over the spot market is strengthened by the macroeconomic announcements.

In this study, we examine the lead/lag relationship of the UK stock index FTSE100 and FTSE100 futures, by using the following regression model:

$$R_{a,n} = \alpha + \sum_{k=-12}^{+12} \beta_k R_{b,n+k} + \beta_z Z_{n-1} + \varepsilon_n \qquad \ldots\ldots(2)$$

where $R_{a,n}$ and $R_{b,n+k}$ are the stock index (a) and stock index futures (b) returns over the 5-minute interval n, and Z_{n-1} is an error correction term. Based on prior studies, which report an hour lead of the futures market over the spot market, the choice of 12 lead variables and 12 lag variables aims to cover the observations during an hour before and after the announcements. By using high frequency data, at 5-minute interval, the regression result from Equation 2 should enable us to identify a more specific timing of the lead/lag effect taken place between the two markets.

Again, the GMM method is employed for the estimation of the regression model. By following Fleming et al (1996), the error correction term Z_{n-1} is included here to account for the cointegration, which is induced by the arbitrage relationship between a security and its derivatives. In the presence of cointegration, the lagged difference between the levels of two series provides information beyond that contained in a finite number of changes in the independent variable. This information is captured by the inclusion of the error correction term which is defined as the difference between the logs of the level of cash index and its futures at time n-1. The intuition is that differences in levels at time n-1 will tend to get smaller at time n due to arbitrage activity.

Next, we make a further investigation to identify any existence of the macro announcement impact on the lead/lag relationship by including the multiplicative terms of the announcement dummy variables and futures returns as shown in Equation 3. This method was previously adopted in Frino et al (2000), whose results show a lead of futures over the cash index for up to 20 minutes in the Australian markets. The dummy variables used in Frino et al (2000) have a value of 1 for 30-minute range around the news releases, or 0 otherwise. Instead, our dummy variables D_m have the value of 1 for each 5-minute interval on the announcement day, starting from the market opening up to an hour after the news releases, or 0 otherwise. This is based on the previous findings of Abayankar (1995) and ap Gwilym and Buckle (2001) that the UK stock index futures market lead the spot market by an hour. By using observations of the 5-minute frequency, this study aims to obtain more precision on the timing and the extent of the impact from macroeconomic announcements.

$$R_{a,n} = \alpha + \sum_{k=-12}^{+12} \beta_k R_{b,n+k} + \sum_{k=-6}^{+6} \lambda_k D_m R_{b,n+k} + \beta_z Z_{n-1} + \varepsilon_n \tag{3}$$

where $R_{a,n}$ and $R_{b,n+k}$ are the stock index (a) and stock index futures (b) return over the 5-minute interval n, and Z_{n-1} is an error correction term. D_m is the announcement dummy variable, which has the value of 1 for each interval on the announcement day, starting from the market opening up to an hour after the news releases, and 0 otherwise, irrespective of the category of macroeconomic announcements. Again, we employ the GMM method to obtain the estimates of this regression model.

The λ_k coefficients capture the additional impact of the macroannouncement (k) on the lead/lag relationship between the stock index and stock index futures. The announcement dummy variables D_m are constructed to represent all macroannouncements or combination of macroeconomic announcements under investigation, (see Table 1, page 64).

3.4 Regression analysis results of the impact of macroeconomic announcements on the lead/lag relationship

We first examine the lead/lag relationship by estimating Equation 2, with 12 lead variables and 12 lag variables. The regression results in Table 3 show that the futures market has a lead over the spot market by 50 minutes as indicated by the significant positive coefficient of the futures lag variable 1-10 (at 1% level), $\beta_{-1} - \beta_{-10}$. The first immediate preceding 5-minute lagged variable of futures return possesses the largest positive coefficient (β_{-1}) of 211.47 with the t-statistic value of 70.76, which implies a very strong futures lead of 5 minutes over the spot market. It is followed by the next preceding 5 minutes, which has the coefficient (β_{-2}) of 116.58 with a t-statistic value of 48.99. The coefficient value β_{-3} - β_{-10} has quickly subsided after that which implies a much weakening futures lead. The contemporaneous relationship is also very strong as shown by its coefficient value of 195.26 with the t-statistic 47.19. This relationship provides a respectable adjusted R^2 value of 0.43 as compared to the R^2 of 0.74 reported by ap Gwilym and Buckle (2001), using hourly data. The coefficient of the error correction term, β_z, is highly significant and negative as expected, having a value of –4.11 with the t-statistic of –11.55. It is consistent with ap Gwilym and Buckle (2001) who also reported the negative β_z value of –0.03 with the t-statistic of -10.37. This indicates that the lagged difference provides information about the lead/lag relationship. The negative coefficient indicates that the time *n* change in the index level is negative (positive) if the cash index is above (below) the futures price at time *n-1*.

This is consistent with a narrowing basis as expiry approaches. Although the error term is highly significant, it does not meaningfully impact the other coefficients in the lead/lag coefficient magnitudes and t-statistics are very similar whether or not the error correction term is included.

The overall result is somewhat consistent with the previous findings of both Abayankar (1995) and ap Gwilym and Buckle (2001) who report a futures lead of an hour. By using higher frequency data, this study has been able to narrow down the UK stock futures lead over the spot market to only 50 minutes. This lead is however larger than what was reported in previous research on the lead/lag relationship of non-UK stock indices. For example, most studies on the US indices (S&P500 and MMI) document a futures lead of 15-20 minutes (Kawallar , Koch and Koch 1988, 1993, Herbst, McCormack and West 1987, Kutner and Sweeney 1991, Ghosh 1993, Fleming, Ostdiek and Whaley 1996, Pizzi et al 1998, Chan 1992). Similarly, Chung et al (1994) also report the finding of a 20-minute futures lead whereas Sim and Zurbreugg (1999) find only 10-minute lead of the Nekkei stock index futures over its corresponding spot market. Hodgson et al (1993) report a futures lead of 30 minutes for the Australian stock index, All Ord. The German futures index market, DAX30, is reported by Grunbichler, Longstaff and Schwartz (1994) to have a lead of 15 minutes over its spot market.

To observe the impact of the macroannouncements on the lead/lag relationship, the regression analysis is next undertaken using Equation 3, with 12 lead variables and 12 lag variables together with an addition of 6 multiplicative terms between the announcement dummy variables and lead variables plus 6 multiplicative terms of the announcement dummy variables and lag variables. Table 4 presents an existence of the macroannouncement impacts on the lead/lag relationship between FTSE100 and FTSE100 futures, which is shown by the significant positive coefficients of the multiplicative terms of the lag variables and announcement dummy variables at lag 1 to lag 10. The coefficient values of the lead/lag relations, β_{-n} or β_n, obtained from using Equation 3 yield similar results to those obtained from using Equation 2. The strongest futures lead of 5 minutes is also found, although its coefficient value is slightly smaller, 208.54 with a t-statistic of 66.88 as compared to 211.47 with a t-statistic of 70.76 when using Equation 2. The coefficient values up to β_{-10} are also significantly positive at the 1% level. The significant positive coefficients of the multiplicative terms between the lagged variables of futures returns and the announcement dummy variables are obtained from the estimation for the contemporaneous and lag 1 variable (λ_0, λ_{-1}). The contemporaneous variable (λ_0) has the largest significant positive coefficient value of 51.17 with the t-statistic value of 3.61, followed by λ_{-1}, 46.46 with the t-statistic value of 4.54. This implies that the futures lead of 10 minutes over the spot market is additionally strengthened by the impact of the macroeconomic news releases. The value of the adjusted R^2 has increased to 0.4338 as compared to 0.4325 in Table 2, the result obtained when estimating without capturing the announcement effect using Equation 2. This confirms that the macroannouncement effect variables have in fact helped in explaining the lead/lag relationship. Although the coefficient of the error correction term, β_z, is smaller than when using Equation 2, it is also significantly negative as expected, having the value of -4.09 with the t-statistic value of -11.54.

Table 3

Regression results of lead/lag relationship between FTSE100 and FTSE100 futures

	Coefficient**	Std.dev	t-statistic	Probability
α	-0.01*	0.000001	-7.49	0
β_z	-4.11*	0.00036	-11.55	0
β_{-12}	1.10	0.00193	0.57	0.5694
β_{-11}	1.39	0.00211	0.66	0.5085
β_{-10}	6.49*	0.00213	3.05	0.0023
β_{-9}	11.12*	0.00214	5.19	0
β_{-8}	13.60*	0.00213	6.39	0
β_{-7}	18.08*	0.00204	8.87	0
β_{-6}	24.44*	0.00217	11.28	0
β_{-5}	34.09*	0.00230	14.83	0
β_{-4}	45.08*	0.00267	16.87	0
β_{-3}	65.32*	0.00257	25.43	0
β_{-2}	116.58*	0.00238	48.99	0
β_{-1}	211.47*	0.00299	70.76	0
β_0	195.26*	0.00414	47.19	0
β_{+1}	18.21*	0.00283	6.44	0
β_{+2}	3.72	0.00233	1.60	0.1105
β_{+3}	0.66	0.00199	0.33	0.7404
β_{+4}	-0.21	0.00220	-0.09	0.9246
β_{+5}	2.41	0.00203	1.19	0.2354
β_{+6}	2.94	0.00198	1.49	0.1366
β_{+7}	-2.32	0.00208	-1.12	0.2630
β_{+8}	3.17	0.00199	1.60	0.1102
β_{+9}	2.57	0.00202	1.28	0.2023
β_{+10}	1.90	0.00194	0.98	0.3286
β_{+11}	0.21	0.00186	0.11	0.9104
β_{+12}	2.60	0.00184	1.41	0.1578
Adj.R^2	0.4325			

Note: * Significant at the 1% level, **Coefficients are multiplied by 1000.

Table 4
Regression results of lead/lag relationship between FTSE100 and FTSE100 futures (with Macroannouncement impact)

	Coeff.***	Std.dev	t-statistic	Prob.		Coeff.***	Std.dev	t-statistic	Prob.
α	-0.01*	0.000001	-7.048	0	λ_{-6}	4.18	0.00800	0.52	0.6010
$\beta_{=}$	-4.09*	0.00036	-11.54	0	λ_{-5}	-8.49	0.00848	-1.00	0.3166
β_{-12}	1.12	0.00193	0.58	0.5601	λ_{-4}	-23.14	0.00974	-2.38	0.0175
β_{-11}	1.33	0.00211	0.63	0.5272	λ_{-3}	-10.41	0.00952	-1.09	0.2743
β_{-10}	6.57*	0.00212	3.10	0.0020	λ_{-2}	-0.69	0.00903	-0.08	0.9392
β_{-9}	11.16*	0.00215	5.19	0	λ_{-1}	46.46*	0.01025	4.54	0
β_{-8}	13.48*	0.00213	6.33	0	λ_{0}	51.17*	0.01419	3.61	0.0003
β_{-7}	17.87*	0.00204	8.75	0	λ_{+1}	12.65	0.01138	1.11	0.2664
β_{-6}	23.97*	0.00224	10.69	0	λ_{+2}	-3.16	0.01256	-0.25	0.8012
β_{-5}	34.57*	0.00241	14.41	0	λ_{+3}	-4.19	0.01191	-0.35	0.7248
β_{-4}	46.82*	0.00278	16.83	0	λ_{+4}	11.98	0.01024	1.17	0.2421
β_{-3}	65.96*	0.00266	24.79	0	λ_{+5}	-2.55	0.01069	-0.24	0.8118
β_{-2}	116.50*	0.00246	47.29	0	λ_{+6}	3.65	0.01091	0.33	0.7377
β_{-1}	208.54*	0.00312	66.88	0					
β_{0}	192.25*	0.00433	44.39	0					
β_{+1}	17.47*	0.00289	6.05	0					
β_{+2}	3.97**	0.00235	1.69	0.0916					
β_{+3}	0.89	0.00200	0.45	0.6552					
β_{+4}	-0.73	0.00227	-0.32	0.7458					
β_{+5}	2.34	0.00206	1.14	0.2554					
β_{+6}	2.66	0.00201	1.32	0.1853					
β_{+7}	-2.40	0.00208	-1.15	0.2486					
β_{+8}	3.22	0.00199	1.62	0.105					
β_{+9}	2.41	0.00202	1.20	0.2314					
β_{+10}	1.89	0.00194	0.97	0.3306					
β_{+11}	0.25	0.00186	0.14	0.8919					
β_{+12}	2.56	0.00184	1.39	0.1646					
Adj.R^2	0.4338								

Note: *Significant at 1% level, **Significant at 10% level, ***Coefficients are multiplied by 1000.

3.5 Market reaction to unexpected news from macroeconomic announcements

3.5.1 Type of News

Macroeconomic announcements can create three types of news in the financial markets: good, neutral and bad news. Here, the figure releases are considered good news when the actual statistics announced are better than the market expectation, or bad news when the figures released are worse than market expectation. The news is neutral when the actual statistic figures released are the same as the market forecast. The market price is assumed to be based on the market forecast of the announcement until the arrival of new information. According to the Efficient Market Hypothesis (EMH), an efficient market should react only to the unexpected part of the information releases.

To examine the market reaction to unexpected news, only three macroannouncements, Inflation (RPI), Production Price Index (PPI) and Unemployment, are chosen for further investigation on the lead/lag relationship. The selection criterion is based on their relative significance on the market, amount of data and a clear distinction of the news types generated by the announcements. In Table 2 on page 70, the inflation or RPI announcement had relatively the strongest impact on the stock index return volatility, as indicated by its largest significant coefficient. Unemployment and the PPI had the next strongest impacts.

Table 5 displays the scenarios and percentage shares of news types created by the three announcements over 1994-1996. During this period, the unexpected news from inflation announcement (RPI) is equally split between good and bad news, 50:50. The majority of RPI good news is contributed to by the fact that the actual inflation rise is less than market forecast whereas the larger portion of bad news is obtained when there is a rise in inflation instead of a fall as the market prediction. Similar to inflation, the Production Price Index (PPI) announcements also generate almost equal shares between good news (38.9%) and bad news (41.7%), of around 40%. Interestingly, nearly one-fifth of market forecast produces an accurate prediction for the PPI figures, as indicated by the 20% share of the neutral news type for this particular announcement whereas the inflation or unemployment announcement only generates either good or bad news. As for unemployment, more than 65% of figure releases deliver good news to the financial market, i.e. when the actual fall in unemployment is greater than the market forecast.

Table 5
Percentage shares of news types generated by macroannouncements (%)

	RPI	PPI	Unemployment
Good news:			
1. actual decrease greater than forecast decrease	0.0	2.8	65.7
2. actual increase less than forecast increase	30.6	22.2	0.0
3. actual decrease, forecast increase	19.4	13.9	0.0
sub-total	50.0	38.9	65.7
Bad news:			
1. actual decrease less than forecast decrease	0.0	2.8	20.0
2. actual increase greater than forecast increase	16.7	2.8	14.3
3. actual increase, forecast decrease	33.3	36.1	0.0
sub-total	50.0	41.7	34.3
Neutral news:			
actual same as forecast	0.0	19.4	0.0
Total	100.0	100.0	100.0

3.5.2 Methodology

The good news, bad news and neutral news as classified above are represented by the news type dummy variables, D_{gd}, D_{bd} and D_{nt} respectively. These dummy variables take the value of 1 for every 5-minute interval on the announcement days according to the news types i.e. $D_{gd} = 1$ if good news, or 0 otherwise. We use the multiplicative terms between the lag variables and news dummy variables to capture the effect of various news types (good, bad or neutral) on the lead/lag relationship between the stock index futures and its underlying spot market.

Based on the EMH mentioned above, the financial market will react to unexpected news, either good or bad, from the macro announcements. No abnormal trading behaviour is expected from the announcements of neutral news as traders must have already incorporated the market forecast into their investment decision earlier. Other studies have found that traders react more quickly during a bad news period than a good news period. McQueen et al (1996) reports a "delayed reaction" from the traders during the good news period, when traders would shop around more before purchasing small-firm stocks. The corresponding market reaction to the news should reflect first in the futures market because of the ease in trading, due to its lower trading cost and high liquidity with a subsequent adjustment by the spot market. Jennings and Starks (1985) also state that bad news typically disseminates quicker than good news. As a consequence, we expect that bad news from the announcements would strengthen the lead/lag relationship between the stock index futures and its underlying equity. Meanwhile, Tan and Gannon (2002) report that the information effect from the macro announcements (i.e. CPI, CAD and GDP) on the Australian stock index futures (SPI) subsides within 10 minutes after the news releases. Hence, we expect to see the impact of the unexpected news from the announcements on the futures lead over the spot market to disappear within a very short period of time. As a result, we set up a hypothesis as follows:

H_2: The lead/lag relationship between the stock index and stock index futures would be strengthened by non-neutral news, either good or bad, generated by the macroannouncements.

As a result of some previous studies, for example, Blasco et al (2002) who test the impact of economic news on stock volatility and found that the asymmetric behaviour of variance is largely responsible by the effect of bad news from the announcements, Sentana and Wadhawani (1992) who document that responses to bad news lead to greater volatility than do responses to good news and Brown et al (1988) who find that unfavourable news tends to produce greater stock price reactions than favourable one, we further formulate the third hypothesis based on these findings as follows:

H_3: The impact from bad news generated by the macroeconomic announcements on the lead/lag relationship between the stock index futures and its underlying cash index is greater than the impact from good news and will be incorporated into the market adjustments at a higher speed.

The impact of unexpected news, either good or bad, on the lead/lag relationship is examined by using the following model:

$$R_{a,n} = \alpha + \sum_{k=-6}^{+6} \beta_k R_{b,n+k} + \sum_{k=-1}^{-4} \beta_{gd} D_{gd} R_{b,n+k} + \sum_{k=-1}^{-4} \beta_{bd} D_{bd} R_{b,n+k} \sum_{k=-1}^{-4} \beta_{nt} D_{nt} R_{b,n+k} + \beta_z Z_{n-1} + \varepsilon_n \ldots(4)$$

where D_{gd}, D_{bd}, and D_{nt} are the dummy variables for the good news, bad news and neutral news from the macro announcements. These dummy variables take the value of 1 for every 5-minute interval on the announcement days according to the news types i.e. $D_{gd} = 1$ if good news, or 0 otherwise. We use the multiplicative terms between the lag variables and news dummy variables to capture the effect of various news types (good, bad or neutral) on the lead/lag relationship between the stock index futures and its underlying spot market.

$R_{a,n}$ is the log return of the interval *n* of the stock index and $R_{b,n}$ is that of stock index futures. Z_{n-1} is an error-correction term. In order to cover the period with relatively strong impact from the macroannouncements, the observations used here are from the period of the first 30 minutes after the information releases.

3.5.3 Regression results of the impact of unexpected news from macro announcements

Table 6 shows the result of a futures lead over the spot market, which is indicated by the significant positive coefficients of all lagged variables, β_{-1} - β_{-6}. Similar to the estimation of Equation 2 and Equation 3, the futures lead of 5 minutes is found to have the largest coefficient value at 244.71 with the t-statistic of 30.24. D_{bd} has a significant positive coefficient of lag 1 variable at 60.52 with the t-statistic of 2.73, followed by the significant negative coefficient –41.02 and –42.50 with the t-statistic value of –2.49 and –1.84 for the lag 2 and lag 3 variable of bad news effect, respectively. This confirms that the hypothesis

H_2 is true because the result indicates that a lead of futures over the spot market for up to 5 minutes is strengthened by the additional effect from the bad news. This information effect has quickly subsided after market adjustments. The negative coefficient of the lag 2 and lag 3 variables imply a feedback from the spot market to the futures market. As for the good news effect, we obtain a significant negative coefficient value of -4.03 with the t-statistic of -2.09 for the good news type with lag 1 variable. It indicates that a lead of the futures over the spot market of up to 5 minutes is eroded by the feedback from the spot market. This is consistent with Tan and Gannon (2002), who studied 28 Australian macroeconomic announcements, and find some reaction of the futures market return within 1 minute but reports that the announcement effect disappears within 5 minutes. The result also confirms that the hypothesis H_3 is true that the bad news has stronger impact on the lead/lag relationship than good news. This is indicated by the size of the significant coefficient of bad news effect variable ($\beta_{bd,-1}$), 60.52, which is much higher than the good news effect one, -4.03. The error correction term coefficient, β_z, here is also significantly negative, having the value of –5.03 with t-statistic –3.94. The estimation of this relationship provides the adjusted R^2 of 0.5343.

Table 6

Impact of unexpected macroannouncement news on the lead/lag relationship Between FTSE100 and FTSE100 futures

	Coeff.***	Std.dev	t-statistic	Prob.		Coeff.***	Std.dev	t-statistic	Prob.
α	-0.01	4.94E-06	-1.05587	0.2911	$\beta_{bd,-4}$	-9.59	0.022476	-0.42649	0.6698
β_z	-5.10*	0.001293	-3.94504	0.0001	$\beta_{bd,-3}$	-42.50***	0.023096	-1.83993	0.0658
β_{-6}	19.37*	0.005452	3.553257	0.0004	$\beta_{bd,-2}$	-41.02**	0.016507	-2.48489	0.013
β_{-5}	25.02*	0.005333	4.691921	0	$\beta_{bd,-1}$	60.52*	0.022219	2.723815	0.0065
β_{-4}	35.98*	0.005839	6.162558	0					
β_{-3}	76.87*	0.006302	12.19814	0	$\beta_{gd,-4}$	-38.47	0.018198	-0.22139	0.8248
β_{-2}	140.12*	0.00649	21.59022	0	$\beta_{gd,-3}$	1.22	0.017512	0.346998	0.7286
β_{-1}	247.52*	0.009436	26.23171	0	$\beta_{gd,-2}$	6.08	0.0153	0.079965	0.9363
β_0	244.71*	0.008093	30.23817	0.0001	$\beta_{gd,-1}$	-4.03**	0.018431	-2.08743	0.0369
β_{+1}	36.89*	0.007741	4.765536	0					
β_{+2}	7.07	0.006586	1.072877	0.2834	$\beta_{nt,-4}$	-94.32**	0.037998	-2.48227	0.0131
β_{+3}	-21.82*	0.006988	-3.12192	0.0018	$\beta_{nt,-3}$	-0.57	0.028015	-0.02035	0.9838
β_{+4}	1.86	0.006279	0.295418	0.7677	$\beta_{nt,-2}$	-1.94	0.046012	-0.04223	0.9663
β_{+5}	-2.25	0.006588	-0.34073	0.7333	$\beta_{nt,-1}$	-22.89	0.048801	-0.46907	0.639
β_{+6}	-4.84	0.006345	-0.76346	0.4452					
Adj.R^2	0.5343								

Note: *Significant at 1% level, **Significant at 5% level, ***Coefficients are multiplied by 1000.

3.6 Conclusion

This study contributes additional empirical evidence on the impact of macroeconomic announcements on the lead/lag relationship between stock index futures and its underlying cash index. The observations utilized are the high-frequency data at 5-minute intervals of FTSE100 cash and futures index over a two-year period, 1994-1996. A selection of nine UK macroeconomic announcements is utilized here. All economic statistics under investigation have the same scheduled time for the figure release at 0930 GMT. The study examines not only the economic news impact on the lead/lag relationship from single macro announcements, but also when several types of announcements are simultaneously released on the same trading day (or multiple announcements). All these announcements, single or multiple, are tested for their statistical significance in order to identify which one has any significant influence on the stock index futures market and to what extent. To achieve this, the study adopts the method developed by Ederlington and Lee (1993) to test the statistically significant impact from the macro announcements on the stock index futures volatility. The selected announcements are all found to have significant impact on the stock index futures market.

The multiple regression model (Equation 2) is initially set up to examine the lead/lag relationship between the futures index and its underlying cash index in general. The regression analysis result shows a stock index futures lead of 50 minutes over the cash index in the UK markets. This is consistent with the results from previous studies on the lead/lag relationship of the UK stock index and its futures index by Abayankar (1995) and ap Gwilym and Buckle (2001), who report a futures lead of an hour over the cash index. To capture the effect of macroeconomic announcements on the lead/lag relationship, the multiple regression model is modified by the inclusion of multiplicative terms between the announcement dummy variables and the lagged variables of the futures returns (see Equation 3), as in Frino et al (2000). The estimation result shows that the futures lead of up to 5 minutes is strengthened by the macroeconomic announcements. However, the additional strengthening impact of the macroannouncements does not exist for the futures leads of more than 5 minutes.

The investigation also examined the impact of unexpected news from macroeconomic announcements on the lead/lag relationship. The macroeconomic announcements usually consist of a high content of unexpected news, which can be either good or bad news. Previous studies widely document the asymmetric responses between good and bad news on equity prices. A proxy for unexpected news is devised to identify the type of news surprises. News surprise generally occurs when the economic figure released is different from the market forecast. The study makes use of the Money Market Services (MMS) data of the market forecasts of the economic statistic figures, which are statistically tested and accepted for their unbiasedness. This is reported by several studies (Pearce and Roley 1985, Almeida et al 1998, Balduzzi et al 2001), which found the MMS data to be unbiased. The market forecast of economic statistics and the corresponding actual figures are observed in detail to identify the news types generated by these data, i.e. good, bad or neutral news. This information is then incorporated into the multiple regression model (Equation 4) to capture the effect of unexpected news on the lead/lag relationship. The results show that an asymmetric response to good and bad news does exist in the context of the lead/lag relationship between the stock index futures and its underlying cash index. The futures lead of 5 minutes over the spot market is strengthened by the effect of bad news generated by the macro announcements. The results also illustrate that good news causes a price lead from the spot market to the futures market instead. When considering the extent of the impact, bad news appears to possess larger impact on the lead/lag relationship than good news.

Appendix 2

Table 7
Single Macroeconomic announcement Days

	Single Announcement								
Announcement index	1	2	3	4	5	6	7	8	9
No. of announcement days	31	22	26	16	16	27	15	48	49
Dates:	930119	930121	930115	930222	930311	930120	930125	930112	930105
	930216	930218	930212	930312	930622	930217	930427	930209	930203
	930316	930318	930319	930426	930921	930317	930727	930309	930301
	930420	930422	930416	930723	931220	930423	931026	930413	930405
	930716	930520	930521	931022	940324	930721	940124	930510	930506
	930817	930715	930714	940121	940624	931020	940426	930614	930602
	931018	930812	931013	940425	940923	940421	940726	930712	930705
	931116	931014	940323	940722	941222	940519	941025	930809	930803
	931216	931118	940415	941021	950324	940720	950124	930913	930903
	940718	940112	950323	950123	950626	940818	950725	931011	930930
	940816	950412	950413	950721	950922	940915	951024	931108	931004
	940916	950614	950511	951023	951221	941019	960123	931213	931103
	941018	950913	950713	960122	960326	941117	960423	940117	931202
	941216	960214	950817	960429	960628	941215	960723	940214	940107
	950216	960313	951012	960726	960924	950119	961022	940314	940204
	950316	960417	951214	961025	961220	950421		940418	940304
	950420	960515	960215			950518		940516	940406
	950616	960612	960321			960221		940613	940506
	950718	960717	960516			960320		940711	940603
	950918	960814	960613			960425		940808	940704
	951017	960911	960711			960523		940912	940803
	951218	961113	960815			960619		941010	940905
	960216		960912			960724		941114	941004
	960318		961010			960821		941212	941103
	960517		961114			960918		950116	941205
	960618		961212			961023		950213	950106
	960716					961120		950313	950203
	960816							950410	950303
	960917							950515	950331
	961119							950612	950505
	961217							950710	950602
								950814	950703
								950911	950802
								951009	950901
								951113	951003
								951211	951101
								960115	951201
								960212	960108
								960311	960201
								960415	960229
								960513	960329
								960610	960501
								960708	960530
								960812	960701
								960909	960729
								961014	960830
								961111	960930
								961209	961029
									961129

Note : Date format is YYMMDD. For example, 961129 is 29/Nov/1996.

Announcement index

1. PBSR
2. Unemployment
3. RPI
4. GDP
5. BOP
6. Retail sales
7. CBI
8. PPI
9. MO&M4

Table 8
Multiple Macroeconomic Announcement Days

	Multiple Announcement											
Announcement index	12	13	16	23	26	36	47	123	126	136	236	1236
No. of announcement days	5	2	3	7	6	6	1	3	2	1	2	1
Dates	930916	951116	930519	930617	950315	930818	950425	940518	940316	940119	931215	940216
	940420	960418	930616	940615	950719	930915		941116	950816		950215	
	950517		940616	940713	951018	931117		950118				
	960117			940817	951115	950615						
	961016			940914	951213	950914						
				941012	961218	960118						
				941214								

Note : Date format is YYMMDD. For example, 961129 is 29/Nov/1996.

Announcement index

12. PBSR + Unemployment
13. PSBR + RPI
16. PSBR + Retail sales
23. Unemployment + RPI
26. Unemployment + Retail sales
36. RPI + Retails sales
47.GDP + CBI
123.PBSR + Unemployment + RPI
126. PBSR + Unemployment + Retail sales
136. PBSR + RPI + Retail sales
236. Unemployment + RPI + Retail sales
1236. PBSr + Unemployment + RPI + Retail sales

Chapter 4

The international transmission of arbitrage information across futures markets

4.1 Introduction

The existence of linkages across international markets has been well documented, particularly in relation to stock markets in developed economies. The decline in international investment barriers experienced over the past two decades, combined with the move toward globalisation of financial markets, have increased international capital movements which in turn has accelerated inter-market correlations of economic activity. Associated with these changes has been an apparent higher degree of market integration and correlation of asset price movements across markets. A substantial focus of research in this area has been concentrated on equity price movements, both in relation to return co-movements and volatility spillovers. The evidence from these studies supports the existence of contagion effects and "meteor showers" across markets (e.g. Hamao et. al (1990)).

The development of derivative securities has allowed investors to more effectively manage their exposures. In the presence of arbitrage forces, the prices of derivative instruments are generally regarded as a function of the prices of their underlying asset. Hence, to the extent that international relations exist between price movements in spot market assets, it can be reasonably expected that such relations should also be present in the associated derivative assets. For instance, if two equity markets exhibit co-movement then their stock index futures contracts should also exhibit the same relation. If this were not the case, then there would appear to be arbitrage opportunities between the spot and futures in at least one of the domestic markets. This concept can be thought of more formally in the context of cointegration. Specifically, if two spot markets are cointegrated then it is reasonable to expect their futures markets to be similarly cointegrated. However, there is limited evidence on international linkages between derivative markets.

As an alternative to testing for international relations across derivative markets, a more direct and potentially revealing test would be to examine spillovers between mispricing series. This is the purpose of this study. Specifically, the study focuses on stock index futures and their mispricing series. Previous evidence has shown small but persistent patterns of mispricing in domestic futures markets (e.g. Cornell and French (1983)). The aim of this research is to examine whether potential arbitrage opportunities identified in one market carry information such that they can predict subsequent potential arbitrage opportunities in another market. As an example, the futures and spot markets became delinked in October 1987 and the question arises as to whether such instances are widespread and whether they flow over market boundaries. The reason for the deviation in the domestic spot-futures relation is not important here. Rather, given that a deviation exists, this study seeks to examine whether the deviation spills across markets. Similarly, King and Wadhwani (1990) attempt to explain how common falls in stock market indices are observed around crash dates. Despite vastly differing economic conditions, they propose that price changes in foreign markets may be systematically interpreted as relevant information for the local market, even if the foreign market price change is induced by idiosyncratic events.

This study has implications as to the efficiency of international capital markets and whether international investors can exploit windows of arbitrage opportunity identified in one market in another market. The analysis focuses on three markets on which there is evidence of existing correlations in the spot market - Australia, the UK and USA. Domestic mispricing series are constructed for each market and using the time zone differences between the three markets, a vector autoregression (VAR) model is constructed to examine whether their domestic mispricing series are related.

The study is constructed as follows. The next section reviews the literature on international market linkages. Section 4.3 discusses known features of stock index futures pricing. Section 4.4 documents the data used in the study and the construction of the VAR. Section 4.5 provides a description of the three mispricing series, while section 4.6 contains the results of the analysis. In short, all mispricing series exhibit autocorrelation and there is evidence of bi-directional spillovers across the markets. A trading strategy is employed to examine the economic significance of apparent profits. The results show that some profits are possible but that a long horizon, probably beyond the scope of most traders, is required to exploit the spillover information. The final section contains the conclusion.

4.2 Linkages Across International Markets

Many studies have reported the existence of linkages among financial markets. Awad and Goodwin (1998) have found the evidence of dynamic linkages, particularly in the long run, among real interest rates of the markets of G-10 countries (USA, Canada, UK, Japan, Belgium, Germany, France, Italy, Switzerland, Netherlands). Rouwenhorst (1999) reports a decrease in the interest rate spreads among the 12 European Monetary Union (EMS) countries following the Maastricht Treaty in 1992. In the context of stock markets, it is well-known that international correlations exist. International asset pricing models predict that price spillover effects will occur as price changes in foreign markets are interpreted as relevant economic information which is subsequently incorporated into prices on the local stock market (see Stulz (1981), Solnik (1983), Cho et al (1986)). Eun and Shim (1989) use a VAR model to study linkages among nine developed stock markets and find evidence of US market innovations flowing to the other markets, with limited evidence of foreign market influence back to the USA. Similarly, Copeland and Copeland (1998) study 29 countries across the Americas, Europe and the Pacific and report statistically significant one-day leads of the US market over the other markets. The developments in computer technology have been an impetus for high-speed information transmission across markets. In support, Solnik et al (1996) find that, on average, the correlations between national stock market indices of industrial countries have increased over time.

Interaction between financial centres has also been observed in price volatility. Engle et al (1990) first introduced the "heat wave" and "meteor shower" terminology, in an attempt to distinguish between country-specific autocorrelation and volatility spillovers across international borders. In the context of equity markets, Hamao et al (1990) find evidence of daily volatility spillovers between the share price indices on the London, New York and Tokyo exchanges. The spillover effects are unidirectional in nature, flowing from New York to London, but not from London to New York (Becker et al (1990), Hamao et al (1990)). Koutmous and Booth (1995) report a strong market interdependence among the US, UK and Japanese markets and also note asymmetry in the relationship during good and bad news periods.

Spillover effects in price movements have not been limited to equity markets. Kim and Sheen (2000) find evidence of a lagged impact of US interest rate announcements on Australian interest rates. Similarly, Abhyankar (1995) examines mean return and volatility spillovers between the Eurodollar futures contracts traded on the Singapore Monetary Exchange (SIMEX) and Chicago Mercantile Exchange (CME), and finds evidence of both a lagged spillover effect in the mean flowing in a unidirectional form from the CME to the SIMEX. Lospodis (1998), by examining the exchange rate returns, reports a significant volatility spillover between the EMS markets (France, Netherlands, Belgium, Canada, USA, Japan). Speight and McMillan (2001) examine the foreign exchange rate black markets of five central European countries (Poland, Romania, Czech Republic, Bulgaria, Hungary) and find some evidence of volatility spillovers.

There is also evidence of volatility spillovers among the markets of close proximity. For example, Christofi et al (1999) examine five Latin American countries, Argentina, Brazil, Chile, Colombia and Mexico and find stronger volatility spillovers of stock index returns among them than with other regions of the world. Alles and Murray (2001) report the volatility spillovers from the UK to the Republic

of Ireland. Booth et al (1997) also detect volatility spillovers of stock index returns when observing the four Scandinavian markets (Norway, Sweden, Finland, Denmark). Brailsford (1996) finds a bi-directional volatility spillover of the stock index returns between Australia and New Zealand.

In the context of futures markets, Booth et al (1997) study volatility spillovers using daily data on the USA, UK and Japanese futures. In support of the 'meteor shower' hypothesis, they find significant spillovers between the USA and UK. However, Japanese futures volatility tends to follow an autoregressive trend, as suggested by the heat-wave hypothesis and as such is independent of US and UK volatility. Gannon and Choi (1998) report volatility spillovers in stock index futures from the USA to the Hong Kong futures market. Tse (1998), on the other hand, finds no evidence of volatility spillovers between the interest rate futures markets of the Eurodollar and Euroyen.

In summary, there is substantial evidence that price and price volatility spillovers exist across all types of markets. The strong evidence of stock market linkages means that due to the arbitrage relationship between the spot and futures markets, linkages should also exist between index futures markets. Indeed, the limited empirical evidence tends to support this claim.

4.3 Stock Index Futures Pricing

4.3.1 Cost-of-Carry Model

According to Cornell and French (1983), under the assumption that the spot markets are perfect and frictionless - that is, there are no tax and transaction cost and all market participnats having equal access to the risk-free interest rate, the borrowing and lending can take place at a constant continuously compounded interest rate *r*, deposit and performance margins can be posted in interest bearing assets and the underlying basket of shares pay dividends continuously at a rate *d* - then the theoretical (or fair) price of a stock index futures contract at time *t* with the maturity date *T* can be given by the "Cost-of-Carry" model, as follows:

$$F^{*}_{t,T} = S_t e^{(r-d)(T-t)} \qquad \text{..........(1)}$$

where

$F_{t,T}^{*}$ = the theoretical price at time *t* for a futures contract expiring at *T*;
S_t = the underlying stock index price at *t*;
$r(T-t)$ = the yield at time *t* of a discount risk-free bond maturing at time *T*;
$d(T-t)$ = the continuous dividend yield over time *t* to *T*.

Any deviation of the market price from theoretical price results in the mispricing of stock index futures contract. Futures mispricing can be classified into two groups: negative mispricing (underpricing) and positive mispricing (overpricing). When underpriced, the futures market price is higher than the futures theoretical price, and vice versa for the over-priced futures contracts.

4.3.2 Measure of Mispricing Errors

The model can be transformed as in Equation (2) to obtain the mispricing series as follows:

$$MP_t = F_{t,T} - S_t e^{(r-d)(T-t)} \qquad \text{..........(2)}$$

where $F_{t,T}$ is the observed (spot or market) futures price at time t for a futures contract expiring at T.

A profitable arbitrage opportunity arises when the level of mispricing exceeds the arbitrage boundaries, or transaction costs associated with the trade execution. Transaction costs include the stamp duty, market commissions, bid-offer spread in the respective equity and futures markets and any market impact costs which reflect the trade size and liquidity of the market. When overpricing (or positive mispricing) occurs, a profitable arbitrage can be obtained, provided that the extent of mispricing exceeds the upper transaction cost limit, by undertaking a short futures arbitrage position. That is, arbitrageur would sell the futures contracts and buy the underlying basket of stocks, or vice-versa in case of underpricing (or negative mispricing).

4.3.3 Previous Evidence of Mispricing Errors

There is substantial evidence on the mispricing of index futures (for example, Sutcliffe (1997) and ap Gwilym and Sutcliffe (1999) provide good reviews). The bulk of the work in the US has investigated the S&P500 and reported small, negative mispricing (e.g. Cornell and French (1983), Figlewski (1984), Chung (1991)). Studies in other markets have also documented occurrences of small, negative mispricing such as in the UK, Australia, Germany and Switzerland (Bowers and Twite (1985), Brailsford and Hodgson (1997), Kempf (1998), Stulz et al (1990), Yadav and Pope (1990)). Positive mispricing is reported in Japan and Hong Kong (Bhatt and Cakici (1990), Brenner et al (1989)) but overall, the results indicate a greater tendency of negative mispricing (underpricing).

Larger levels of mispricing are generally observed under circumstances where transaction costs are relatively high. For instance, Brailsford and Hodgson (1997) report a consistent negative mean pricing error in Australia, where transaction costs are relatively higher than the USA. But they report no sustainable arbitrage profits due to the low frequency of large futures pricing errors. Fung and Draper (1999) report that relaxing the short sales restrictions could reduce the mispricing level in Hong Kong. Gay and Jung (1999) report a persistent underpricing in the Korean futures market, caused essentially by high transaction costs. Butterworth and Holmes (2000) examine mispricing of the FTSE 100 and FTSE 250 contracts. They find a small magnitude of mispricing in both futures contracts, but with a higher level of mispricing in the FTSE 250, and reduced arbitrage opportunities after the introduction of FTSE 250 in 1994.

Mispricing series have been found to exhibit systematic properties. MacKinlay and Ramaswamy (1988) note the presence of autocorrelation in the mispricing series. Yadav and

Pope (1992) find a mean-reverting process in the mispricing series of the US and UK stock futures markets. Kempf (1998) documents a similar result in the German market. Vaidyanathan and Krehbiel (1992) explicitly recognise that the mispricing series exhibits systematic linear and non-linear trends, predominantly positive in some periods and negative in other periods. Non-synchronous trading in the constituent stocks can induce autocorrelation in the stock index which, in turn, can lead to arbitrage opportunities being falsely identified. Miller et al (1994) show that any mispricing series constructed from hypothetical arbitrage between the spot and futures could be contaminated and exhibit spurious mean reversion.

In summary, in the presence of arbitrage traders and the absence of market frictions, the expected value of any mispricing series is zero. Moreover, a mispricing series should exhibit small, random fluctuations. However, various factors that tend to be related to market microstructure, induce some small mispricing. As these factors are market-specific, any mispricing in one market should be independent of mispricing from another market. If relations between mispricing series exist across markets then arbitrage forces should eliminate them. If systematic relations across these series are found, it is prima facie evidence of the inefficiency of international capital markets.

4.4 Data and Methodology

4.4.1 Stock Index and Futures Descriptions

Australia

AOI (All Ordinaries Share Price Index or All Ords)

AOI index is made up of the weighted share prices of approximately 500 of the largest Australian companies traded at the Australian Stock Exchange (ASX). Established by ASX at 500 points in January 1980, it is the predominant measure of the overall performance of the Australian share market. The companies are weighted according to their size in terms of market capitalisation (total market value of a company's shares).

SPI (Share Price Index Futures)

SPI is the underlying futures contract of AOI, with four delivery months in March, June, September and December. The futures contract expires at 4.30 p.m. (or other time determined by SFE) of the last trading day of the contract month.

U.K.

FTSE 100 (Financial Times - Stock Exchange 100 Share Index)

FTSE 100 was introduced on 31 December 1983, and popularly known as FTSE 100 or "'Footsie". It is an arithmetic price weighted index of 100 quoted companies with the UK largest market capitalisation. This index is computed using the average of the best bid and ask price quotation taken from SEAQ, rather than using transaction prices, as in the US.

FTSE 100 Futures

FTSE 100 Futures is the futures contract of the underlying FTSE 100 index, with four delivery months in March, June, September and December. Unlike Australia, the UK futures contract has a predetermined contract expiry date for each quarter. At any one time, there are three nearest delivery months available for trading.

U.S.A.

S&P 500 (Standard & Poor's 500 Index)

Standard and Poor's 500 Index is a capitalization-weighted index of 500 stocks currently trade on the New York Stock Exchange. The index is designed to measure performance of the broad domestic economy through changes in the aggregate market value of 500 stocks representing all major industries. The index was developed with a base level of 10 for the 1941- 43 base period. Since the S&P 500 tracks many more companies than the Dow Jones Industrial Average (DJIA), which tracks only 30 companies, the S&P500 has become a much more accurate measurement of the market's daily movements. It is used to measure the performance of the entire U.S. domestic stock market.

S&P 500 Futures

Also having four delivery months as FTSE100 futures, but the last day of trading is the business day immediately preceding the day of determination of the Final Settlement Price (normally, the Thursday prior to the 3rd Friday of the contract month).

4.4.2 Details of Data

The study requires a time series of mispricing on the three markets under investigation - Australia, UK and USA. These markets are selected because of their known linkages. There is little point testing for spillovers of arbitrage information if the underlying markets are not related. In order to generate the mispricing series, the cost-of-carry is used, as in Equation (1) and Equation (2). Daily closing data are obtained for both the spot and futures markets over a 13-year period, 2 January 1985 to 30 December 1998, yielding a total of 3471 matching daily observations. However, no dividends are available for the UK in the year 1985 so these dates are omitted. If any of the countries experiences a holiday, the data for that day is omitted for all three markets. After making these adjustments, 2996 observations remain.

In order to implement the Cost-of-Carry model, dividend and interest rate series are also required. The dividend series is taken as the yield on the underlying index in each market. For the risk-free proxy, the following are used: 13-week Treasury bill rate for Australia; 3-month Treasury bill rate for the UK and the 3-month Treasury bill rate for the USA. Data are obtained from Datastream, LIFFE and Economic Research Division, Federal Reserve Bank of St. Louis, USA.

4.4.3 Methodology

As noted earlier, evidence has shown that mispricing series can exhibit time-series properties such as autocorrelation. As such, the mispricing series for each market is assumed to be influenced both by its prior own-market mispricing in addition to the variables of interest, that is, the mispricing series from the other markets. The vector autoregression (VAR), a method commonly used for forecasting systems of interrelated time series and for analysing the dynamic impact of random disturbances on the systems, is used here to test these relationships. Since only lagged values of the endogenous variables appear on the right-hand side of each equation, there is no issue of simultaneity, and OLS is the appropriate technique for the estimation. The assumption of no serial correlation in the disturbances is not required here as any serial correlation could be absorbed by adding more lagged endogenous variables. The model is estimated using equal information lags, as follows:

$$MP_{AU,t} = \alpha_{AU} + \sum_{i=1}^{n} \beta_i^{AU} MP_{AU,t-i} + \sum_{i=1}^{n} \gamma_i^{AU} MP_{UK,t-i} + \sum_{i=1}^{n} \lambda_i^{AU} MP_{US,t-i} + \varepsilon_{AU,t} \qquad \ldots(3a)$$

$$MP_{UK,t} = \alpha_{UK} + \sum_{i=1}^{n-1} \beta_i^{UK} MP_{AU,t-i} + \sum_{i=1}^{n} \gamma_i^{UK} MP_{UK,t-i} + \sum_{i=1}^{n} \lambda_i^{UK} MP_{US,t-i} + \varepsilon_{UK,t} \qquad \ldots(3b)$$

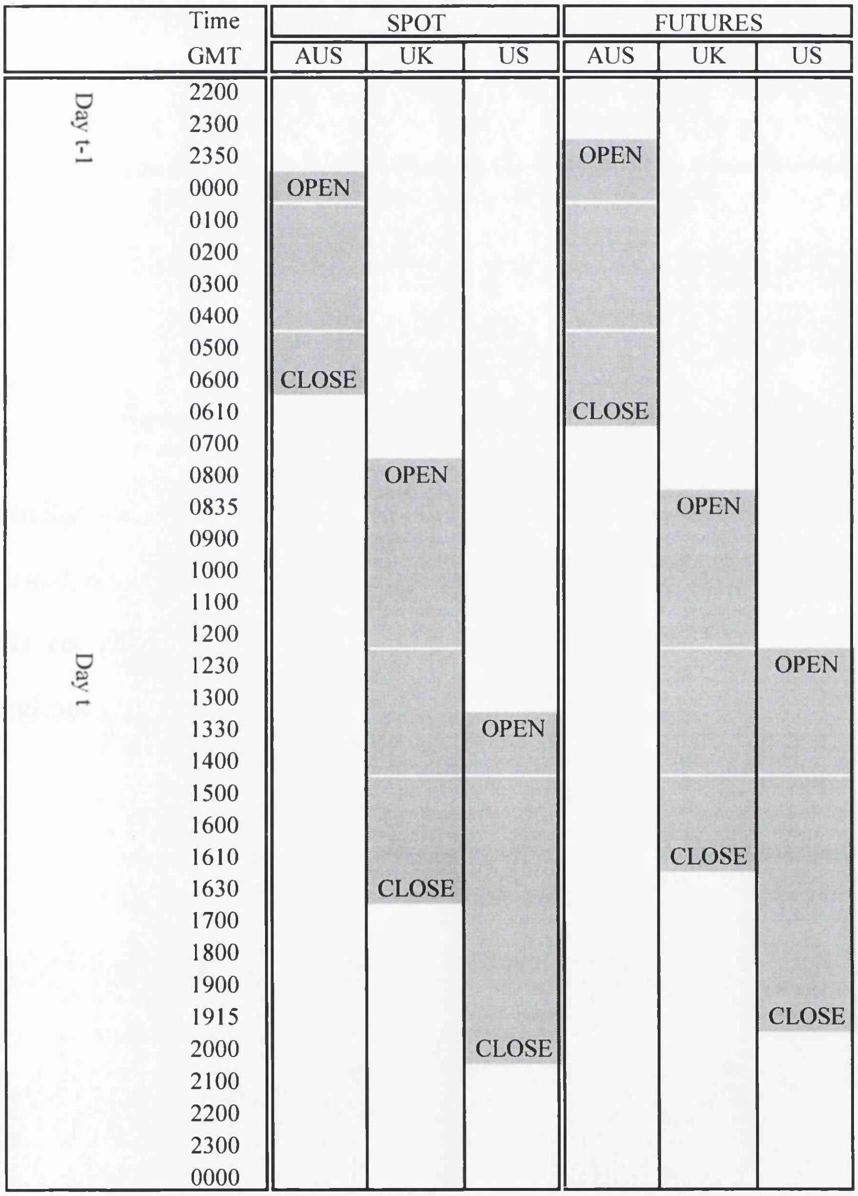
$$MP_{US,t} = \alpha_{US} + \sum_{i=1}^{n-1} \beta_i^{US} MP_{AU,t-i} + \sum_{i=1}^{n} \gamma_i^{US} MP_{UK,t-i} + \sum_{i=1}^{n} \lambda_i^{US} MP_{US,t-i} + \varepsilon_{US,t} \qquad \ldots(3c)$$

where $MP_{AU,t}$, $MP_{UK,t}$, $MP_{US,t}$ are the mispricing series from the Australian, UK and US futures markets respectively generated from Equation (2).The t subscript denotes calendar dates and $t-i$ indicates the lagged variable of i number of days. The number of lags, n, utilized here is 5.

An issue arises as to the impact of different trading times and different time zones. For the spot markets, the local trading times are as follows: Australia is open from 10am to 4pm, London from 8am to 4:30pm and the New York Stock Exchange (NYSE) from 8:30am to 3:15pm. For the futures markets, the Australian market is open from 9:50am to 4:10pm, London is open from 8:35am to 4:10pm and the Chicago Exchange is open from 9:30am to 4pm. The opening times are expressed in GMT in Figure 1. The Australian market opens first, followed by the UK and then the USA. Given this sequencing, the VAR models in Equation 3a-3c only use observations from other markets that are available at the time (i.e. close-to-close prices).

Figure 1

Trading Hours of the Markets (in GMT) – Spot and Futures



	Time	SPOT			FUTURES		
	GMT	AUS	UK	US	AUS	UK	US
Day t-1	2200						
	2300						
	2350				OPEN		
Day t	0000	OPEN			▨		
	0100	▨			▨		
	0200	▨			▨		
	0300	▨			▨		
	0400	▨			▨		
	0500	▨			▨		
	0600	CLOSE			▨		
	0610				CLOSE		
	0700						
	0800		OPEN				
	0835		▨			OPEN	
	0900		▨			▨	
	1000		▨			▨	
	1100		▨			▨	
	1200		▨			▨	
	1230		▨			▨	OPEN
	1300		▨			▨	▨
	1330		▨	OPEN		▨	▨
	1400		▨	▨		▨	▨
	1500		▨	▨		▨	▨
	1600		▨	▨		▨	▨
	1610		▨	▨		CLOSE	▨
	1630		CLOSE	▨			▨
	1700			▨			▨
	1800			▨			▨
	1900			▨			▨
	1915			▨			CLOSE
	2000			CLOSE			
	2100						
	2200						
	2300						
	0000						

4.5 Empirical Evidence of Mispricing Errors

4.5.1 Percentage shares of mispricing errors by type

Empirical evidence shows that futures pricing errors usually have a wave-like form of fluctuation. Figure 2 displays the mispricing series of Australia, the UK and the USA during the period of 1986-1998. Extreme outliers are observed during the October 1987 crash periods in all series.

In comparison, Table 1 reveals the percentage shares of mispricing occurrences according to its type (negative, positive, zero) of the three markets. On an annual basis, the futures mispricing in Australia has been predominantly negative until the mid-1990s. Meanwhile, the UK has had more experience of positive mispricing but more negative mispricing has set in since 1997. The US futures mispricing has, except for 1994, been positive throughout 1990-1998.

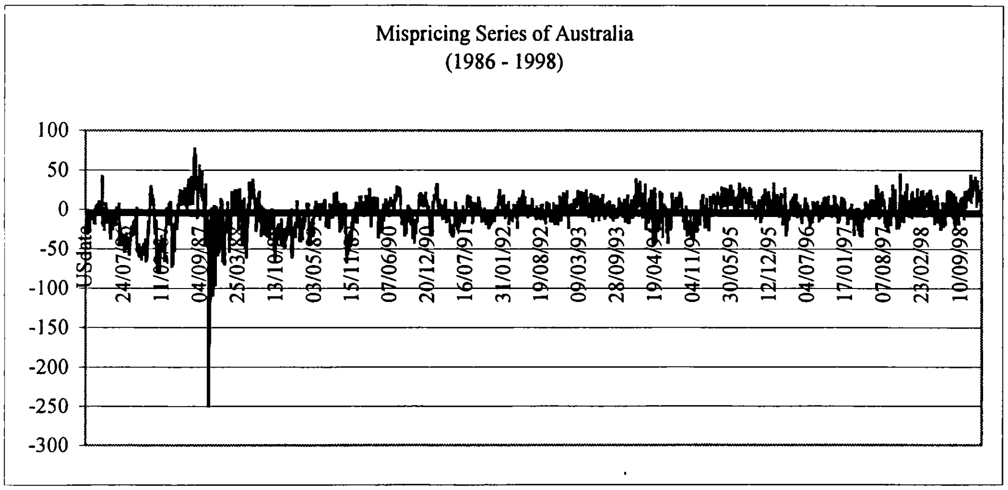
Table 1
Percentage Shares of Mispricing Errors by Type

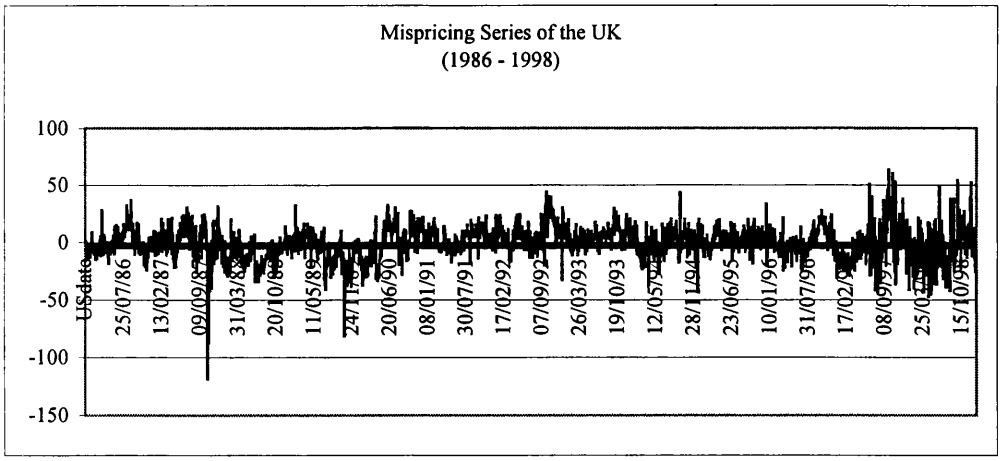
Year	N	Australia			UK			USA		
		neg	**pos**	**zero**	**neg**	**pos**	**zero**	**neg**	**pos**	**zero**
1986	246	82.1	17.9	0	53.7	46.3	0	48.8	51.2	0
1987	244	57.8	42.2	0	42.6	57.4	0	40.2	59.8	0
1988	249	73.5	26.5	0	80.7	19.3	0	45.5	54.6	0
1989	250	70.4	29.2	0.4	66.4	33.6	0	25.2	74.8	0
1990	248	43.2	56.5	0.4	45.6	54.4	0	31.9	68.1	0
1991	249	65.1	34.9	0	37.4	62.7	0	22.9	77.1	0
1992	249	52.6	47.4	0	28.1	71.9	0	41.0	59.0	0
1993	247	39.7	59.5	0.8	19.4	80.9	0	23.1	76.9	0
1994	247	55.1	44.9	0	49.0	51.0	0	54.7	45.3	0
1995	248	14.5	84.7	0.8	38.3	61.7	0	37.9	62.1	0
1996	251	46.6	53.0	0.4	48.6	51.4	0	36.2	63.7	0
1997	250	51.2	48.4	0.4	57.6	42.4	0	26.0	74.0	0
1998	247	26.3	73.7	0	61.1	38.9	0	23.1	76.9	0
All	3225	52.2	47.6	0.2	48.3	51.7	0	35.1	64.9	0

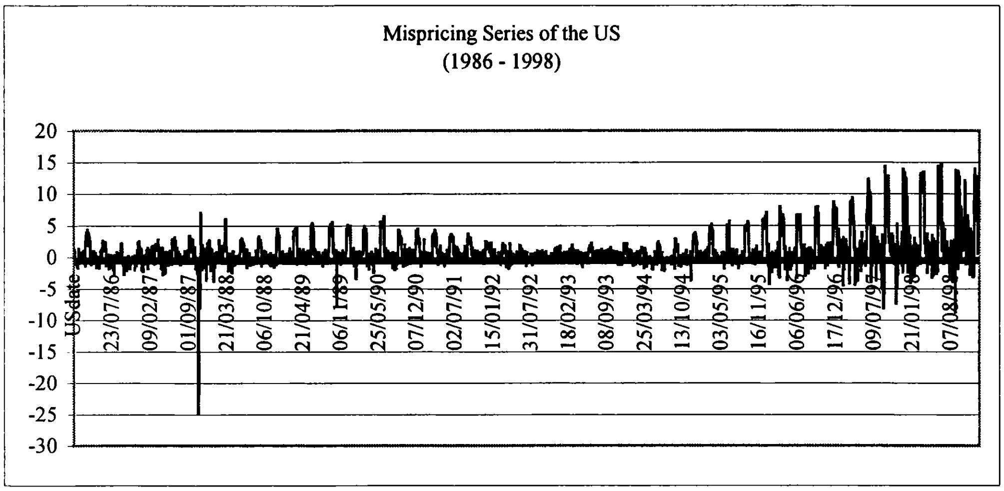
Table 2
Descriptive Statistics of Mispricing Series

	Mispricing Series during 1986-1998		
	Australia	UK	USA
Mean	-3.79	-0.28	0.96
	(-10.64)	*(-1.15)*	*(21.15)*
Median	-0.61	0.46	0.37
Minimum	-249.61	-118.53	-24.78
Maximum	76.86	63.20	14.77
Std. Dev	20.22	13.85	2.57
Skewness	-1.66	-0.44	1.59
Kurtosis	10.87	3.39	11.80

Figure 2: Daily Patterns of Mispricing Series







4.5.2 Distribution of Mispricing Errors

According to Table 2, the UK mispricing series is normally distributed around a zero mean whereas the Australian mispricing series is leptokurtic (peaked) with a negative skewness (_1.7), which indicates a long left-tailed distribution, and fluctuates around a negative mean of -3.8.This is confirmed by the mean test, which has statistically rejected the null hypothesis of zero mean for the Australian mispricing series but accepted the zero mean hypothesis for the UK series. The t-statistic value (in parenthesis) is -10.64 and -1.15 for Australia and UK, respectively. Furthermore, the standard deviation of the Australian msipricing series appears to be much higher than the UK (20.2 and 13.9). The US mispricing series distribution is also leptokurtic (peaked) with the kurtosis value of 11.8 but, unlike Australia, it has positive skewness of 1.6 which indicates a long right tail as displayed in Figure 3-5. The statistics in Table 2 are taken from unadjusted levels of mispricing series.

Figure 3: Distribution of Australian Mispricing Errors

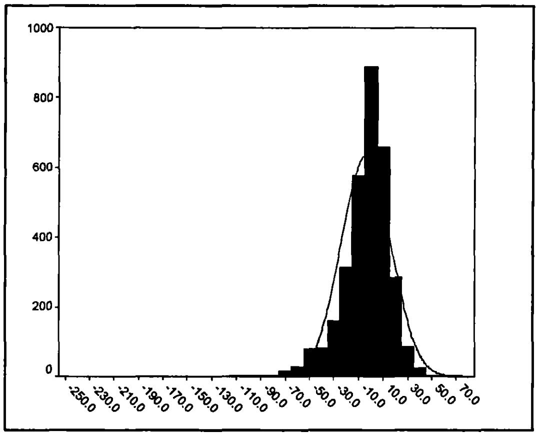


Figure 4: Distribution of UK Mispricing Errors

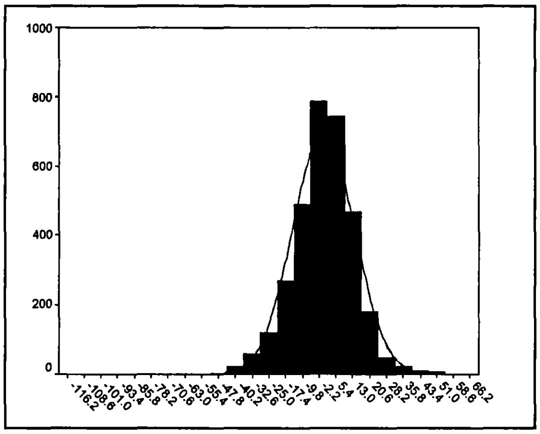
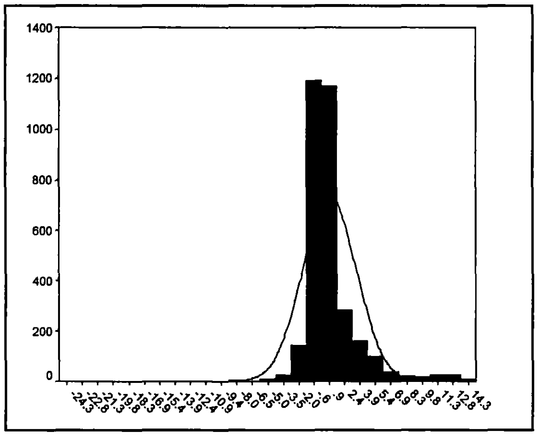


Figure 5: Distribution of US Mispricing Errors



4.5.3 Descriptive Statistics of Mispricing Series

Table 3 reports descriptive statistics on the mispricing series. This table includes information on a scaled series where the mispricing is scaled by the spot series to account for differences in index values across the markets. The mispricing series for Australia and the UK are negative on average, whereas the USA exhibits positive average mispricing. The medians of the UK and US series are positive, whereas the Australian mispricing median is negative. Australia has the largest level of mispricing, a result which remains after the series are scaled. However, all series are small with the mean scaled mispricing less than 0.5% in all three markets, consistent with the presence of competitive and efficient markets. The larger absolute mispricing in Australia probably reflects greater arbitrage bounds in this market. That is, the smaller levels of mispricing in the UK and US markets may reflect lower transaction costs and higher liquidity compared with the Australian market. Moreover, the dominance of negative mispricing may be explainable by greater restrictions on short sales in the Australian market.

Table 3
Descriptive Statistics of Mispricing Series Across Markets

	Mean	**Median**	**Std Dev**	**Minimum**	**Maximum**
AUSTRALIA					
Mispricing	-3.66	-0.39	20.34	-249.614	76.855
Scaled Mispricing by S_t	-0.0031	-0.0002	0.01315	-0.16112	0.03728
UK					
Mispricing	-0.405	0.256	13.881	-118.525	63.2
Scaled Mispricing by S_t	-0.0003	0.00008	0.00548	-0.05775	0.02199
USA					
Mispricing	0.964	0.378	2.585	-24.777	14.769
Scaled Mispricing by S_t	0.00165	0.00089	0.00515	-0.11013	0.0281

4.5.4 Unit Root and Cointegration Tests

Before examining the relations between the mispricing series, we conduct Augmented Dickey-Fuller unit root tests on the variables used in calculating the cost-of-carry using:

$$\Delta Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 t + \sum_{j=1}^{p} \gamma_j \Delta Y_{t-j} + \varepsilon_t \qquad \ldots\ldots\ldots\ldots(4)$$

The lag orders in the testing equations are determined by AIC, such that the errors are rendered white noise. The results show evidence of a unit root in all series except the ratio of the futures closing price to the spot price and the mispricing series. These results are consistent across the Australian, UK and US markets.

Table 4 contains the results of cointegration tests on the cost-of-carry variables. The comparison of variables across markets is undertaken bearing in mind time zone differences so that markets are compared at common times (as per Figure 1). The approach used to test for a cointegrating relation follows that of Dickey and Fuller. The test for no cointegration is obtained by testing for a unit root in the residuals of Equation (4), viz:

$$\Delta\varepsilon_t = \alpha_1 \varepsilon_{t-1} + \sum_{j=1}^{p} \gamma_j \Delta\varepsilon_{t-j} + U_t \qquad \ldots\ldots\ldots\ldots(5)$$

The data are drawn from index futures on the Australian SPI contract, UK FTSE100 contract and the US S&P 500 contract. The sample covers from January 1986 to December 1998. The number of observations is 2,996. The null hypothesis of the ADF test is $H_0 : I(1)$ or unit root with null hypothesis that $\alpha_1 = 0$. ADF tests are run with time-trend included with lag order determined by AIC.

Table 4
Cointegration Tests Across Markets

	AUS_t/UK_{t-1}	**UK_t/US_{t-1}**	**US_{t-1}/AUS_t**
Futures	-3.77*	-2.78	-3.38*
Spot	-3.54	-3.03	-3.35*
Futures/Spot	-5.70*	-2.76	-5.68*
Mispricing	-5.81*	-3.13*	-5.68*

The futures closing prices are cointegrated across Australia and the UK, and across the USA and Australia but the UK-USA pairing is mildly insignificant. A similar result holds for the spot series and the ratio of futures-to-spot. These results confirm prior studies of closely related market movements. Of note is that the mispricing series are cointegrated across all market pairings. Recall that these series should prima facie be independent.

4.6 VAR Analysis of Mispricing Errors Across Markets

Table 5 reports on the relations between the mispricing series in each market. An OLS regression is run for each market where the scaled mispricing series is regressed against its own lagged series and the lagged series from the two foreign markets. That is, the model assumes that each mispricing series is a function of a first-order autoregressive process and by the most recent available information from the foreign markets. The mispricing series is scaled by the spot series to avoid distortions from differing index values. At this stage of the analysis only one (daily) information lag is used. The regressions are:

$$MP_{AU,t} = \alpha_{AU} + \beta_1^{AU} MP_{AU,t-1} + \gamma_1^{AU} MP_{UK,t-1} + \lambda_1^{AU} MP_{US,t-1} + \varepsilon_{AU,t} \qquad \ldots(6)$$

$$MP_{UK,t} = \alpha_{UK} + \beta_1^{UK} MP_{AU,t} + \gamma_1^{UK} MP_{UK,t-1} + \lambda_1^{UK} MP_{US,t-1} + \varepsilon_{UK,t} \qquad \ldots(7)$$

$$MP_{US,t} = \alpha_{US} + \beta_1^{US} MP_{AU,t} + \gamma_1^{US} MP_{UK,t} + \lambda_1^{US} MP_{US,t-1} + \varepsilon_{US,t} \qquad \ldots(8)$$

The data are drawn from index futures on the Australian SPI contract, UK FTSE100 contract and the US S&P500 contract. The sample covers January 1986 to December 1998. The mispricing series is calculated from the Cost-of-Carry model as in Equation(2) using daily closing values and scaled using spot values. The number of observations is 2,996. Table 5 reports on the following regressions. Standard errors have been adjusted for heteroscedasticity and autocorrelation using the Newey-West procedure. T-statistics are presented in parentheses.

Table 5
Analysis of Mispricing Series and Cross-Market Relations

	$\mathbf{MP}_{AU,t}$	$\mathbf{MP}_{UK,t}$	$\mathbf{MP}_{US,t}$
Constant	-0.00107** (-3.42)	-0.00002 (-0.25)	0.00065** (-4.52)
$MP_{AU,t}$		0.02920** (-2.80)	0.01266* (-1.77)
$MP_{AU,t-1}$	0.80884** (-31.07)		
$MP_{UK,t}$			0.07912 (-1.21)
$MP_{UK,t-1}$	0.0645 (-1.21)	0.70176** (-34.07)	
$MP_{US,t}$			
$MP_{US,t-1}$	0.27746* (-1.84)	0.00404 (-0.12)	0.64413** (-8.99)
Adjusted R^2	0.72	0.524	0.455

**Significant at 5% level.

From Table 5, the model appears to explain the relationship well, with all adjusted R^2 values in excess of 45%, with Australia exhibiting the highest value of 72%. The explanatory power of the model appears to be driven mainly by an own market influence, that is, mispricing appears to be persistent and positively related to its level in the previous period, consistent with prior evidence (e.g. MacKinlay and Ramaswamy 1988). This result is consistent across all markets. Despite the presence of this strong autoregressive relationship, mispricing from the foreign markets also has an impact. The coefficients on the cross-market lagged mispricing series are generally significant. These results suggest that innovations in the mispricing series in one market spillover to the mispricing series in another market. Prima facie, these results are anomalous and inconsistent with the concept of integrated and competitive international capital markets. Of note, the intercepts are consistent with the results in Table 3, with Australia being negative, US positive and UK being small and slightly negative.

To date, only first-order effects have been considered, since it was assumed that only information contained in the period immediately proceeding the period of interest had some effect. Further, Table 5 reports on separate regressions for each market. We now consider a less restrictive model, whereby higher order impacts and cross-correlations are considered within a single estimation. The framework of Equation (3a), (3b) and (3c) is employed, again using scaled mispricing. Consistent with most studies incorporating daily data, five lags are used for the VAR. The specification takes into account time zone differences between the markets such that only information that is known is included. For instance, in the UK regression, the contemporaneous Australian mispricing variable is included as an additional explanatory variable. In the US regression, contemporaneous variables for Australia and the UK are included. The results are presented in Table 6.

The results in Table 6 confirm those in Table 5. First, own-country effects dominate whereby the lagged mispricing series in each market is generally significant. The coefficients on the first lag are large for each of the three markets. Second, lagged foreign mispricing again exerts a significant influence on domestic mispricing, with large positive coefficients on the most recent lag. The only exception is the impact of lagged US mispricing on the UK series. There is some evidence of reversals with the trend of a positive relation to the most recent mispricing and a negative relation to mispricing from prior periods.

In a VAR, reliance on individual coefficients can be misleading given the large number of parameters that are estimated. Hence, an F-test is conducted for the restriction that the mispricing coefficients for each market in each regression are jointly equal to zero. The F-values in Table 6 indicate that the null hypothesis that the coefficients are jointly equal to zero can be rejected for each market in each regression. That is, the mispricing coefficients in each market are jointly significant. This result confirms the influence of cross-market correlations in the mispricing series on each domestic market's mispricing series.

The key result to date is that the analysis consistently indicates that mispricing from foreign markets is related to current mispricing in each market. This evidence is consistent with potential arbitrage profits. We have been careful to use only known information so there is no look-ahead bias. One reason as to why the potential arbitrage profits are not realised is there may be barriers to investment across borders. However, given the developed nature of these markets, it is difficult to believe that such barriers exist for sophisticated investors. An alternative explanation is that while statistical significance is achieved, the potential profits are not economically significant either because transactions costs are sufficiently large to prevent exploitation of the arbitrage window or the frequency of occurrence is rare. To investigate this issue further, a trading strategy is developed below.

Table 6
VAR Analysis of Cross-Market Relations in Mispricing

	$MP_{AU,t}$	$MP_{UK,t}$	$MP_{US,t}$
Constant	-0.001**	0	0.000**
	(-4.02)	(-0.81)	(4.73)
$MP_{AU,t}$		0.074**	0.042**
		(7.59)	(4.06)
$MP_{AU,t-1}$	0.607**	-0.038**	-0.089**
	(32.46)	(-3.28)	(-7.37)
$MP_{AU,t-2}$	0.110**	-0.007	0.039**
	(5.04)	(-0.58)	(3.17)
$MP_{AU,t-3}$	0.050**	0.007	0.012
	(2.26)	(0.59)	(0.97)
$MP_{AU,t-4}$	0.148**	-0.009	-0.008
	(6.72)	(-0.74)	(-0.64)
$MP_{AU,t-5}$	-0.018	-0.021**	0.007
	(-1.01)	(-2.17)	(0.66)
F-test	1411.5	10.78	9.29
	[0.000]	[0.000]	[0.000]
	$MP_{AU,t}$	$MP_{UK,t}$	$MP_{US,t}$
$MP_{UK,t}$			0.156**
			(8.22)
$MP_{UK,t-1}$	0.221**	0.415**	0.014
	(6.32)	(22.13)	(0.68)
$MP_{UK,t-2}$	-0.204**	0.178**	-0.097**
	(-5.42)	(8.85)	(-4.61)
$MP_{UK,t-3}$	-0.041	0.125**	-0.056**
	(-1.08)	(6.19)	(-2.66)
$MP_{UK,t-4}$	-0.023	0.041**	-0.022
	(-0.60)	(2.03)	(-1.04)
$MP_{UK,t-5}$	0.060*	0.096**	0.009
	(1.74)	(5.16)	(0.47)
F-test	10.88	751.53	15.81
	[0.000]	[0.000]	[0.000]
	$MP_{AU,t}$	$MP_{UK,t}$	$MP_{US,t}$
$MP_{US,t}$			
$MP_{US,t-1}$	0.464**	0.025	0.535**
	(13.89)	(1.34)	(28.09)
$MP_{US,t-2}$	-0.171**	-0.048**	0.014
	(-4.41)	(-2.31)	(0.65)
$MP_{US,t-3}$	0.118**	0.111**	0.155**
	(3.04)	(5.4)	(7.23)
$MP_{US,t-4}$	-0.064*	-0.013	0.029
	(-1.65)	(-0.60)	(1.36)
$MP_{US,t-5}$	-0.209**	-0.061**	0.054**
	(-6.17)	(-3.33)	(2.88)
F-test	49.22	8.39	483.48
	[0.000]	[0.000]	[0.000]
Adjusted R^2	0.751	0.593	0.505

* Significant at 10% level, **Significant at 5% level.

4.7 Trading Strategy

In order to exploit the cross-market correlation, a trader should execute a trade when the information from the foreign markets carries predictive ability. In Table 6, the largest coefficients on the foreign mispricing series are observed on the most recent information and in all cases these coefficients were positive. This observation translates into a trader taking the following position. Considering each market in turn, if both the foreign markets exhibit positive (negative) mispricing in the most recent period, then this information drives expectations of positive (negative) mispricing in the domestic market.

Depending on the expected value of the mispricing series from the trading rule, the trader would take the appropriate arbitrage position and hold it until either the mispricing series reverted to zero and or expiry. Under either approach, the gains from the strategy are the dollar value of the mispricing.

In order to investigate the potential returns that such a strategy would deliver, we first count the number of times that the trading strategy would be executed. However, note that the means of the mispricing series are non-zero (as per Table 3) and hence the distributions of the series will not be symmetrical around zero. With this prior knowledge, we can estimate the number of times that the trading strategy would be implemented if the cross-market correlations in the mispricing series are zero. That is, if we assume that the three mispricing series are independent, then the incidence observing two immediately prior positive (negative) observations in the two foreign markets followed by a positive (negative) observation in the market of interest can be expressed as a proportion of the total number of observations. This number is reported in Table 7 in the column labelled as "naïve" and represents a benchmark.

Table 7
Comparison of Trading Strategies Using Conditioned Mispricing Information

Filter	Description	Naïve		Actual
Panel A - Australian Mispricing Conditioned on US and UK				
Filter	Description	Naïve		Actual
0%	# Trades	1427		1693
	Proportion	0.4763		0.5651
	Z-test		9.73**	
0.10%	# Trades	1077		965
	Proportion	0.3596		0.3221
	Z-test		-4.28**	
0.25%	# Trades	613		348
	Proportion	0.2045		0.1162
	Z-test		-11.98**	
0.50%	# Trades	186		86
	Proportion	0.0621		0.0287
	Z-test		-7.58**	
1.00%	# Trades	48		12
	Proportion	0.0163		0.0004
	Z-test		-6.87**	
Panel B - UK Mispricing Conditioned on Australia and UK				
Filter	Description	Naïve		Actual
0%	# Trades	1481		1779
	Proportion	0.4943		0.5938
	Z-test		10.89**	
0.10%	# Trades	1133		1129
	Proportion	0.3785		0.3768
	Z-test		-0.19	
0.25%	# Trades	762		575
	Proportion	0.2543		0.1919
	Z-test		-7.84**	
0.50%	# Trades	337		210
	Proportion	0.1127		0.07
	Z-test		-7.39**	
1.00%	# Trades	6		20
	Proportion	0.002		0.0007
	Z-test		-1.59	
Panel C - USA Mispricing Conditioned on UK and Australia				
Filter	Description	Naïve		Actual
0%	# Trades	1511		1814
	Proportion	0.5043		0.6055
	Z-test		11.08**	
0.10%	# Trades	1218		1351
	Proportion	0.4067		0.4509
	Z-test		4.93**	
0.25%	# Trades	841		843
	Proportion	0.2806		0.2814
	Z-test		0.1	
0.50%	# Trades	394		370
	Proportion	0.1316		0.1235
	Z-test		-1.31	
1.00%	# Trades	36		90
	Proportion	0.0119		0.03
	Z-test		9.14**	

** Significant at 5% level

However, in the presence of cross-market correlations in the mispricing series, the proportion of observations that result in execution of the trading strategy (labelled as 'actual' in Table 7) will differ from the naïve proportion. This difference will be attributable to the extent of cross-market correlations in the series and can be tested using a z-test. Table 7 reports on such a test. Moreover, implementation of the trading strategy in reality would incur transaction costs. To account for these costs, several filters are applied such that the trading strategy is executed only when the mispricing series from the conditioned foreign markets exceed the filter. These filters range from 0.1% to 1.0%. Given the positive correlation documented between the three mispricing series using the most recent information, then increases in the (absolute) magnitude of mispricing in the foreign markets should translate to a proportionate increase in the (absolute) magnitude of mispricing in the domestic market

Table 7 reports on a trading strategy that assumes taking an arbitrage position in each market if the most recent mispricing from the two foreign markets are both positive (negative). Each market is analysed separately using conditional information from the two foreign markets. The naïve strategy assumes independence between the mispricing series across markets but uses the sample means and standard deviations to estimate the number and proportion of trades, whereas the actual strategy uses the observed correlations between the mispricing series. The mispricing series is calculated from the cost-of-carry model as in Equation (2) using daily closing values and scaled using spot values. The z-test is a test of the null hypothesis that there is no difference between the actual and naïve proportions, calculated as $Z = \frac{p' - p}{\sqrt{\frac{pq}{n}}}$.

The results in Table 7 are revealing. First, for every market, the trading strategy is significant when there is no filter. Prima facie, this indicates a large number of potential arbitrage opportunities. Second, as the filter increases in size, the difference between the actual and naïve proportions diminishes, and in most cases reverses such that the proportion of actual trades is less than that expected under the assumption of independence between the mispricing series. These cases are highlighted by a negative value on the z-statistics in the table. Hence, there are few, if any, arbitrage opportunities once a filter is imposed. The implication of these findings is that while there appears to be many potential arbitrage opportunities, they are probably insufficiently large to cover transaction costs. At the extreme end, there appears to be a few potentially large arbitrage profit opportunities (given the filter) but these are very infrequent.

As a final investigation, the magnitude of the potential dollar profits from the trading strategy is examined. Table 8 reports the average dollar profit in index points from the trading strategy. To illustrate, if we expect the mispricing series on a particular market at day t to be positive (negative) and it indeed is positive (negative) on day t then the value of the mispricing is a gain. Conversely, if we expect the mispricing series in a particular market at day t to be positive (negative) and it is negative (positive) on day t then the value of the mispricing is a loss. The figures in Table 8 are the average of the gains and losses per trade (and only from days when a trade occurs). The dollar value of the profit is then the number of contracts by the dollar value per index point (which differs across contracts) multiplied by the average mispricing figure in Table 8.

Table 8 reports on a trading strategy that assumes taking an arbitrage position in each market if the most recent mispricing from the two foreign markets are both positive (negative). Each market is analysed separately using conditional information from the two foreign markets. The table reports on the average gain per trade in index points. The number of times the trading strategy is executed is presented in parentheses. The data are drawn from index futures on the Australian SPI contract, UK FTSE100 contract and the US S&P500 contract. The sample covers January 1986 to December 1998. The mispricing series is calculated from the cost-of-carry model as in Equation (2) using daily closing values and scaled using spot values.

Table 8

Returns from Trading Strategies Using Conditioned Mispricing Information

Filter	Australia	UK	USA
0%	4.96 (1693)	2.87 (1779)	0.29 (1814)
0.10%	6.39 (965)	3.68 (1129)	0.37 (1351)
0.25%	10.04 (388)	4.95 (566)	0.35 (843)
0.50%	17.30 (86)	5.84 (210)	0.42 (370)
1.00%	70.6 (12)	22.79 (20)	0.96 (90)

First, note that in every market and in every case, the gain is positive implying that the trading strategy appears to work. Focusing on the no filter case, we observe a relatively large number of instances where the trading rule is invoked (as per Table 8) of somewhere between 1,500 and 2,000 or about half of the trading days in the sample. Ignoring transactions costs, the average profit in index points per day ranges from almost 5 in Australia to 0.29 in the USA. The profit calculation is based on the corresponding currency of each market. To put this in perspective, this translates to a dollar value per contract of $A 62 in Australia and $US 72 in the USA. We believe these gains are modest and probably not sufficiently large enough to exceed transactions and execution costs. Moreover, on a year-by-year analysis, there is considerable variability in the gains. Hence, an investor would have to have exercised a great deal of patience over a long horizon to have realised these potential profits.

Worthy of note, the average gains are negatively associated with the dollar value per index point. As the filter increases, so the number of days on which the trading rule is invoked decreases. However, there is a simultaneous rise in the average gain. There is a monotonic rise in the dollar gain per contract as the filter is increased. Using a 1% filter, there appears to be potentially large gains to be realised. Again, to put these in perspective, the gains translate to a dollar value per contract of $880 in Australia and $240 in the USA. But recall that the reported numbers are averages and are not realised on every occasion Moreover, there are very few instances when the trading rule is invoked. In the case of Australia, the trading rule is exercised using the 1% filter just 12 times in 13 years. The occasions when the trading rules are executed tend to be clustered, especially for the higher filters. For example, again using the case of Australia with a 1% filter, out of the 12 times the trading rule is executed, 7 of these dates are clustered in October 1987 and 4 of these dates are clustered in June 1990. Again, our summary is that while positive returns appear to be present, a very long investment horizon would have been required to realise them.

4.8 Conclusion

There is considerable evidence that information from one market spills over into other markets, especially in relation to developed markets. However, this evidence is generally limited to spot markets. We extend the literature by investigating spillovers in derivative instruments across international markets. Moreover, we focus on whether there is information in a mispricing series from a domestic index futures contract that is relevant to a mispricing series in another market. In theory, even if the underlying markets are correlated, there is no a priori reason as to why mispricing series should also be related. To investigate this question, three well-known index futures contracts are examined in the Australian, UK and USA markets.

The study first constructs a mispricing series for each market using daily data. Then, after allowing for time-zone differences, the study examines correlation across the three mispricing series. The findings first reveal that each mispricing series has strong autocorrelation properties, consistent with prior literature. Second, using a VAR framework, evidence is found of bi-directional spillovers between the three mispricing series. These results suggest that a mispricing series in one market is predictable. In order to examine whether the statistical significant results translate into economically significant profits, a trading rule is tested that uses conditional information from markets over the previous day. We find that the trading rule generates a large number of small profitable trades, however these profits quickly disappear when a filter is applied that proxies for transactions costs. In summary, the results show that some profits are possible but that a long horizon, probably beyond the scope of most traders, is required to exploit the spillover information.

Chapter 5

Market Efficiency of UK Financial Futures Contracts

5.1 Introduction

Market efficiency has been a subject of extensive research over the past three decades. Most researchers focus their studies on the efficiency of security markets. Although the role of the underlying derivatives markets, both futures and options, has substantially increased in the financial world, the issue of their market efficiency has received very little interest and empirical work is sparse. This study aims to contribute more empirical evidence on the question of market efficiency of financial derivatives instruments by examining three UK futures markets.

A market is a mechanism for the public to purchase and sell goods. The fundamental role of every market is price formation. It provides some means of collecting and disseminating information and generally represents a consensus of traders' opinion. Financial markets, in particular, comprise of a large number of traders with different levels and capability of investment analysis resulting in different perceptions, a different time horizon for trading execution, different motive and reaction to unexpected news, etc. As a result, the market transaction is driven by the difference in opinion of traders on the news arrival and their investment decisions are made under various constraints as mentioned above. The aggregate expectation of all trading participants is reflected via the equilibrium price mechanism.

Most empirical studies are generally based on the notion of informational market efficiency. This concept has developed from the early theoretical literature of Bachelier (1900), a pioneer of the random walk model for security and commodity prices. He assumes that successive price differences are independent and normally distributed, with a distribution of zero mean and variance proportional to the interval between these periods. The random walk behaviour of futures prices was initially suggested by Working (1934), who later developed a theory of anticipatory prices as in Working (1958). The empirical study of Samuelson (1965) is acknowledged as the first crucial application of the random walk hypothesis to financial markets. His finding supports the proposition that anticipated security prices fluctuate randomly. Later, Fama (1965) summarized the idea of informational market efficiency, which has subsequently led to numerous articles on financial market efficiency. He concludes that a market is efficient if the market determined price of a security is the reflection of its inherent value, with respect to all available information in the market, and no one can make continuous superior returns exceeding that of the risk-adjusted market equilibrium. An underlying assumption is that the market is largely participated by well-informed and rational investors. To test whether traders can use various sets of information to make continuous excessive profits, he distinctively defined three forms of market efficiency, called the Efficient Market Hypothesis.

Based on the information set, the Efficient Market Hypotheses (EMH) are classified into three categories: (1) weak-form EMH, (2) semi-strong form EMH and (3) strong-form EMH. For weak-form efficiency, the information set includes only the history of prices or returns. For semi-strong efficiency, the information set includes all publicly available information, i.e. macroeconomic announcements of inflation rate, unemployment, trade deficits or firm-specific announcements like dividend earnings, mergers, acquisitions etc. For strong-form efficiency, the information set includes all information, including private or insider information. The market is considered inefficient if the information set can be used to consistently outperform the market. A market is said to be weakly inefficient if traders can use historical data of past prices (or returns) to forecast the future prices and continuously generate a superior profit. The semi-strong inefficient market is identified when traders can use public information to consistently make excessive profits. A market has a strong-form efficiency when having knowledge of insider information does not allow traders to consistently obtain on excess return. The weak-form tests investigate whether market prices reflect all available information, and the most efficient market should have a completely random and unpredictable price process. The semi-strong tests are based on so-called event studies where the degree of market reaction to news announcements is analysed. The strong-form tests examine whether traders having insider (or private) information can continuously make superior profits.

During the past two decades, the theory of market efficiency has been vigorously refined and tested. Grossman and Stiglitz (1980) have addressed several important analytical issues of this theory, particularly the relevant cost of arbitrage which violates the underlying assumption of the efficient market hypothesis. By using a simple model with a constant absolute risk-aversion utility function, their results show that costless information is a sufficient and necessary condition for efficient markets to have prices fully reflecting all available information, and not just a sufficient condition as previously accepted by many theorists.

A large number of empirical studies concentrate their investigations on the weak-form efficiency of financial markets. Based on the assumption of a frictionless market and costless trading, traders can quickly incorporate the newly available information into their investment decision. The aggregate expectations of traders are reflected via the security prices due to the equilibrium price mechanism. The opportunity of making continuous excessive profits would therefore be unsustainable because of an instantaneous price adjustment. The more efficient the market is, the more random the sequence of price changes generated by such a market would be and the most efficient market will have completely random and unpredictable price changes.

As a result, the Random Walk Hypothesis and Efficient Market Hypothesis have become closely related. The confirmation of a random walk is considered to be a sufficient condition of the market efficiency. Nevertheless, the rejection of a random walk does not necessarily imply market inefficiency.

ap Gwilym and Sutcliffe (1999) summarize that the weak-form efficiency is closely associated with the degree of dependence over time in futures returns. Semi-strong form of efficiency is usually based on event studies looking at market reaction to the public release of information. Strong-form efficiency requires that all private information be reflected in prices, which is unlikely to be the case in reality. The time series of price returns can be used in testing these hypotheses. A market is efficient with respect to past prices, or a weak-form EMH, if it is impossible to make profits by trading on the basis of knowing past prices. If returns follow a random walk or martingale time-series process, they are independent over time and the autocorrelation of returns is zero. If the autocorrelation is non-zero, the market may have weak-form inefficiency and past returns can be used to forecast subsequent returns using a linear model.

Several researchers have tested these EMH hypotheses by using different data sets. The results obtained varied greatly. This is due partly to a variation in methodology used in testing, the length of observation period and data frequency.

When new information involving the securities under interest becomes publicly available, prices will be adjusted to reflect the new market demand and supply equilibrium.

Although there could well be a brief period of under-valued securities before the full price adjustment takes place, which traders can exploit to generate excessive profits. If this cannot be persistently achieved after the new price formation, the market is considered to be efficient.

Previous studies largely focus their empirical investigations on the market efficiency of stock indices, particularly of the US S&P500. As mentioned earlier, empirical research on financial futures market efficiency is sparse. This study aims to contribute to the empirical evidence on the efficiency of derivatives markets by examining three UK futures markets, FTSE100 futures (stock index futures), Long Gilt (bond futures) and Short Sterling (interest rate futures). For robustness, the testing process employs three different methods, the Augmented Dickey-Fuller (ADF) unit-root test, the KPSS test and the Lo-MacKinlay Variance Ratio test. The ADF unit root test is documented to have a shortcoming in failing to distinguish between a unit root and a weakly stationary series. To counter for this, the KPSS test is additionally undertaken to test for the stationarity of a price series. In contrast to the ADF test, the KPSS has stationarity as its null hypothesis and nonstationarity as the alternative. The combined results from both ADF and KPSS test, which is the acceptance of the ADF unit root null hypothesis and the rejection of stationarity from the KPSS test, will provide firmer evidence of the nonstaionarity of the price series under investigation. As the unit root tests also fail to detect some important departures from the random walk, we employ the Variance-Ratio test, which is considered a better alternative, to test for a random walk process. In addition to this, the study also examines whether the introduction of an electronic trading system has induced any changes in the market efficiency of the three futures contracts under investigation.

The study is outlined as follows. Section 5.2 reviews some previous empirical work on the market efficiency of financial markets. The methodologies used for the testing procedures are explained in Section 5.3, which is then followed by the report of empirical results in Section 5.4. Section 5.5 presents the conclusion. All software programmes written to implement the testing methods are detailed in Appendix 3-4.

5.2 Literature Review

A great deal of research has examined the efficiency of different financial markets. By using various methodologies, several prior studies have reported the findings of efficiency in the markets under their investigation. Most previous investigations are based on the notion of informational market efficiency, which states that the market is considered efficient if traders could not use any information to outperform the market and continuously generate profits. The most well-known and popularly used concept of market efficiency is based on the Efficient Market Hypothesis (EHM).

The Efficient Market Hypothesis (EMH) implies that when new information involving the securities under interest becomes publicly available, prices will adjust to reflect the new market demand and supply equilibrium. Although there could well be a brief period of under-valued securities before the full price adjustment takes place, which traders can exploit to make excessive profits. This cannot, however, be persistently achieved after the new price formation, which leads to the EMH concept.

While there have been studies showing that strong trading performers continue to outperform over certain periods, several recent studies have demonstrated that investors should not expect recent strong trading performers to outperform in the future. A substantial number of studies on mutual fund performance have found little or no correlation between strong performers (who consistently make a profit) from one period to the next. The lack of consistent performance persistence among active investment managers is further evidence in support of the EMH.

Empirical studies on mutual fund traders' performance display mixed results. However, it is found that, on average, there is little evidence supporting strong performer persistence. This conclusion, therefore, indicates the market efficiency in mutual fund trading.

Hendricks, Patel and Zeckhauser (1993), Goetzmann and Ibbotson (1994), Brown and Goetzmann (1995), Wermers (1997) and Carhart (1997) find evidence of short-term persistence in mutual funds. Grinblatt and Titman (1992), Elton, Gruber and Blake (1996) and Volkman and Wohar (1995) observe persistence over longer periods. On the other hand, Shukla and Trzcinka (1994), Khan and Rudd (1995), Malkiel (1995) and Carhart (1997) find that performance is generally not persistent among mutual fund traders

As quoted in Pugh (2002), Fisher Black had stated that the market was probably 90-95% efficient. Pugh suggested that knowledge of anomalies could be used to outperform the market and 5-10% inefficiency occurs in trading using public information i.e. inflation rate, unemployment figures, firm dividend earnings etc.

In reality, financial markets are neither perfectly efficient nor completely inefficient, i.e. Cutler, Poterba and Summers (1990a,b) and Shleifer (2000). All markets are efficient to a certain extent, some more so than the others. More knowledgeable investors can outperform less knowledgeable ones. Different characteristics of financial instruments and types of traders can largely affect the degree of the market efficiency. For example, government bond markets and foreign exchange markets where most trading is conducted by professional traders are considered to be extremely efficient. In contrast, small capitalization stocks are considered to be less efficient than markets in large ones.

Most empirical studies focus their investigations on using the random walk process of the security prices or returns as an indicator of market efficiency. Earlier studies of the US stock markets, i.e. Working (1934, 1960), Samuelson (1965), Fama (1965), all report that security prices fluctuate randomly. Fama (1965) found that successive runs of stock price changes validated the Random Walk Hypothesis (RWH). His result shows that (1) neither trends nor charts can be used to create abnormal profits, (2) The market is efficient with respect to all publicly available information such as financial reports, financial press news, historical economic information and more and (3) all information, including insider information, is already reflected in any security price that the public sees. Several other studies have examined the market efficiency via the measure of the security prices autocorrelation and considered significant non-zero autocorrelation as the indicator of market weak-form inefficiency. ap Gwilym and Sutcliffe(1999) summarise the findings of 36 empirical studies, using high frequency data, on the dependence in returns of stock index futures, interest rate futures, spot equities and spot foreign exchange rates. Most studies, except Anderson and Bollerslev (1977), found a negative first-order autocorrelation on the S&P500 futures returns, i.e. Goldenberg (1988 & 1989), Cheung and Ng (1990), Fung et al (1994). Similarly, other investigations (i.e. Neftci and Policano (1990), Lee and Mathur (1999), Piccinato et al (1998)) also report the finding of negative first-order autocorrelation in interest rate futures returns. The negative autocorrelation is also found in the studies on spot equity returns (i.e. Hasbrouck and Ho (1987), Stoll (1989), Madhavan et al (1997), Lin et al (1999)) and foreign exchange returns (i.e. Goodhart and Figliuoli (1991), Goodhart and Guigale (1993), Goodhart et al (1996), Low and Muthuswamy (1996)).

As for the UK, ap Gwilym, Brooks, Clare and Thomas (1999) have found a non-linear dependence (e.g. Arch effects) in price returns of the FTSE100 futures, Long Gilt and Short Sterling contracts. Lee and Mathur (1999) carried out the efficiency tests in six Spanish futures markets: Spanish stock index futures (IBEX 35), interest rate futures MIBOR (90 day), MIBOR (360 day), national bond (10 year), national bond (3 year) and foreign exchange rate (Deutsche Mark:Spanish Peseta). For robustness of the testing procedures, they undertook three testing methods on the Spanish futures price returns, including the ADF unit-root test, the KPSS test and the Variance-Ratio test. Their results show a strong evidence of the weak-form market efficiency of the six Spanish futures markets under investigation.

In fact, a large number of more recent empirical studies find that security prices do not follow a random walk process. By using the Lo-MacKinlay Variance Ratio test, Ayadi and Pyun (1994) find that South Korean equity market does not follow random walk when tested under homoscedasticity assumption but follows the random walk process when using heteroscedasticity-adjusted test statistics. Madhusoodanan (1998) reports that the Indian BSE sensitive and BSE national indexes do not follow a random walk. Based on weekly stock returns, Grieb and Reyes (1999) find non-random walk behaviour in the Mexican market but a random walk in the Brazilian market.

More recently, Chang and Ting (2000) use the Lo and MacKinlay variance-ratio test to examine the randomness of Taiwanese stock prices during 1971-1996. Their results show that with weekly value-weighted market index, the null hypothesis of a random walk is rejected, and the autocorrelation decreases after the 1990 speculation fad and is inversely related to the range of price limits. The study also finds that the random walk hypothesis cannot be rejected with monthly, quarterly and annually value-weighted market indexes.

Huber (1997) uses the multiple variance ratio test developed by Chow and Denning (1993) to test for a random walk of daily stock returns on the Vienna stock exchange during 1990-1992. The test result rejects the random walk hypothesis at all conventional significance levels for each and every title and for both indices tested and suggests that, as the market becomes institutionally more mature and more liquid, returns approach a random walk. Individual shares seem to follow a random walk when weekly returns are considered, while the hypothesis is rejected for both indices.

Poshakwale (2002) examines the random walk hypothesis in the emerging Indian stock market using daily data on individual stocks. The result rejects the random walk hypothesis as the daily returns of individual stocks and an equally weighted portfolio show significant non-linear dependence and persistent volatility effects. The non-linear dependence takes the form of ARCH-type conditional heteroskedasticity and does not appear to be caused by nonstationarity of underlying economic variables. Though conditional volatility is time varying, it does not explain expected returns.

Li and Zu (2002) examine the Efficient Market Hypothesis using four New Zealand Stock Exchange indices (NZSE 10, NZSE 30, NZSE 40, and NZSE SC) within the random walk, cointegration and Granger causality test framework. The test results show that the small-firm stock market is semi-strong form efficient to a certain degree. However, results concerning large firms are sensitive to the choice of index. The share market of the top ten companies is not even weak-form efficient, while the share markets covering the top 30 and 40 large companies are weak-form efficient but not semi-strong form efficient.

Ryoo and Smith (2002) test the random walk hypothesis for the Korean stock market during 1988-1998. During this time there are five regimes of daily price limits. The test sample covers 55 actively traded stocks with a marked number of limit moves. The study finds that the price limit system prevents security prices from following a random walk process, resulting in the market being inefficient. As the daily price limits are increased, the proportion of stock prices following a random walk increases. That is, the stock market as a whole approaches a random walk as price limits are relaxed.

Smith, Jefferis and Ryoo (2002) test the random walk hypothesis for South Africa, five medium-sized markets (Egypt, Kenya, Morocco, Nigeria and Zimbabwe) and two small new markets (Botswana and Mauritius) using the multiple variance ratio test of Chow and Denning (1993). The hypothesis is rejected in seven of the markets because of autocorrelation in returns. Their study reports that the stock price of South African market index follows a random walk.

Magnusson and Wydick (2002) examine whether the eight largest African stock markets are weak-form efficient, as characterised by a random walk process of stock returns. Their result indicates the existence of weak-form efficiency in these markets as compared with the emerging stock markets in South-east Asia and Latin America.

Majnoni and Massa (2001) examines whether automation and other reforms introduced by the Italian Stock Exchange from 1991 to 1994, i.e. an introduction of specialised intermediaries, an obligation to trade on the official markets, screen-based trading and cash settlement, has increased the market efficiency. They employ both the traditional information efficiency model, which tests market efficiency by verifying the predictability of prices model, conditional on some information subset, and a microstructure approach that measures efficiency as the distance of the price movements from their efficient components, represented by a random walk process. The joint analysis of daily and intraday data on prices and volumes validates the hypothesis that most of the reforms have increased market efficiency over the sample period, except for cash settlement, which appears to have substantially reduced it.

Freund and Pagano (2002) measure the degree of market efficiency before and after automation at the New York and Toronto Stock Exchanges. Overall, the results show that the level of informational efficiency remains effectively unchanged during the automation period. Despite several deviations from a random walk process, the returns for stocks on these exchanges do not appear to exhibit consistent patterns that investors can exploit to generate abnormal returns. Automation coincides with an improvement in market efficiency at the Toronto Stock Exchange when compared to the New York Stock Exchange.

Previous studies have employed various methods to investigate the efficiency of financial markets. For robustness, the empirical analysis in this study has employed three testing methods of the Augmented Dickey-Fuller (ADF) Unit Root test, KPSS test and Lo-MacKinlay Variance Ratio test to examine the randomness of the financial futures price series under investigation, which can be used as an indicator of weak-form informational market efficiency.

5.3 Data and Methodology

Details of Data

The data used in this study are daily (closing) prices of the three UK financial futures contracts; FTSE100 Futures (stock index futures), Long Gilt (bond futures) and Short Sterling (interest rate futures). It covers a 13-year period during 1 January 1990 and 19 September 2002. Contract specifications are described in Section 2.3.2.

The study first examines the descriptive statistics (i.e. mean, standard deviation, skewness, kurtosis) of the time series, of both price levels and price returns. Next, testing of market efficiency is undertaken by employing three different methods: (1) Augmented Dickey-Fuller (ADF) unit root test, (2) KPSS test and (3) Variance Ratio test of Lo and MacKinlay (1988).

The ADF method is very popular for testing the unit root (nonstationarity) of a time series. However, its null hypothesis, and the way it is tested, dictates that the null hypothesis be accepted unless there is a strong evidence against it. The main problem is that most time series are not very informative about whether or not there is a unit root. In other words, the standard ADF tests are not very powerful against relevant alternatives. To overcome this lack of power of rejecting the null hypothesis of a unit root, we need to test for stationarity in addition to the test of the null hypothesis of a unit root (nonstationrity). This is achieved here by using the KPSS test, devised by Kwiatkowski et al (1992). The KPSS test is specifically designed to perform a test that has stationarity as the null hypothesis and a unit root (non-stationarity) as the alternative hypothesis. The detection of a unit root in a price return series has been used as a basis for supporting the random walk hypothesis, hence the efficiency of the underlying market.

Although the unit root is one of the implications of the random walk process, some previous studies (i.e. Liu and He (1991)), had found that unit root tests cannot detect certain important departures from random walk. To compensate for this problem, the Variance-Ratio test developed by Lo and MacKinlay (1988) could be used to test the random walk hypothesis. Their study compared variance estimators derived from data at various levels of frequencies for weekly stock market returns in the New York Exchange and American Stock Exchange during a 32-year period. They improved the variance ratio statistic by taking an overlapping period and corrected the variances used in estimating the statistic for bias. They also proposed a test statistic Z*, which is robust under the heteroscedastic random walk hypothesis, and therefore can be used for a longer time series analysis. An extensive Monte Carlo simulation was conducted by Lo and MacKinlay (1989) to find out the size and power of these tests in finite samples. They identified that the variance of random walk increments was linear in all sampling intervals. They claimed that this test is more powerful than either the Box-Pierce or ADF tests against several alternative hypotheses, including AR (1), ARIMA (1,1,1,) and ARIMA (1,1,0).

Methodology

5.3.1 Augmented Dickey-Fuller (ADF) Unit-Root Test

The Augmented Dickey-Fuller (ADF) test has been popularly used for testing the nonstationarity of the time-series data. It was modified from the Dickey-Fuller (DF) test (1979), to make a parametric correction for higher-order correlation by assuming that the time-series under investigation follows an autoregressive (AR) process.

Initially, the Dickey-Fuller (DF) test considers an AR (1) process as follows:

$$Y_t = \mu + \rho Y_{t-1} + \varepsilon_t$$

where μ and ρ are parameters and ε_t is assumed to be white noise. Moreover, Y_t is a stationary series if $-1 < \rho < 1$. If $\rho = 1$, the Y_t is a nonstationary series (a random walk with drift). If the process is started at some point, the variance of Y_t increases steadily with time and goes to infinity. If the absolute value of ρ is greater than one, the series is explosive. Therefore, the hypothesis of a stationary series can be evaluated by testing whether the absolute value of ρ is strictly less than one. The DF test takes the unit root as the null hypothesis H_0: $\rho = 1$. Since the explosive series do not make much economic sense, this null hypothesis is tested against the one-sided alternative H_1: $\rho < 1$.

The DF test is carried out by estimating the following equation:

$$\Delta Y_t = \mu + \gamma Y_{t-1} + \varepsilon_t$$

where $\gamma = \rho - 1$ and the null and alternative hypotheses are

$$H_0: \gamma = 0, \qquad H_1: \gamma < 0.$$

The DF test is invalid if the series does not follow an AR(1) process as the white noise assumption of the disturbance would be violated when the series is correlated at higher order lags. A modified test, called the Augmented Dickey-Fuller (ADF) test, has replaced the original DF test. The ADF test has a control for higher-order correlation by adding lagged difference terms of the dependent variable in the regression equation as follows.

$$\Delta Y_t = \mu + \beta T + \gamma Y_{t-1} + \sum_{i=1}^{L} \alpha_i \Delta Y_{t-i} + \varepsilon_t$$

The null hypothesis (H_0) of a unit root, when $\gamma = 0$, is tested against the alternative hypothesis (H_1), when $\gamma < 0$. The trend time variable T is optional.

In general, the ADF test can be performed with an inclusion of a constant, a constant and linear trend, or neither in the test regression. The choice is important since the distribution of the test statistic under the null hypothesis differs among these three cases. As trend is typically one of the inherent characteristics of time series data, particularly financial prices, a constant and a linear trend are therefore included in the test regression of this analysis.

The null hypothesis of a unit root is rejected (accepted) if the ADF test statistic is less (more) than the critical value at 1%, 5% and 10% level of significance. Here, the critical values used are from MacKinnon (1991), a much larger set of simulation that allows for any sample size and number of independent variables in the test regression.

5.3.2 KPSS Test

Kwiatkowski, Phillips, Schmidt and Shin (1992) proposed another method, called the KPSS test, to examine the stationarity of the time series. They pointed out that the standard unit root tests fail to reject the null hypothesis of a unit root for many economic time series. An influential result is reported by Nelson and Plosser (1982), who document that the unit root tests performed by using three Dickey-Fuller type tests (1976, 1979) have given a false rejection of a unit-root null hypothesis of all, except one, of 14 annual U.S. time series data.

They believe that the way the classical unit-root hypothesis testing is carried out ensures that the null hypothesis is rejected only if there is strong evidence against it. However, as most economic time series are not very informative about the existence (or absence) of a unit root, the standard unit root tests are, as a result, not very powerful against the alternative hypothesis. This observation has also been supported by the empirical research of DeJong et al (1989), who found that DF tests had low power against stable autoregressive alternatives with roots near unity. Later, Diebold and Rdebusch (1990) also reported that DF tests had low power against fractionally integrated alternatives.

In contrast to the ADF unit root (nonstationarity) test, the KPSS method sets the stationarity around a deterministic trend of the series under investigation as the null hypothesis (H_0) and non-stationarity (or unit root) as the alternative hypothesis (H_1). The series is expressed as the sum of a deterministic trend, random walk and stationary error. The test is the LM test of the hypothesis that the random walk has a zero variance.

The test statistic is calculated as:

$$\eta_u = \frac{T^{-2}\sum_{t=1}^{T} S_t^2}{S^2(L)}$$

where L is the lag parameter, S_t is the cumulative sum of the residuals (e_t) from a regression of the series on a constant and a linear trend (t).

$$P_t = \alpha + \beta t + e_t,$$

$$S_t = \sum_{i=1}^{t} e_i , \qquad t = 1,2, \ldots,\mathrm{T};$$

and

$$S^2(L) = T^{-1}\sum_{t=1}^{T} e_t^2 + 2T^{-1}\sum_{s=1}^{L}[(1-\frac{s}{L+1})\sum_{t=s+1}^{T} e_t e_{t-s}].$$

5.3.3 Variance-Ratio Test

According to Lo and MacKinlay (1988), the variance ratio can be used as an alternative test of the random walk hypothesis, based on the fact that the variance of random walk increments in a finite sample increases linearly with the sampling interval. For example, the variance of monthly sample series must be four times as large as the variance of weekly data or the variance of weekly sample series must be five times as large as the variance of daily data. Variance-Ratio tests involve testing whether the ratio of variances of different intervals weighted by their length is one.

Let p_t be the natural logarithm of price series. Under the random walk hypothesis, p_t, follows the following form:

$$p_t = \alpha + p_{t-1} + \varepsilon_t$$

and the variance of its q-differenced series, $(p_t - p_{t-q})$, would be q times the variance of its first-differenced series, $(p_t - p_{t-1})$, Therefore, given nq+1 observations of the price series, p_1,

$p_2, p_3, \ldots p_{nq+1}$, the ratio of 1/q of the variance of the series to the variance of the series should equal one.

The variance ratio of q-differenced series is defined as:

$$VR(q) = \frac{\sum \sigma_c^2(q)}{\sum \sigma_a^2(q)}$$

where q is any integer greater than 1. $\sum \sigma_c^2(q)$ is an unbiased estimator of 1/q of the variance of the q-differenced series and $\sum \sigma_a^2(q)$ is an unbiased estimator of the variance of the first-differenced series.

More specifically,

$$\sum \sigma_c^2(q) = \frac{1}{m} \sum_{t=q+1}^{nq+1} (p_t - p_{t-q} - q\mu)^2$$

where

$$m = q(nq + 1 - q)(1 - \frac{q}{nq}),$$

$$\mu = \frac{1}{nq}(p_{nq+1} - p_1)$$

and

$$\sum \sigma_a^2(q) = \frac{1}{nq-1} \sum_{t=2}^{nq+1} (p_t - p_{t-1} - \mu)^2.$$

The standard Z test statistic is

$$Z(q) = \frac{VR(q) - 1}{\sqrt{\phi(q)}}$$

where

$$\phi(q) = \frac{2(2q-1)(q-1)}{3q(nq)}.$$

To adjust for heteroscedasticity, an inherent characteristic of financial time series, Lo and MacKinlay proposed a modified test statistic, called $Z^*(q)$ to use in the statistical inference instead of $Z(q)$ as shown below:

$$Z^*(q) = \frac{VR(q) - 1}{\sqrt{\phi^*(q)}}$$

where

$$\phi^*(q) = \sum_{j=1}^{q-1} \left[\frac{2(q-j)}{q} \right]^2 \delta(j)$$

and

$$\delta(j) = \frac{\sum_{t=j+2}^{nq+1} p_t - p_{t-1} - \mu)^2 (p_{t-j} - p_{t-j-1} - \mu)^2}{\left[\sum_{t=j+2}^{nq+1} p_t - p_{t-1} - \mu)^2 \right]^2}.$$

Both $Z(q)$ and $Z^*(q)$ are asymptotically normally distributed with zero-mean and a standard deviation of 1.

5.4 Empirical Results

5.4.1 Descriptive Statistics of Price Returns

Table 1 presents the descriptive statistics of the daily price returns of FTSE100 Futures, Long Gilt and Short Sterling contracts during the period of 1990-2002. Price return here is the difference of natural logarithms of two successive daily closing prices. The average return of FTSE100 Futures, Long Gilt and Short Sterling prices is 0.000156, 0.000718 and 0.000361 respectively. The corresponding t-statistic values of the mean test with the null hypothesis of zero mean are 0.77, 0.73 and 0.76, indicating that none of these futures price series has its mean significantly different from zero. For symmetry, the standard normal distribution should have zero skewness. FTSE100 futures returns, with a skewness of -0.10, appears to have its distribution closer to normality as compared to the other two contracts. Meanwhile, the distribution of Long Gilt price returns appears to have a long right tail, in contrast to that of Short Sterling which has a long left tail, indicated by the magnitude of the skewness of -6.53 and 11.4 respectively. For peakedness, the conventional normality statistic requires the kurtosis to be 3. With the kurtosis level of 5.52 for FTSE100, 188.64 for Long Gilt and 355.55 for Short Sterling, these estimates indicate that both Long Gilt and Short Sterling price returns have a very high peak while that of FTSE100 futures is very close to the standard normal distribution. It is evident that FTSE100 futures return distribution is the closest to normality as compared to the other two contracts.

Table 1 : Descriptive Statistics of Futures Price Returns

	FTSE100 Futures	Long Gilt	Short Sterling
Mean (t-statistic) (Prob.)	0.000156 (0.7709) (0.4408)	0.000718 (0.73406) (0.4630)	0.000361 (0.76215) (0.0718)
Median	0	0.000913	0
Maximum	0.063727	0.036529	0.036595
Minimum	-0.069409	-0.153647	-0.014553
Std. Deviation	0.011442	0.005542	0.001161
Skewness	-0.100237	-6.531112	11.42938
Kurtosis	5.524812	188.6353	355.5519

Notes: Price return is the difference of the natural logarithm of daily closing prices. The observation period covers from January 1990 to September 2002. The null hypothesis of zero mean is rejected at 5% significant level if the t-statistic has the probability (Prob.) less than 0.05.

5.4.2 Market Efficiency Test Results

a). Augmented Dickey-Fuller (ADF) Test

First, the ADF unit-root test is used to determine whether the price series under investigation contain a unit root. The results from this test provide evidence of an absence (or existence) of a unit root for the series examined. Table 2 reports the statistical results of the ADF tests on the futures prices of FTSE100 futures, Long Gilt and Short Sterling contracts. The time series data used here are the natural logarithms of daily closing prices. An ADF test is conducted on both the level and the first difference of the data series. The tests are also undertaken at various lag lengths, from 0 to 6. As stated in Section 5.3.1, this method has a unit root as the null hypothesis (H_0), which is tested against the one-sided alternative hypothesis (H_1). The null hypothesis of a unit root is rejected (or accepted) against the one-sided alternative if the t-statistic is less (or greater) than the conventional critical values. Here, the critical values at 1%, 5% and 10% level of significance are -3.9664, -3.4139 and -3.1287 respectively.

In general, the ADF test can be performed with an inclusion of a constant, a constant and linear trend, or neither in the test regression. The choice is important since the distribution of the test statistic under the null hypothesis differs among these three cases. As trend is typically one of the inherent characteristics of time series, particularly of financial prices, a constant and a linear trend are therefore included in the test regression of this analysis.

At levels and the choice of lag 1, the ADF test statistic of FTSE100, Long Gilt and Short Sterling futures price series is -0.882, -2.657 and –2.123 respectively. When examining the price first differences (or price returns), the ADF test statistic become -43.03,

-40.1188 and -44.77 for FTSE100 Futures, Long Gilt and Short Sterling contracts. As the lag length increases, the estimated ADF test statistics both at levels and first-difference become larger. For all lag lengths, 0-6, The ADF test statistics at levels are all greater than the critical values whereas the ADF test statistics at first-difference are all less than the critical values, at 1%, 5% and 10% significant level. As a result, the ADF tests fail to reject the null hypothesis of a unit root (H_0) in levels but rejects H_0 in first differences for all three contracts. This implies that the time series of the futures prices under investigation contains one unit root and is integrated of order one I(1).

The ADF tests are also undertaken with an exclusion of the constant and time trend from the test regression. The tests also yield similar results when including them; that is, the tests significantly fail to reject the null hypothesis of a unit root for all futures contracts. Consequently, the test results are quite robust to the lag length specification and inclusion of the time trend in the regression as the test statistics fail to reject the null hypothesis of unit root for all lag lengths (0 to 6), either with or without the time trend in the test regression. The ADF tests therefore provide supporting evidence of nonstationarity for all futures price series of FTSE100 Futures, Long Gilt and Short Sterling contracts. Therefore, the daily prices of the three UK futures contracts are all significantly nonstationary, signifying a random walk process of the three futures price series under investigation.

Table 2 : Augmented Dickey-Fuller (ADF) Test Results of Futures Prices

	FTSE 100		Long Gilt		Short Sterling	
	W/O trend	With trend	W/O trend	With trend	W/O trend	With trend
(a) Level						
ADF lag						
1	-1.296	-0.882	-1.789	-2.657	-2.362	-2.123
2	-1.281	-0.679	-1.770	-2.644	-2.378	-2.055
3	-1.264	-0.422	-1.761	-2.600	-2.386	-2.111
4	-1.276	-0.465	-1.795	-2.591	-2.427	-2.120
5	-1.258	-0.318	-1.838	-2.615	-2.457	-2.163
6	-1.270	-0.128	-1.807	-2.532	-2.495	-2.153
(b) First-difference						
ADF lag						
1	-43.01	-43.03	-40.1239	-40.1188	-44.75	-44.77
2	-37.21	-37.23	-33.2984	-33.2947	-33.56	-33.50
3	-31.07	-31.10	-28.8483	-28.8459	-29.45	-29.48
4	-28.28	-28.31	-25.5515	-25.5502	-25.67	-25.71
5	-26.63	-26.67	-24.0610	-24.0605	-24.20	-24.24
6	-24.69	-24.73	-23.4010	-23.4011	-22.63	-22.68

	Critical values:	
Significance	W/O Trend	With Trend
1% level	-3.4355	-3.9664
5% level	-2.863	-3.4139
10% level	-2.5675	-3.1287

Notes: The Test statistic is the t-statistic on γ from the ADF regression as follows.

$$\Delta Y_t = \mu + \beta T + \gamma Y_{t-1} + \sum_{i=1}^{L} \alpha_i \Delta Y_{t-i} + \varepsilon_t$$

The null hypothesis (H_0) of a unit root, when $\gamma = 0$, is tested against the alternative hypothesis (H_1), when $\gamma < 0$. The trend variable T is optional. The null hypothesis of unit root (or nonstationarity) is rejected if the test statistic exceeds the critical values. Here, the Davidson and MacKinnon critical values at 1%, 5% and 10% level of significance are shown for both ADF regression with and without a constant and the trend variable.

b). KPSS Test

As stated earlier in Section 5.3.2, the KPSS test has the stationarity of the time series as the null hypothesis (H_0) and a unit root (nonstationarity) as the alternative hypothesis (H_1). In this test, the null hypothesis of stationarity is rejected in favour of the unit root alternative if the calculated test statistic exceeds the critical values estimated in Kwiatkowski et al (1992).

Table 3 reports the KPSS test statistics up to 35 lag lengths for the three futures contracts. The KPSS test statistic value with the choice of lag 1 is 15.35, 18.57 and 22.83 for FTSE100, Long Gilt and Short Sterling contracts, respectively. The KPSS statistics decline monotonically as the lag length L increases up to around 8. For the three futures price series under our investigation, these estimates are excessively larger than the critical values at all significant levels. Even when the choice of lag (L) increases, the magnitude of the decreased KPSS test statistic is still considerably larger than the critical values at all significant levels. At L = 8, the KPSS test statistic value has dropped to 3.46, 4.17 and 5.10 for FTSE100, Long Gilt and Short Sterling contracts, respectively. Based on KPSS critical values simulation, the critical value is 0.216, 0.146 and 0.119 for the 1%, 5% and 10% level of significance.

According to Kwiatkowski et al (1992), they considered the value of the lag truncation parameters L, used in the estimation of the long-term variance $S^2(L)$ from 0 to 8. Their choice of 8 as the maximal value of lag length (L) is based on two considerations. First, the long-run variance estimate settled down reasonably well when reaching L=8 for most data series. Second, based on their simulations, L=8 is the compromise between the large size distortions under the null (for L=4) and the very low power under the alternative (for L=12). They reported that the values of KPSS test statistics were unfortunately sensitive to the choice of L. Specifically, the value of test statistics decreases as L increases.

This occurs because $S^2(L)$ increases as L increases, and is a reflection of large and persistent positive autocorrelations in the data series.

In comparison with the simulated critical values in Kwiatkowski et al (1992) (Table 1, pp. 166), the null hypothesis of stationarity is significantly rejected for all three futures contracts under investigation by the KPSS test at conventional significant levels i.e. 1%, 5%, 10%. This finding has further supported the results from the unit root ADF tests and provides further evidence of the nonstationarity of futures prices of FTSE100 Futures, Long Gilt and Short Sterling contracts.

Table 3 : KPSS Test Results

Lag L	FTSE100	Long Gilt	Short Sterling
1	15.3497	18.5746	22.8301
2	10.2562	12.4053	15.2322
3	7.7079	9.3195	11.4321
4	6.1783	7.4675	9.1518
5	5.1583	6.2327	7.6315
6	4.4296	5.3505	6.5455
7	3.8830	4.6888	5.7310
8	3.4577	4.1741	5.0975
9	3.1175	3.7622	4.5906
10	2.8390	3.4252	4.1759
11	2.6069	3.1443	3.8304
12	2.4105	2.9066	3.5380
13	2.2422	2.7028	3.2874
14	2.0962	2.5262	3.0702
15	1.9685	2.3717	2.8801
16	1.8558	2.2353	2.7124
17	1.7556	2.1142	2.5634
18	1.6659	2.0057	2.4301
19	1.5852	1.9081	2.3101
20	1.5122	1.8199	2.2015
21	1.4458	1.7396	2.1028
22	1.3851	1.6663	2.0127
23	1.3296	1.5992	1.9301
24	1.2784	1.5374	1.8541
25	1.2312	1.4804	1.7840
26	1.1875	1.4276	1.7190
27	1.1469	1.3785	1.6587
28	1.1091	1.3329	1.6026
29	1.0739	1.2903	1.5502
30	1.0409	1.2505	1.5012
31	1.0100	1.2131	1.4552
32	0.9809	1.1780	1.4121
33	0.9536	1.1450	1.3715
34	0.9278	1.1139	1.3332
35	0.9035	1.0846	1.2970

Notes: The KPSS test statistic is calculated as: $\eta_u = T^{-2}\sum_{t=1}^{T} S_t^2 / S^2(L)$ where L is the lag parameter, S_t is the cumulative sum of the residuals (e_t) from a regression of the series on a constant and a linear trend variable t, or $S_t = \sum_{i=1}^{t} e_i$; t=1, 2,...T, and $S^2(L) = T^{-1}\sum_{t=1}^{T} e_t^2 + 2T^{-1}\sum_{s=1}^{L}[(1-\frac{s}{L+1})\sum_{t=s+1}^{T} e_t e_{t-s}]$.

This test has stationarity as the null hypothesis (H_0) and nonstationarity (or unit root) as the alternative hypothesis (H_1). Critical values are 0.119, 0.146 and 0.216 at the 10%, 5% and 1% significant levels, respectively. The null hypothesis of stationarity is rejected if the test statistic exceeds the critical values.

c). Variance-Ratio Test

The results of both the ADF test and KPSS test indicate that the price series of the three futures contracts under investigation are all non-stationary and the random walk hypothesis cannot be rejected at all significance levels. Despite these results, the unit root test is questioned for not being a fully efficient method in testing the nonstationarity of price behaviour. Lo and MacKinlay (1988) document that unit root test cannot detect certain departures from random walk and proposed the variance-ratio test as an alternative.

As stated in Section 2.3.1, the electronic trading system has been introduced to the three financial futures markets: FTSE100 futures - 10 May 1999, Long Gilt - 12 April 1999 and Short Sterling - 6 September 1999. To observe its impact on the futures market efficiency, the variance-ratio test is performed on two observation sets, simply called pre-automation and post-automation. The former set includes the observations up to the introduction of electronic trading system (or called "before ET") whereas the latter set includes all observations, both before and after the automation (or called "including ET"). If the series follows a random walk process, its variance ratio should be equal to 1. The closeness to 1 of the variance ratios can be used to identify the efficiency level of a particular financial market. A decrease in the absolute deviation of the variance ratio from 1 is employed here as an indication of an improvement in the futures market efficiency as a result of the introduction of electronic trading system.

Before the introduction of electronic trading system, as presented in Table 4-Panel A, the variance ratio VR (q=2) of FTSE100, Long Gilt and Short Sterling is 1.0067, 1.0016 and 0.9127 respectively. Their heteroscedasticity-adjusted Z* test statistics are 0.26, 0.09 and -0.64, which are all much less than the common critical values. The Z and Z* statistic values have the asymptotically standard normal distribution, whose critical value at 1%, 5%

and 10% is 2.576, 1.96 and 1.645 respectively. As a result, none of the Z* test statistics of the three futures price series is significantly different from zero, and the VR test fails to reject the null hypothesis of a unit-variance, giving supporting evidence of futures prices following a random walk process.

In Table 4-Panel C, the variance ratios (at level) of all contracts are close to zero and proved to be statistically indifferent from zero (or having a unit-variance, VR(q) = 1), implying randomness in futures price series. Traders generally benefit not only from the knowledge of whether market prices follow a random walk generating process but also from the knowledge of the degree of efficiency (or inefficiency) of the markets. This can be obtained via the examination of the absolute deviation of the variance ratio from 1 (as VR(q)=1 indicates a random walk process), rather than its level. As reported in Panel C, Long Gilt VR (q=2) has the least absolute deviation at 0.0016, followed by FTSE100 (0.0067) and Short Sterling (0.0873), indicating that the UK bond futures market is relatively most efficient, followed by FTSE100 and Short Sterling.

The Z* statistics are required for statistical inference in case the homoscedasticity assumption of error terms (or innovations) is violated. It is because the use of Z statistics would lead to the false rejection (or acceptance) of the null hypothesis of a unit-variance (or random walk process). This problem of heteroscedasticity is present in the UK interest rate futures, Short Sterling, market under investigation here. The value of the Z statistic (q=2) of Short Sterling contract is -4.32. If used in statistical inferences, it would lead to the rejection of the random walk null hypothesis. In contrast, the corresponding Z* statistic value is only -0.64, and not significantly different from zero. This result has instead provided a supporting evidence of the random walk process in the Short Sterling price series. The same conclusion is obtained for other lag lengths, i.e. 4, 8, 16. Therefore, the VR tests provide strong evidence that the Short Sterling price series follow a random walk process, which is a sufficient condition to indicate the existence of market efficiency. As displayed in Table 4, the magnitude of the variance ratios of Short Sterling prices decreases as the lag length (q) increases. It has dropped from 0.9127 when q is 2, to 0.8324, 0.7893 and 0.7336 for q = 4, 8, 16.

For the UK bond futures market, the value of Z and Z* statistics of Long Gilt for any lag length q are less than the common critical values at 1%, 5% and 10%. None of the Z* statistics is significantly different from zero and, similarly to the Short Sterling contract, fails to reject the null hypothesis of unit variance (or random walk). At q = 2, the variance ratio of Long Gilt is 1.0016, which has decreased to 0.9962, 0.9586 and 0.9254 when the lag length q increases to 4, 8 and 16 respectively. This implies that the Long Gilt futures market is efficient as its price series appear to follow a random walk process.

As for FTSE100 futures market, the variance ratio of the UK stock index futures has decreased from 1.0067 (q=2) to 0.9563, 0.8041 and 0.8166 as the lag length increases to 4, 8 and 16. Their corresponding Z* statistic values are 0.26, -1.13, -3.04 and -3.81. As for statistical inference, none of these statistics, except for q=16, are significantly different from zero and therefore fails to reject the random walk null hypothesis of FTSE100 futures price series. Again, this result indicates that the UK stock index futures prices follow a random walk process.

After the introduction of electronic trading system, the variance ratios (q=2) have changed to 0.9987 for FTSE100, 1.0071 for Long Gilt and 0.9190 for Short Sterling, which displays a rise in magnitude of variance ratio for Short Sterling and Long Gilt contracts, but a decline for FTSE100 contract. A more accurate indication of any improvement in market efficiency after automation could be obtained via the examination of the absolute deviations of their variance ratios (VR) from 1. As reported in Panel C, the UK interest rate futures, or Short Sterling, market shows an improvement in its market efficiency as indicated by a smaller absolute deviation than before the introduction of an electronic trading system, i.e. 0.0810 and 0.0873. The same conclusion of improved market efficiency after automation has been obtained irrespective of any lag length used in the Lo-MacKinlay Variance Ratio tests.

Among the three UK futures markets, FTSE100 has shown the largest improvement in market efficiency after the introduction of electronic trading system. This is indicated by the smallest absolute deviation of VR from 1 (q=2) at 0.0013, as compared to 0.0067 before automation. At other lag lengths, the absolute deviations are larger than those obtained before the introduction of electronic trading system.

Although identified as the relatively most efficient market among the three markets before the introduction of electronic trading system, the Long Gilt market does not maintain its ranking after automation. Instead, the FTSE100 futures market has become the relatively most efficient market as it has the least absolute deviation from 1 or unit variance, the condition for a random walk process, followed by that of Long Gilt and Short Sterling. Based on the choice of lag 2, the introduction of electronic trading system appears to have increased the market efficiency of both FTSE100 futures and Short Sterling, but not the Long Gilt contracts. An improvement in market efficiency of Short Sterling after automation can be seen for any lag length used.

Table 4 : Variance-Ratio Test Results of VR(q) and Test Statistics Z(q) and Z*(q)

Panel A: Before Electronic Trading System

	FTSE 100			Long Gilt			Short Sterling		
Lag(q)	VR(q)	Z(q)	Z*(q)	VR(q)	Z(q)	Z*(q)	VR(q)	Z(q)	Z*(q)
2	1.0067	0.32	0.26	1.0016	0.08	0.09	0.9127	-4.32	-0.64
4	0.9565	-1.13	-1.13	0.9962	-0.10	-0.14	0.8324	-4.43	-0.82
8	0.8641	-2.23	-3.04	0.9586	-0.68	-1.28	0.7893	-3.52	-0.88
16	0.8166	-2.02	-3.81	0.9254	-0.82	-2.16	0.7336	-2.99	-1.04

Panel B: Including Electronic Trading System

	FTSE 100			Long Gilt			Short Sterling		
Lag(q)	VR(q)	Z(q)	Z*(q)	VR(q)	Z(q)	Z*(q)	VR(q)	Z(q)	Z*(q)
2	0.9987	-0.07	-0.05	1.0071	0.40	0.43	0.9190	-4.59	-0.63
4	0.9152	-2.57	-2.40	0.9972	-0.09	-0.11	0.8425	-4.78	-0.82
8	0.8118	-3.60	-4.56	0.9533	-0.89	-1.60	0.8004	-3.83	-0.89
16	0.7942	-2.64	-4.63	0.9143	-1.10	-2.73	0.7535	-3.18	-1.02

Panel C: Absolute Deviation of Variance-Ratio from 1

	FTSE 100		Long Gilt		Short Sterling	
Lag(q)	Before ET	Incl. ET	Before ET	Incl. ET	Before ET	Incl. ET
2	0.0067	0.0013	0.0016	0.0071	0.0873	0.0810
4	0.0435	0.0849	0.0038	0.0028	0.1676	0.1575
8	0.1359	0.1883	0.0414	0.0467	0.2107	0.1996
16	0.1834	0.2058	0.0746	0.0857	0.2665	0.2465

Notes:

The variance-ratio VR(q) is calculated as $VR(q) = \dfrac{\sum \sigma_c^2(q)}{\sum \sigma_a^2(q)}$, and

$$Z(q) = \frac{VR(q)-1}{\sqrt{\phi(q)}}, \quad Z^*(q) = \frac{VR(q)-1}{\sqrt{\phi^*(q)}}$$

where $\sum \sigma_c^2(q)$ is an unbiased estimator of 1/q of the variance of the q-differenced series and $\sum \sigma_a^2(q)$ is an unbiased estimator of the variance of the first-differenced series. Following the asymptotically standard normal distribution, the critical value of Z and Z* statistics is 2.567, 1.960 and 1.645 at 1%, 5% and 10% significant level, respectively. Price series used here are in natural logarithm form. The null hypothesis of unit variance (random walk) is rejected if the test statistic is greater than the critical values, or accepted otherwise. ET denotes Electronic Trading System.

5.5 Conclusion

This chapter examines the efficiency of UK stock index futures, bond futures and interest rate futures markets, or FTSE100 Futures, Long Gilt and Short Sterling respectively. According to the Efficient Market Hypothesis (EMH), the market is weakly efficient if the information in past prices cannot be used to forecast future prices and generate continuous above normal profits. If this is true, the price path of such financial instruments should follow a random walk process. The analytical framework of this study has been based on the concept of informational efficiency.

Using daily closing prices over the period of 1990-2002, the study has employed three different testing methods to investigate the price behaviour of the futures contracts. These are the Augmented Dickey-Fuller (ADF) unit root test, the KPSS test and the Lo-MacKinlay Variance Ratio test.

The analysis shows that, for all conventional significance levels, the Augmented Dickey-Fuller (ADF) test fails to reject the null hypothesis of unit root (or nonstationarity) at level but rejects the unit root null hypothesis at the first-differences of daily prices of FTSE100 Futures, Long Gilt and Short Sterling contracts. This implies that the price series of these three UK futures contracts contain a unit root and are integrated of order one, I(1). This test is robust to the lag length, specification and inclusion of a time trend variable in the test regression. The ADF test results indicate that the price series of these three UK futures contracts have a unit root and are all significantly nonstationary. As for the KPSS method, the test results have significantly rejected the null hypothesis of stationarity of futures price series of all FTSE100 futures, Long Gilt and Short Sterling contracts at all significant levels. This provides further supporting evidence that all three futures contracts have a nonstationary price generating process. For robustness, the Variance-Ratio test developed by Lo and MacKinlay (1989) was also used to provide corroborating evidence of the randomness, or otherwise, of the price series. This is because the other tests used have been known to fail to detect certain departures from a random walk. In this analysis, the Variance-Ratio tests fail to reject the unit-variance null hypothesis, the condition for a random walk, for all three futures contracts, implying that the price series of FTSE100 Futures, Long Gilt and Short Sterling all follow a random walk process. This result indicates the weak-form efficiency in the three futures markets under investigation. In order to examine the impact of the introduction of electronic trading system on the market efficiency of financial instruments, a measure for relative efficiency is devised and applied to two observation sets, called pre-automation and post-automation. Before the introduction of electronic trading system, the Long Gilt market is found to be the most efficient among the three UK futures markets. After automation, the results show that FTSE100 futures contract has shown the largest improvement in market efficiency and has become the most efficient market, followed by the Long Gilt and Short Sterling market.

Appendix 3:
KPSS Test Programme Listing

This KPSS test programme is written for the MATLAB package.

```
function [kpsstat,laglength] = kpsstest(e,L)

n = length(e);                 % find the total number of data series observations.
s = cumsum(e);                 % calculate the accumulative sum of e_t for S_t .
top = s'*s/n^2;
sum1 = e'*e/n;
lagloop = L;
lag =1;
while (lag < lagloop+1)
  lag1 = lag+1;
  it = 1;
  is = 1;
  sum2 = 0;
        while (is < lag+1)
                it = is+1;
                wsl = 1 - (is/lag1);
                while (it < n+1)
                sum2 = sum2 + wsl*e(it)*e(it-is);
                it = it+1;
                end
                is = is+1;
        end
   sum2 = 2*sum2/n;
   bottom = sum1 + sum2;
   kpsstat(lag) = top/bottom;
   laglength(lag) = lag;
   lag = lag+1;
end
```

Appendix 4:
Variance-Ratio Test Programme Listing

This variance-ratio test programme is written for using with the MATLAB package.

```
% Calculate the Variance Ratio Test (VRTest) of a time series x, with or without the
% heteroskedasticity correction.
%
% vrt is the the value of the VRTest.
% zvrt is the z-score of the VRTest.
% x is the time series.
% q is an index scalar/vector, which must greater than 1.
% cor can take one of the following values
%  'hom' is for homoskedastic time series
%  'het' is for heteroskedastic time series
%
% Reference:
% Lo A, MacKinley AC (1989), The size and power of the variance
% ratio test in finite samples,  Journal of Econometrics, Vol. 40, pp. 203-238.
%
% Alexandros Leontitsis, Institute of Mathematics and Statistics
% University of Kent at Canterbury, Canterbury, Kent, CT2 7NF, U.K.

function [vrt,zvrt]=VRTest(x,q,cor)

if nargin<1 | isempty(x)==1
  error('You should provide a time series.');
else
  % x must be a vector
  if min(size(x))>1
    error('Invalid time series.');
  end
```

```
  x=x(:);
  % n is the time series length
  n=length(x);
end

if nargin<2 | isempty(q)==1
  q=2;
else
  % q must be a scalar or a vector
  if min(size(q))>1
    error('q must be a scalar or a vector.');
  end
  % q must contain integers
  if round(q)-q~=0
    error('q must contain integers');
  end
  % q values must be between 2 and n/2-1
  if length((find(q<2 & q>=n/2)))>0
    error('q values must be between 2 and n/2-1');
  end
end

% If cor is ommited asuume homoskedastic time series
if nargin<3 | isempty(cor)==1
  cor='hom';
end

for i=1:length(q)
  N=floor((n-1)/q(i));
  mu=(x(N*q(i)+1)-x(1))/(N*q(i));
  s1=sum((diff(x(1:N*q(i)+1))-mu).^2)/(N*q(i)-1);
  m=q(i)*(N*q(i)-q(i)+1)*(1-1/N);
  sq=sum(((x(q(i)+1:N*q(i)+1)-x(1:N*q(i)+1-q(i)))-q(i)*mu).^2)/m;
  % The value of the VRT
  vrt(i)=sq/s1;
  % Calculating the variance of the VRT
  switch cor
  case 'hom' % For homoskedastic time-series
    varvrt=2*(2*q(i)-1)*(q(i)-1)/(3*q(i)*(N*q(i)));
```

```
 case 'het' % For heteroskedastic time-series
  varvrt=0;
  for j=1:q-1
   sum1a=(diff(x(1:N*q(i)+1-j))-mu).^2;
   sum1b=(diff(x(j+1:N*q(i)+1))-mu).^2;
   sum1=sum1a'*sum1b;
   sum2=sum((diff(x(1:N*q(i)+1))-mu).^2)^2;
   delta=sum1/sum2;
   varvrt=varvrt+((2*(q(i)-j)/q(i))^2)*delta;
  end
 otherwise
  % cor must take the values "hom" or "het"
  error('cor must take the values "hom" or "het"');
 end
 % The z-score of the VRT
 zvrt(i)=(vrt(i)-1)/sqrt(varvrt);
end


function [resultf,resultl,results] = processvr(q)

af=load('A:\af.txt');
bf=load('A:\bf.txt');
al=load('A:\al.txt');
bl=load('A:\bl.txt');
as=load('A:\as.txt');
bs=load('A:\bs.txt');
q=[2:100];

lnaf = log(af)
lnbf = log(bf);
lnal = log(al);
lnbl = log(bl);
lnas = log(as);
lnbs = log(bs);

[vraf1, zaf1] = VRTest(lnaf, q, 'hom');
[vraf2, zaf2] = VRTest(lnaf, q, 'het');
[vrbf1, zbf1] = VRTest(lnbf,q, 'hom');
```

```
[vrbf2, zbf2] = VRTest(lnbf, q, 'het');

[vral1, zal1] = VRTest(lnal,q, 'hom');
[vral2, zal2] = VRTest(lnal, q, 'het');
[vrbl1, zbl1] = VRTest(lnbl,q, 'hom');
[vrbl2, zbl2] = VRTest(lnbl, q, 'het');

[vras1, zas1] = VRTest(lnas,q, 'hom');
[vras2, zas2] = VRTest(lnas, q, 'het');
[vrbs1, zbs1] = VRTest(lnbs,q, 'hom');
[vrbs2, zbs2] = VRTest(lnbs, q, 'het');

resultf = [vraf1; zaf1; zaf2; vrbf1; zbf1; zbf2];
resultl = [vral1; zal1; zal2; vrbl1; zbl1; zbl2];
results = [vras1; zas1; zas2; vrbs1; zbs1; zbs2];

fid = fopen('resultftse1.txt', 'w');
fprintf(fid, '%10.5f %10.5f %10.5f %10.5f %10.5f %10.5f\n', resultf);
fclose(fid);

fid = fopen('resultlgilt1.txt', 'w');
fprintf(fid, '%10.5f %10.5f %10.5f %10.5f %10.5f %10.5f\n', resultl);
fclose(fid);

fid = fopen('resultsster1.txt', 'w');
fprintf(fid, '%10.5f %10.5f %10.5f %10.5f %10.5f %10.5f\n', results);
fclose(fid);
```

Chapter 6

Summary and Conclusions

This study undertakes an investigation into four issues relating to the UK financial futures markets, which are market microstructure, domestic market linkages, international market linkages and market efficiency.

First, market microstructure is examined through a comparative study of the volume-maturity relationship of three financial futures contracts, all of which have distinctive characteristics. Previous empirical studies widely reported an inverse volume-maturity relationship of futures contracts, or a negative maturity effect on futures traded volume. One of the main objectives of this study is to investigate whether the UK financial futures contracts trading behaviour is influenced by the futures contract maturity as found by prior research. Unlike previous studies, this research investigated the volume-maturity relationship of different maturity groups, not only the pooled data of all contracts as employed in other studies. This enables the factors contributing towards the inverse relationship between maturity and traded volume to be more accurately identified. Apart from the maturity effect, the study also examined other aspects of trading such as the timing of rollover, the hedging and speculative demand of the futures contracts and the impact on the volume-maturity relationship from more recent deregulations, including the change in tick size of FTSE100 futures (UK stock index futures contracts), the decimalisation of Long Gilt (UK bond futures contracts) and the introduction of an electronic trading system.

The main results of this study reveal a significant volume-maturity relationship for all three futures contracts under investigation. By using the pooled data of all maturity contracts, the results display a significant negative volume-maturity relationship as reported by previous studies. However, more detailed investigation illustrates that the inverse relationship between volume and maturity is in fact contributed mainly by the middle contract trading, rather than the near contract. This is due specifically to the rollover trading behaviour of investors, particularly the one(s) holding a long-term hedging position, who do not wish to take up the delivery. The sign and magnitude of the relationship acquired from this analysis can be used to identify the degree (or extent) of a maturity effect and provides insight into the timing of large trades in order to achieve successful trade executions.

FTSE100 futures and Long Gilt traders are found to use the nearest contracts for speculative purpose and the second-nearest contracts for hedging. No obvious conclusion is obtained for Short Sterling contracts. This is probably due to the fact that there are up to twelve maturity horizons available for trading. Consequently, UK interest rate futures contracts appear to have more even spread of hedging demand across maturities.

As for the timing of rollover, both FTSE100 futures and Long Gilt contracts have a clear-cut point of time of trading switching from the near contracts to the middle contracts. The examination reveals that the rollover of FTSE100 futures traded volume is predominantly on the expiry days but the rollover of its open interest occurs 4-8 days prior to expiry days. For Long Gilt contracts, the rollover occurs 23-29 days before expiry dates. This is due mainly to the 21-day notice delivery rule of the UK bond futures contract. In contrast, the traded volume of Short Sterling is far less concentrated across expiry months.

The use of a new tick size and the introduction of electronic trading system appear to have strengthened the inverse relationship between volume and maturity of FTSE100 futures contracts. Meanwhile, the decimalisation of Long Gilt contracts has strengthened the negative maturity effect of the middle contracts and weakened the overall positive maturity effect of the UK bond futures contracts.

Chapter 3 examined the domestic market linkages through the impact of macroeconomic announcements on the lead/lag relationship between the FTSE100 futures contracts and its underlying equity index. The unique feature of this study is to examine the impact of unexpected news from UK macroeconomic announcements on the lead/lag relationship. By using higher frequency data than previous studies, the study aimed to identify more precisely the timing and magnitude of the lead and lag effect in the stock index markets. Also, the study examined the asymmetric responses to good and bad news created by the macroeconomic announcements on the lead/lag relationship. It is the first study to investigate such effects for UK stock index spot and futures markets.

The main results of this study reveal a futures lead over the cash market of the UK stock index of approximately 50 minutes, similar to findings reported by previous studies. This is essentially due to lower transaction cost of futures trading which enables more successful trading executions to take place in the futures market ahead of the cash (or spot) market. The lead/lag relationship is strengthened by the impact of information contained in UK macroeconomic announcements. The results illustrated that the futures lead of up to 5 minutes was strengthened by UK macroeconomic announcements. By employing high frequency data, this research identified that the strongest impact took place in the first 5 minutes after announcements. This study also examined the impact of both single and multiple macro announcements. The release of inflation figures has relatively the largest impact on the lead/lag relationship compared to other macroeconomic announcements under investigation. It is followed by the announcement of Unemployment figures, Production Price Index (PPI), Retail Sale figures and Public Sector Borrowing Requirement (PSBR). However the announcement of Balance of Payments (BOP), Gross Domestic Product (GDP), Money Supply, and Industrial Trends appear to have relatively little impact on the stock index futures market. Despite a very small number of occurrences, the combined effect of simultaneous macro announcements appears to be greater than that of single announcements. The impact from either single or multiple (simultaneous) announcements is concentrated within the first 10 minutes after release at 0930 GMT and all information appeared to be fully compounded into prices by midday.

Asymmetric responses to good and bad news are also found. The impact from bad news generated by the macro announcements appear to strengthen the lead/lad relationship of FTSE futures and its underlying equity index whereas the good news causes a price lead from the spot market to the futures market instead. This finding can be used in making more effective investment decision.

The study also examined in Chapter 4 the international market linkages through an investigation of information spillovers of futures mispricing of one market across international boundaries. The mispricing series of three well-established stock index futures markets, Australia, UK and the US, are constructed and examined using the Cost-of-Carry model. Previous empirical research has substantially documented linkages among international markets, all of which focus on the linkages of equity index prices, either in terms of price (returns) co-movements or volatility spillovers. This is the first study to extend the investigation to financial futures markets.

An extensive look at mispricing error occurrences and distributions reveal that Australian mispricing error was predominantly negative during 1990-1995, but had become positive ever since. Meanwhile, the UK futures market had experienced more positive mispricing errors in the stock index futures trading until 1996 but more negative mispricing errors had set in since 1997. The US futures mispricing errors had been predominantly positive throughout the period 1990-1998. The UK mispricing errors have a normal distribution around a zero mean whereas the Australian mispricing error distribution was found to be leptokurtic (peaked) with negative skewness (long-left tailed) and a negative mean of -3.8 approximately. Similarly, the US mispricing error distribution is also leptokurtic but, unlike Australia, has positive skewness indicating a long right tail. In short, the average of stock index futures mispricing errors is negative for Australia, positive for the US and a small negative for the UK.

To account for the differences in index values across the markets, the mispricng errors are scaled by the corresponding spot (cash) index series. Before scaling, the results exhibit negative mispricing errors for both Australia and UK whereas the US exhibits average positive mispricing. This conclusion remains unchanged even after scaling. Among the three mispricing series, either scaled or non-scaled, Australia has had the largest absolute values of mispricing errors. The small levels of mispricing in the UK and US markets may reflect lower transaction cost and higher liquidity as compared to the Australian market. The dominance of negative mispricing may be explainable by greater restriction on short sales in the Australian market. The examination of cross correlation across the three mispricing series, after allowing for the time zone differences, reveals strong autocorrelation of the three price series under investigation.

By using the VAR framework, the model initially considers only the first-order effect of the mispricing spillover. The explanatory power of the mispricing model of a particular market appears to be driven by its own market influence. That is, the mispricing errors appear to be persistent and positively related to its level in the preceding period. This is in fact consistent to prior research evidence by MacKinlay and Ramaswamy (1988). A similar conclusion is obtained for all markets under investigation: US, UK and Australia. Despite the presence of a strong autoregressive relationship, lagged mispricing error (or mipricing error from preceding period) from foreign market has generally had significant impact on the market under investigation. This indicates the spillover of the mispricing error from one market to another foreign market. Here, there is an evidence of a spillover from the US market, but not the UK market, to the Australian market and from the Australian market to the US market. Overall results suggest that innovations in the mispricing series in one market spillover to the mispricing series in another market. These results contradict the concept of integrated and competitive international capital markets.

Overall, these results indicate that mispricing from foreign markets can be used to forecast the mispricing and potential arbitrage profits in another market. The study undertakes further investigation to examine whether these profits can be realized. This is done by adopting a trading strategy, based on the assumption that a trading execution should take place only when the information from the foreign markets carries predictive ability. The results of testing the trading rule show many potential arbitrage opportunities, however these profits quickly disappear when a filter, used as a proxy for transaction cost, is applied which means that they are not sufficiently large enough to cover the transaction costs. The results also show that some profit is possible but that a long horizon, probably beyond the scope of most traders, is required to exploit the spillover information.

In summary, the main results reveal the existence of bi-directional transmission of mispricing across countries under investigation. The information of mispricing errors in one country can therefore be used for the investment decision in another country, based on the bi-directional finding.

Finally, the study examined the market efficiency of three UK financial futures markets, the stock index futures (FTSE100 futures), bond futures (Long Gilt) and interest rate futures (Short Sterling). The analysis is based on the concept of weak-form informational efficiency as in the Efficient Market Hypotheses (EMH). The randomness of futures price fluctuation generally signifies the market efficiency of the futures contract. Any evidence of market inefficiency implies that futures prices do not follow a random walk process and the past prices of a particular instrument can be used to forecast the future price. Until recently, prior research only focused on the efficiency test of the stock indices of more developed financial markets. This is the first comparative study of the efficiency test of three distinctive financial futures markets, which can give more conclusive evidence on the market efficiency of financial futures instruments in the UK. For robustness, this study employed three test methods; ADF unit root test, KPSS test and Lo-MacKinlay Variance Ratio test.

The ADF unit root test results illustrate that the price series of these three UK futures contracts contain a unit root and are of integrated order one I(1) and are all nonstationary. The KPSS test results have significantly rejected the null hypothesis of stationarity of the futures price series. The combined results have given supporting evidence of the nonstationarity of the three futures prices series under investigation. Finally, Variance-Ratio tests fail to reject the unit-variance null hypothesis, which indicates the random walk process, a sufficient condition to identify market efficiency. Therefore, the overall result of market efficiency tests indicates that all three UK futures markets under investigation are weak-form efficient.

In 1998, an electronic trading system was introduced for the three futures contracts. Further investigation is undertaken in this study to observe whether the automation has any impact on the futures market efficiency. The results show that before automation the UK bond futures contract is found to be the most efficient among the three futures contracts under investigation. However, after automation the FTSE100 futures contract appears to show the largest improvement in market efficiency and has become the most efficient market, followed by the Long Gilt and Short Sterling market.

The findings of this study could be beneficial to traders and policy makers in financial markets. Chapter 2 offers insight into trading behaviour in the futures markets, that the futures trading mostly follow a cyclical pattern based on the delivery rules (i.e. quarterly). The ability to identify the timing of high liquidity of traded volume helps facilitate successful trading executions. The result of the Lead/Lag relationship in Chapter 3 identifies the time window that the prices of the stock index futures contracts can be exploited in forecasting the spot prices of the underlying stock index in the UK markets. However, the analysis of this particular study was constrained by the unavailability of high-frequency data due to the high charges of commercial data providers. Also, the futures lead of 50 minutes in the UK stock index appears to be much higher than the futures lead of other stock index markets, which mostly report the futures lead of around 20 minutes. A further study using more recent data is recommended to examine whether the UK futures lead still remains relatively high as found in this study. If so, the investigation should be extended to find out the underlying reasons of the UK excessive futures lead. Chapter 4 identifies the transmission of arbitrage information across international markets, which traders can use to set up an appropriate arbitrage position to generate profits. Chapter 5 reports the finding of weak-form informational efficiency in the FTSE100 Futures, Long Gilt and Short Sterling markets. However, the report of a stronger futures lead on the days of macroeconomic news releases indicate a possibility that the stock index markets, both futures and cash, could in fact indicate semi-strong form inefficiency, which the traders can exploit the information from event-studies, i.e. macroeconomic announcements, to generate superior profits. This again is an area for further research.

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