THE ECONOMICS OF STOCK INDEX FUTURES: THEORY AND EVIDENCE

A thesis submitted for the degree of Doctor of Philosophy.

by

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Abstract.

This thesis aims to provide detailed investigation into the role and functioning of the FTSE-100 stock index futures contract, by examining four interrelated issues.

Chapter 1 reviews the literature, demonstrating that stock index futures can increase investor utility by offering hedging *and* investment opportunities. Further, the price discovery role of futures is discussed.

Chapter 2 investigates the risk return relationship for the FTSE-100 contract within a CAPM framework. While CAPM adequately explains returns prior to October 1987, post-crash the contract is riskier and excess returns and a day of the week effect are evident.

Chapter 3 examines the impact of futures on the underlying spot market using GARCH, which allows examination of the link between information and volatility. While spot prices are more volatile post-futures, this is due to more rapid impounding of information. The view that futures destabilise spot markets and should be subject to further regulation is questioned.

Chapter 4 examines futures market efficiency using the Johansen cointegration procedure and variance bounds tests which are developed here. Results suggest futures prices provide unbiased predictions of future spot

prices for 1, 2 and 4 months prior to maturity of the contract. For 3, 5 and 6 months prior to maturity the unbiasedness hypothesis does not hold.

Chapter 5 discusses the major role of futures; hedging. Hedge ratios and hedging effectiveness are examined in relation to duration and expiration effects. Hedge ratio stability is also examined. Finally, hedging strategies based on historical information are examined. Results show there are duration and expiration effects, hedge ratios are stationary and using historical information does not greatly reduce hedging effectiveness. The FTSE-100 contract is shown to be a highly effective means by which to hedge risk.

Chapter 6 provides a summary and concluding remarks concerning the relevance of the research carried out here.

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LIST OF CONTENTS

List of Tables

List of Figures

Introduction.

> "Popular narratives of popular movements appeal to the fancy and carry with them all that is pleasing to the public taste, but... [a]musing and instructive as these histories usually are, they frequently fail in defining those connecting links in the general chain of circumstances, a knowledge of which is deemed indispensable by the studious enquirer for arriving at correct results." (Evans, 1849, p1).

Popular narratives and popular beliefs should not form the basis of policy or investment decisions. In order to inform the policymaking and investment decision making processes it is essential that detailed scientific investigation be carried out. Unfortunately, as regards the role and functioning of financial futures markets, while a body of evidence exists for the markets in the USA and much anecdotal evidence has been forthcoming in relation to the UK, detailed enquiry has not previously been undertaken for UK markets. This is particularly true for the market for the FTSE-100 stock index futures contract. Such a lack of understanding also exists as regards the connecting links between the market for stock index futures and the market for the underlying asset.

The main aim of this thesis is to fill this gap in the literature by providing a detailed investigation into the role and functioning of the FTSE-100 stock index futures market. The issues investigated in this thesis, while not being exhaustive in coverage, are seen as relating to the most important aspects of futures markets. As such, rather than concentrating on only one aspect of futures trading, the thesis investigates four different, but interrelated, issues regarding the functioning and impact of futures markets. Hence, the research objectives of this thesis are to examine the risk return relationship in futures markets, the impact of futures trading on the underlying spot market, the efficiency of the market for the FTSE-100 futures contract and the hedging effectiveness of this contract. The analysis of these four issues will be of interest and direct benefit to investors, regulators and the general public.

Before going on to examine these four issues, the thesis begins with an overview of financial futures markets and the economics of futures trading in chapter 1. It is shown in this chapter that stock index futures introduce negative correlation, provide a cheap means of buying into the payoff profile of a broadly diversified portfolio and move an otherwise incomplete market towards completeness. In addition, the chapter provides a review of the literature relevant to the research questions addressed in this thesis, identifies the weaknesses and limitations of previous research and provides a rationale for undertaking the present research and the methodologies adopted here.

The risk return relationship for futures can be seen to be of central concern to investors, both individual and institutional, since futures provide a means of participating in market index movements at low cost, and changing market position rapidly. Given that futures can thus be seen as an alternative form of investment to other financial assets, it is important to examine the risk return relationship within an asset pricing framework. In chapter 2, the Capital Asset Pricing Model (CAPM) framework is used to investigate the risk return relationship for the FTSE-100 futures contract, taking account of the time to maturity dimension of futures trading. Both the Black, Jensen and Scholes and the Fama and MacBeth methodologies are adopted. In addition, the question of whether a day of the week effect in futures returns exists is addressed. It is shown that while before the stock market crash of October 1987 the risk return relationship conforms to the CAPM framework, post-crash the futures contracts became a more risky asset, as shown by the higher beta coefficients. In addition, there is evidence of abnormal excess returns which may be taken as an indication of inefficiency in the market. Excess returns appear to be higher for contracts further away from maturity. The issue of efficiency is further questioned by the finding of a day of the week effect.

The finding of excess returns may seem to give credence to those opposing futures trading, in that it may attract speculators into the market who have a destabilising tendency on the market for the underlying security. This raises the possibility that further regulation of futures markets may be required. For this reason, chapter 3 investigates the impact of the onset of futures trading on the FTSE-100 index on the underlying market. Unlike previous studies, the Generalised Autoregressive Conditional Heteroskedasticty family of techniques is used to examine this issue. This technique enables the connecting link between information and price volatility to be assessed and takes into account time dependence in returns. The chapter demonstrates that while price volatility has increased, this is due to the impounding of information into prices more quickly, rather than being due to destabilising speculation. It is also found that news has a less persistent impact on price volatility. Thus, by addressing the connecting links between information and volatility, increased price volatility can be reconciled with a refutation of the popular belief that futures markets are destabilising.

The results of chapters 2 and 3 provide the rationale for the analysis carried out in chapter 4. In this chapter the efficiency of the FTSE-100 futures market is examined using both the Johansen cointegration procedure and variance bounds tests. While cointegration has previously been used to investigate futures markets efficiency, the distinction between short-term and long-term efficiency is not well documented. In this chapter the distinction is analysed using Error Correction Models. In addition, following Shiller's methodology, variance bounds tests are developed and tested to augment the cointegration analysis. Such tests have not previously been applied to futures markets. Results reveal that the market for futures contracts for 1, 2 and 4 months prior to maturity provide unbiased estimates of future spot prices both in the long-term and the short-term. For 5 months prior to maturity long-term efficiency is established, but there are substantial deviations in the short-term. For 3 and 6 months prior to maturity, the unbiasedness hypothesis is rejected for both the long-term and the short-term.

Chapter 5 addresses what is seen to be the major function of futures markets, namely providing a vehicle for hedging the risk associated with the underlying asset. Hedge ratios and hedging effectiveness are investigated taking account of both the duration of hedge effects and time to maturity effects. In addition, the stability of the hedge ratio is examined. In addressing these issues previous researchers have made an implicit assumption of perfect foresight. In this study hedging strategies and effectiveness based on historical information are compared with the perfect foresight equivalents. Clear evidence emerges that the FTSE-100 futures contracts provide an effective means of hedging the risk associated with holding a stock portfolio. The findings suggest that hedge ratios and hedging effectiveness increase with hedge duration, but the evidence relating to expiration effects is less clear cut. The finding of instability in hedge ratios through time implies that dynamic hedging strategies may be worth pursuing.

Finally, chapter 6 summarises the main findings in this thesis and provides concluding remarks.

Chapter 1: The Economics of Stock Index Futures Trading.

A. An Introduction to Futures Trading.

A1.1 Introduction.

The undertaking of almost any economic activity results in the participant in that activity facing a situation of risk. When a course of action is followed, it is not known with certainty what the outcome of that action will be.[1] While there are occasions where individuals display risk preferring behaviour (see, for example, Friedman and Savage (1948)), for the vast majority of economic actors any risk associated with major consumption and investment decisions is a source of disutility. It is this fact which provides the main justification for the existence of markets in insurance.

A major source of risk for many producers relates to the prices at which they will be able to sell the commodities they produce and to the prices they will have to pay for inputs into the production process. At the time the production decision is taken it is not known what the prevailing prices will be when buying and selling takes place at some point in the future. Traditionally, this price risk has been seen to be of considerable importance to the producers and users of agricultural commodities and, more recently, precious metals. This led to the search for means by which risk relating to future prices could be reduced and to the introduction of futures contracts on agricultural commodities at the Chicago Board of Trade in 1865.

Definition.

A futures contract is an agreement to buy or sell a standard quantity of a particular commodity or financial instrument at a future date for a price which is agreed at the time the contract is drawn up. A futures contract involves an obligation on the part of both the buyer and the seller to fulfil the conditions of the contract[2].

Until relatively recently futures contracts were limited to agricultural commodities and metals. However, in the late 1960s and early 1970s there was a breakdown in the agreement on fixed exchange rates, which had been reached at Bretton Woods in 1944. This led to a period of floating exchange rates and to substantial volatility in both exchange rates and interest rates. Such volatility is a source of considerable risk for many producers and the impact of this risk is, arguably, much more pervasive than that associated with the prices of agricultural and metal commodities. Once more, means were sought by which risk could be hedged and the 1970s saw the birth of futures contracts on financial instruments. In 1972 financial futures contracts were introduced, with the onset of futures trading in foreign currencies at the International Money Market of the

Chicago Mercantile Exchange, and futures contracts on fixed income securities (i.e. interest rate futures) were introduced in 1975 at the Chicago Board of Trade. In addition, there has been a growth in the availability of other derivative securities, such as options and swaps contracts.

As the effectiveness of financial futures became evident, the range of instruments on which futures contracts were traded increased and on 16 February 1982 trading began in the first stock index futures contract at the Kansas City Board of Trade. This first contract was the Value Line Composite Index (VLCI) futures. Stock index futures contracts are futures contracts written on stock indexes and as such they represent a futures contract on the portfolio of shares which underlie the stock index. Stock index futures contracts which are held to maturity are not delivered but rather cash settlement takes place. The reason why cash settlement must take place is that the index itself is not an actual asset and construction of a portfolio for delivery which perfectly matches the index would involve the purchase of, in the case of the FTSE-100 index, 100 shares in exact proportions to their weights in the index.

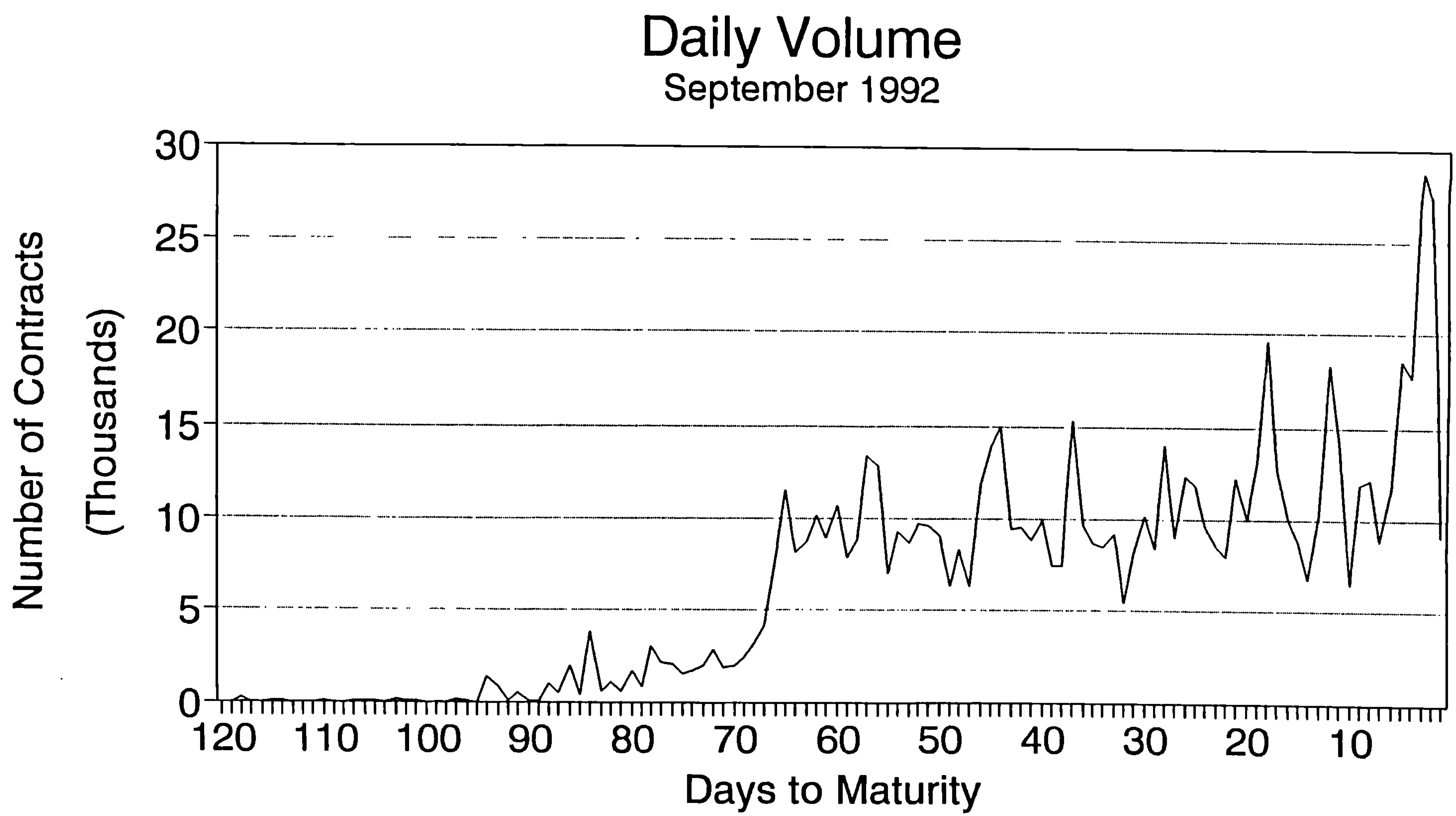
In April 1982 the Chicago Mercantile Exchange began trading another stock index futures contract, the

Standard and Poor's 500 (S&P 500), and in May of 1982 the New York Futures Exchange introduced the New York Stock Exchange (NYSE) Composite Index futures contract.

The first (and, to date, only) stock index futures contract for an index in the UK began trading in May 1984, when the London International Financial Futures Exchange (LIFFE) introduced contracts based on the FTSE-100 stock index[3,4]. This contract has proved very popular, with the volume of trading now accounting for approximately half of the turnover in the underlying securities.

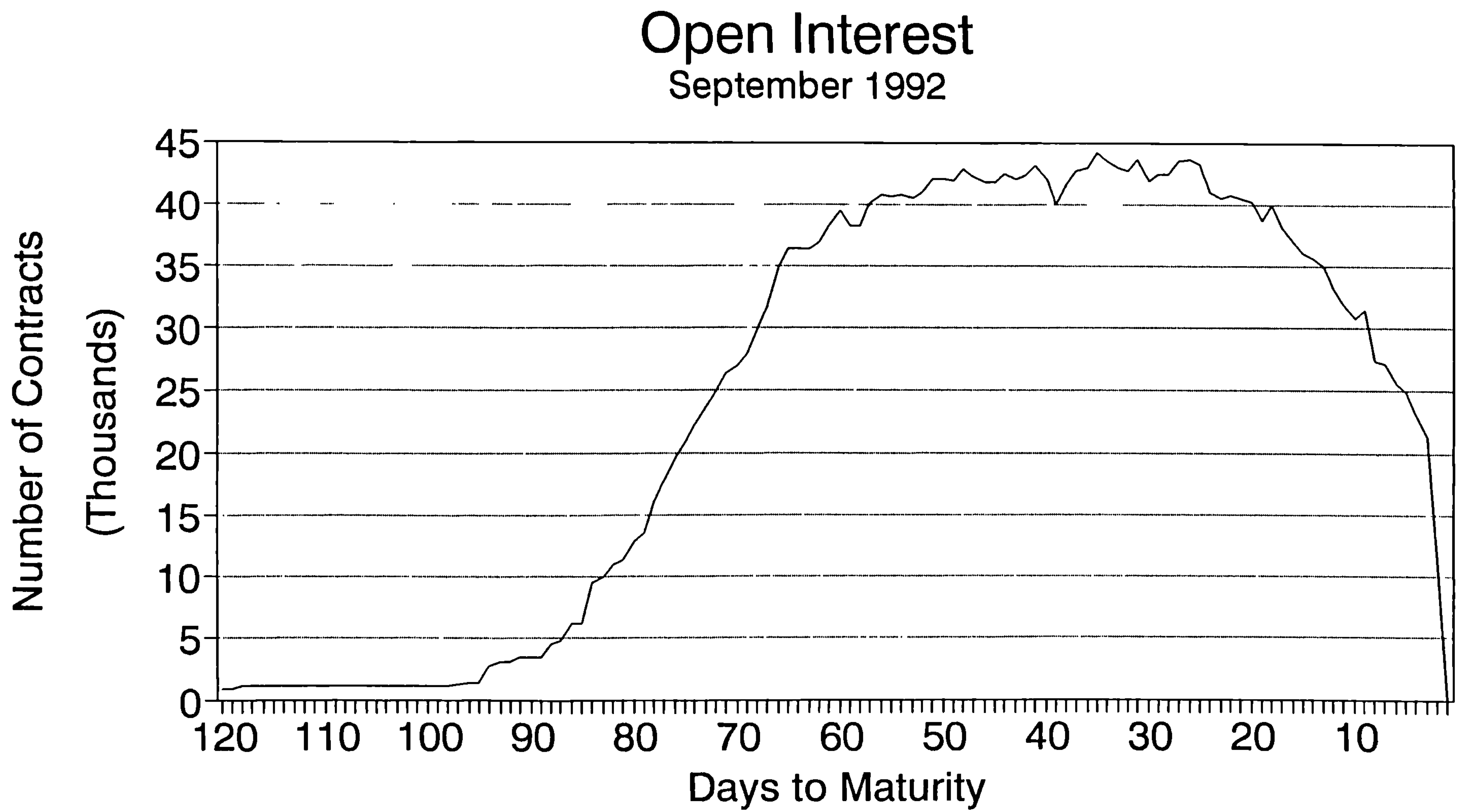
Figures 1.1 and 1.2 show daily volume and daily open interest for the FTSE-100 futures contract by days to maturity for the September 1992 contract. As can be seen from the diagrams, daily volume reached a peak of over 27,000 contracts and open interest a peak of 44,000 contracts. The unit of trading of the FTSE-100 futures contract is £25 per full index point. For example, when the stock index stands at 2600 the unit of trading and the value of the contract will be £65000. The contract is traded in a three month cycle, with contracts maturing in March, June, September and December. The last trading day for each contract is the last business day in the delivery month[5] and trading ceases at 11.20 a.m. on that day. The delivery day, i.e. the day on which settlement of the futures contract takes place, is

Figure 1.1



Daily Volume
September 1992
Number of Contracts
(Thousands)
30
25
20
15
10
5
0
120
110
100
90
80
70
60
50
40
30
20
10
Days to Maturity

Figure 1.2


Open Interest
September 1992
Number of Contracts
(Thousands)
45
40
35
30
25
20
15
10
5
0
120
110
100
90
80
70
60
50
40
30
20
10
Days to Maturity

the first business day following the last trading day. The price of the futures contract is quoted as index points (e.g. 2600) and the minimum price movement, also known as the tick, is 0.5 of an index point. Thus the tick has a value of £12.50. Finally, the initial margin for the contract is £2500 which represents less than 5% of the value of the contract when the index is above 2000.[6]

Financial futures in general, and stock index futures in particular, have proved extremely popular. Indeed, financial futures trading now dominates futures markets, with the volume of transactions in financial futures far outweighing that in the more traditional commodities.

In order to understand the reasons for the success of this futures contract in terms of trading volume it is necessary to examine the nature and economic role of futures markets in general and stock index futures in particular. In addition, the success of the contract cannot simply be viewed in terms of trading volume. It is necessary to consider whether the FTSE-100 stock index futures contract has succeeded in fulfilling the role expected of such a contract and whether it has had any positive or adverse effects on the underlying spot market. In the remainder of this section the nature and role of futures markets are discussed. The issues which are perceived by the author to be important in assessing the impact, success and economic role of futures contracts are examined in section B.

A1.2 The Role of Futures Trading.

In the previous section it was noted that financial futures markets were established with the prime objective of enabling companies and individuals to insure against the possible adverse effects of changes in interest and exchange rates. Similarly, stock index futures were established to enable portfolio managers and other investors to insure against the possible adverse effects of changes in stock prices. Thus the main role of financial futures markets is the reduction of risk or 'hedging'.

Futures markets can be shown to enhance the range of risk management strategies available to investors. They thus allow those investors who hold a particular position in the spot market to reduce uncertainty with regard to future price movements without altering the composition of the spot portfolio. In doing this, futures contracts reduce the disutility associated with price uncertainty.

Modern portfolio theory has established that the risk associated with any asset can be divided into two component parts: systematic and unsystematic risk (see Markowitz (1952)). While the latter component can be diversified away, the former exists in all assets except those specifically designed to have zero beta. Broad market portfolios, such as that which underlies the FTSE-100 index, can reasonably be expected to have removed almost all country specific diversifiable risk. Further risk reduction can be achieved by international diversification. However, while the correlations between various stock and bond markets are less than unity, internationally diversified portfolios are still subject to systematic risk (see, for example, Jorion (1985), Levy and Sarnat (1970) and Eun and Resnick (1984)). Short sales provide one means by which market participants can eliminate systematic risk, but such sales are severely restricted with the result that they are limited in the extent to which they can be used to introduce negative correlation. Derivative securities, such as futures contracts, are not subject to such severe restrictions and are thus better able to allow investors to reduce the risks which they face. Because futures trading also introduces negative correlation not found in assets in the spot market, they enable the enhancement of investor utility.

To illustrate the way in which stock index futures can be used for hedging, consider an investor who holds a portfolio of stocks which exactly mirrors the FTSE-100 index. Let the current value of the portfolio be V_0, the current level of the spot index S_0 and the number of spot index units held N_s. For example, the current value of the stock portfolio may be £10 million and the current level of the FTSE-100 index 2500. This means that the investor holds the equivalent of four thousand units of the index (i.e. N_s=4000). The investor has the opportunity of hedging some of the risk faced in the spot market by purchasing or selling futures contracts. Let N_f be the number of index units traded in the futures market. Finally, we define the hedge ratio, h, as the ratio of the number of units traded in the futures market to the number of units held in the spot market. Thus the hedge ratio is:

$$h = N_f/N_s$$

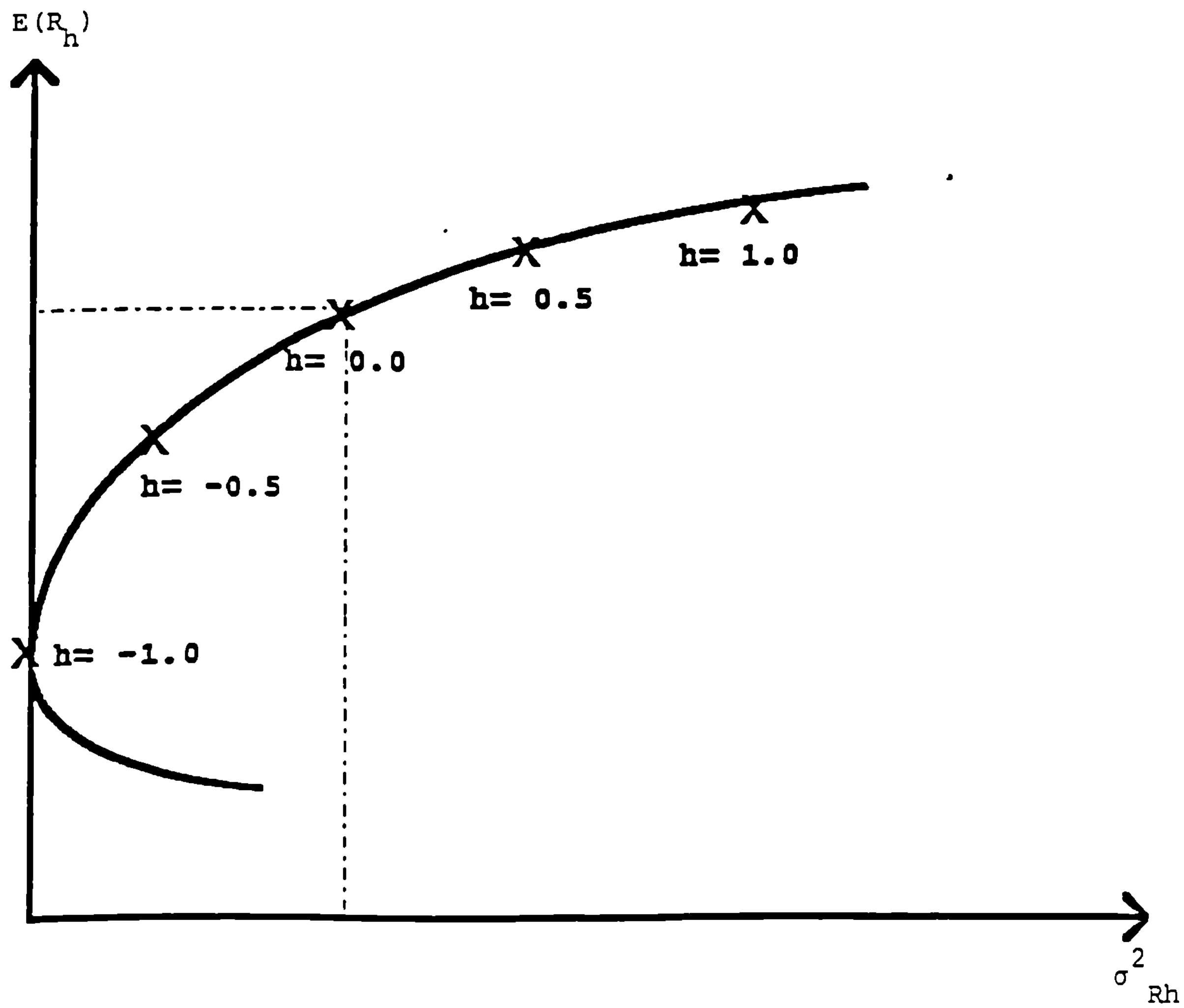
Clearly, as h changes so will the risk-return combination offered by the portfolio of futures and spot assets, as shown in figure 1.3. The expected return on the hedged portfolio, ($E(R_h)$), is simply the weighted average of the returns on the spot and futures positions:

$$E(R_h) = E(R_s) + h.E(R_f) \qquad (1.1)$$

where $E(R_s)$ is the expected return on the stock portfolio and $E(R_f)$ is the expected return on the futures contract.

Figure 1.3

Portfolio Risk-Return Possibilities for Different Values of h, The Hedge Ratio



The variance of the return for the hedged portfolio is:

$$\sigma^2_{Rh} = \sigma^2_{Rs} + h^2\sigma^2_{Rf} + 2h\mathrm{Cov}(R_s,R_f) \qquad (1.2)$$

With reference to figure 1.3, h=0 represents the unhedged position where no futures contracts are purchased or sold. Hence, the risk return combination is simply that offered by the spot index. Points to the left of h=0 involve selling futures contracts (a short position in futures) and points to the right involve buying futures (a long futures position). Given that the stock portfolio held by the investor exactly mimics the FTSE-100 index, the returns achieved from selling futures will be perfectly negatively correlated with the returns from the spot position (assuming no dividends and the absence of arbitrage opportunities). Thus a rise in the FTSE-100 index would be exactly matched by a fall in the futures price and vice-versa. With a hedge ratio of -1 the risk-free rate of return would be earned with zero risk.

The investor can choose any value of h and can thus achieve any of the points on the risk-return curve in figure 1.3. A risk-averse utility maximizing investor will choose h so that his/her indifference curve is tangential to the upper part of the opportunity set (i.e. a hedge ratio of -1 or greater).

In this example the value of h which minimises the variance of returns is -1 because the spot index and the futures contract are perfectly positively correlated. However, in practice, there is unlikely to be perfect correlation between the spot and futures prices and hence the hedge ratio which minimises the variance of returns will differ from -1 (see Figlewski (1984)). This arises for two reasons: firstly, in practice the underlying portfolio of assets which is to be hedged will not exactly mirror the index on which the futures contract is written; and secondly, basis[7] risk exists. Basis risk relates to the uncertainty regarding how the basis will change over the life of the hedge.

Figlewski (1984) identifies two main sources of basis risk. Firstly, futures contracts do not yield dividend income whereas the spot position will yield such income. Secondly, while the activities of arbitrageurs will ensure that the futures price must equal the spot price at expiration, at other times the spot and futures prices may diverge. Perfect arbitrage is not possible for stock index futures, because in practice arbitrageurs are only likely to hold some of the shares in the underlying index. In order for there to be perfect arbitrage it would be necessary for arbitrageurs to buy or sell all stocks in the index whenever the futures price deviates from its theoretical level. Since this will not occur in practice, there will be a range in which futures prices can deviate from their theoretical levels without inducing arbitrage transactions. Thus, in practice, stock index futures do not allow the elimination of risk, rather they replace the risk associated with cash price changes with the risk associated with changes in the basis.[8]

While futures do not eliminate price risk, they do allow investors to greatly reduce the risks which they face and thus to increase their utility. The above discussion has considered the use of futures to hedge an established spot position. Futures can also be used to hedge the risk associated with an anticipated spot position. For example, a fund manager may decide it is appropriate to move out of UK equities and into, say, Australian equities. In the absence of stock index futures the fund manager has two options. Firstly, s/he can make the move over a period of time, and thus expose the fund to the risk of adverse price movements in the two markets. Alternatively, the move can be made very rapidly with the possibility that large buy and sell orders move the markets unfavourably. However, stock index futures enable the fund manager to establish the desired positions rapidly without such an adverse effect on the spot markets. A short futures position is established in the UK, and a long futures position in Australia. The spot and futures positions can then be adjusted over time, with any adverse movements in spot prices being offset by opposing movements in the futures positions. As with the hedging of an established spot position, such anticipatory hedging is also subject to basis risk.

In addition, it can be seen from figure 1.3 that futures can be used to expand the risk return opportunities which investors face by taking a long position in futures and moving to the right of the point where h=0. In relation to stock index futures it has been argued that

> "With the advent of futures contracts on stock indexes, active and offensively minded portfolio risk management, in its broadest sense, became practicable. In effect, the risk manager and *the individual investor* gained new degrees of freedom.... He or she can now consider *opportunistic strategies rather than only defensive strategies*." (Fabozzi and Kipnis, 1984, p1, emphasis added).

The prime reason for using stock index futures as an investment vehicle is that they give investors the opportunity to participate in market index movements at relatively little cost and with a small cash commitment, due to margin requirements. Transactions costs in futures markets are typically in the range of 0.1% of the value of the contract, compared to a figure of 1-2% for the spot market. In addition, as Carlton (1984) points out, laws relating to cash and futures markets differ not only in relation to margin requirements, but also in terms of taxation and insider trading.

The above discussion clearly illustrates the fact that futures provide investors with increased opportunities both in terms of risk reduction and an expansion of the risk return opportunity set. Indeed, given that transactions costs will prevent investors from establishing portfolios that exactly mirror a broad stock index, stock index futures can be seen to be moving the market towards completeness. The concept of market completeness is very important in welfare economics. As such, the way in which futures markets can complete the market should be examined in order that their role in increasing welfare is fully understood.

A market is said to be complete when investors can establish portfolios to suit their own individual preferences based only on existing securities. In such markets there is no need to create additional securities since all possible payoffs can be created and thus uncertainty can be removed.

Ross (1976a) has demonstrated that options provide one means by which markets can be completed. It can equally be shown that stock index futures can bring about market completeness. Before going on to demonstrate the use of futures contracts, it is important to understand the significance of market completeness. In a two-period world of certainty it can easily be shown that the existence of perfect and complete capital markets leads to a Pareto efficient position. This arises because investors whose initial endowment does not conform to their desired consumption pattern, can rearrange this pattern by either borrowing or lending in capital markets (see Hirshleifer (1958)).

Moving beyond a world of certainty, it can still be shown that the existence of complete markets is necessarily Pareto efficient. In contrast, while incomplete markets may in some circumstances achieve Pareto efficiency, there are other circumstances in which Pareto inefficiency will result (see Arrow (1964) and Debreu (1959)). Thus Arrow shows that insufficient markets in contingent claims may be a source of inefficiency.

Following Ross (1976a) we will consider securities as vectors of payoffs, with each possible state of the world having an associated payoff from a particular security. Hence, an asset x is simply a map from the state space Ω to the line E:

$$x: \Omega \dashrightarrow E$$

With m possible states of the world and n securities there will be a m by n state space tableau, denoted X. As Ross argues, typically there will be more states than primitives[9], with the result that all states cannot be spanned and competitive equilibrium is inefficient. However, he points out that even though X fails to span Ω the rank of X can be augmented by forming options on existing primitives. The same argument holds true for futures. This can be demonstrated by the use of an example.

Consider a situation where X contains three assets, x1, x2, x3, which have payoffs (£) in four states

$$[x1\ x2\ x3] = \begin{bmatrix} 0 & 2 & 0 \\ 0 & 2 & 2 \\ 0 & 0 & 2 \\ 2 & 2 & 2 \end{bmatrix}$$

Clearly, with four states of the world and three securities X cannot span Ω. More formally, the rank of X, $\rho(X)$, is less than the number of states of the world, m. By combining the three assets into an index it is possible to generate a fourth asset. For example, if equal weighting is given in the index to x1, x2, and x3 then the index, I, would have the following payoffs in the four states:

$$[I] = \begin{bmatrix} 2 \\ 4 \\ 2 \\ 6 \end{bmatrix}$$

However, while there are now as many assets as there are states of the world, the market is not complete. This is because the fourth asset is simply a linear combination of the other three assets. However, by writing a futures contract on any of the securities x1, x2, or x3 it is possible to complete the market. For example, if a futures contract is written on x2, where the agreed price is £1, $\rho(X) = m$ and the market is complete. The payoff from buying the futures contract is:

$$f(x2) = \begin{bmatrix} 1 \\ 1 \\ -1 \\ 1 \end{bmatrix}$$

and the rank is full[10].

In this example state space is spanned by writing a futures contract on a single security. Equally it is possible to write a futures contract on the index to complete the market. A futures contract on the index, with a price of, say, £3, has the following payoffs:

$$f(I) = \begin{bmatrix} -1 \\ 1 \\ -1 \\ 3 \end{bmatrix}$$

Once again the rank is full and the market is complete.

In practice financial markets are not and cannot be complete, with the result that Pareto efficiency cannot be guaranteed. However, it is possible to move towards completeness by the introduction of new securities, thus making the achievement of Pareto efficiency more likely. The use of derivative instruments is particularly important in moving markets towards completeness, for, as Ross states

> "in general, it is less costly to market a derived asset generated by a primitive than to issue a new primitive." (Ross, 1976a, p76).

Thus in addition to introducing negative correlation and providing a cheap means of buying into the payoff profile of a broadly diversified portfolio, futures on stock indexes can help to move the market towards completeness.

A further important function of futures markets relates to their price discovery role. Since futures contracts are traded for delivery of an asset at various dates in the future, futures prices will reflect current market expectations concerning expected spot prices at the maturity dates. Hence, futures trading expands the information set available to market participants and such expanded information enables fund managers and investors in general to anticipate changes in demand and supply at some time in the future.

B. The Economics of Futures Trading.

B1.1 Introduction.

It has been shown in section A of this chapter that the prime function of futures markets is to provide a means by which risk can be hedged. In addition, it has been argued that futures have an important role to play in terms of price discovery. Finally, it has been seen that stock index futures can be used as a means of investment. While stock index futures may provide important benefits in these regards, they have also been heavily criticised for encouraging speculation and, the argument goes, destabilising the market for the underlying asset.

If the success of the FTSE-100 stock index futures contract is to be assessed, it is necessary to examine the way in which it performs in relation to the three functions mentioned above. Assessing the performance of the contract as a means of investment requires an examination of the risk return relationship which it offers. The price discovery role of the contract will be determined in large part by the efficiency of the market for the contract. As far as hedging is concerned, the performance of the contract will depend upon its ability to reduce the risk faced by investors. In addition, it is necessary to assess the impact, if any, of the onset of trading in this contract on the market for the underlying asset.

An assessment of these four issues in relation to the FTSE-100 contract forms the main part of this thesis in chapters 2 to 5. However, before going on to undertake analysis of these issues it is appropriate to examine previous work which addresses these questions. By doing this, the work to be carried out later in the thesis can build on the strengths of earlier studies and by recognising and learning from the weaknesses of that work, avoid the pitfalls. The following sections therefore review previous work relating to the issues identified above.

B1.2 The Risk Return Relationship in Futures Markets.

For any financial asset investors are likely to be crucially concerned with the risk return relationship which characterises that asset. In addition, given the central role of risk reduction in relation to futures contracts, the risk return relationship has been both a matter of considerable interest and of considerable disagreement. The search for a risk premium in futures prices in relation to expected spot prices has a long history (see, for example, Gray, 1961). However, the search has been inconclusive. For example, Telser (1958, 1960) and Cootner (1960) produced contradictory evidence regarding normal backwardation[11]. Hence, a divergence of opinion remains about the risks associated with futures transactions and the returns which they generate.

However, the development of portfolio theory and the capital asset pricing model (CAPM) provided a different means by which the risk return relationship in futures markets could be viewed. It is the fact that futures can be used as a means of investing that led Dusak (1973) to argue that futures could be viewed as a financial asset, much the same as any other financial asset. Dusak therefore argued that the risk return relationship associated with futures contracts should be examined within a CAPM framework.

Dusak's article has proved highly influential in the futures literature and has led to many studies which examine the futures risk return relationship within a CAPM framework. Given the special role of stock index futures in terms of investment opportunities and the widespread acceptance and use of the notion of systematic risk, it seems appropriate to consider these studies more fully and to examine the futures risk return relationship from the stand-point of nondiversifiable risk.

The first paper in which futures contracts were analysed within a CAPM framework was that by Dusak (1973). She estimated the market model, adapted for futures, using the value-weighted Standard and Poor Index of 500 (S&P 500) Common Stocks as a proxy for the market portfolio. Dusak estimated the equation for wheat, corn and soybean contracts over the period 1952 - 1967 and found the βs to be close to zero. Since mean returns on these contracts were also close to zero she concluded that commodity futures returns conform to the CAPM, with the contracts tested not being risky assets when held as part of a well diversified portfolio of assets.

Carter, Rausser and Schmitz (1983) (hereafter CRS) criticised Dusak for her choice of proxy for the market portfolio. CRS used an alternative proxy which gives equal weight to the S&P 500 stock index and the Dow-Jones commodity futures index. In addition to estimating the market model for corn, wheat and soybean contracts (the same as those used by Dusak) the equation is estimated for cotton and cattle futures markets. Although Dusak presents the analysis in her paper as different to the normal backwardation or contango approaches to futures pricing, CRS refer to her approach as the newer Dusak version of normal backwardation. Thus they emphasise that while the measure of risk is different from that discussed by Keynes, nonetheless the principle underlying the two approaches is the same. In contrast to the findings of Dusak the results of CRS

> "reveal significant and positive systematic risk for a number of futures contracts" (1983 p. 330).

Thus futures contracts are seen by CRS as being risky assets in systematic risk terms. In addition, they find that the degree of systematic risk is conditioned by whether speculators are net long or net short. They conclude that their results support the Keynesian theory of normal backwardation.

CRS were criticised by Marcus (1984) who argued that not only should the market index exclude futures contracts (since futures contracts have zero net aggregate supply), but also that even where a cash commodity index is included in the market proxy it should be given a much smaller weight (Marcus suggested a weight of .1). Following this criticism Baxter, Conine and Tamarkin (1985, hereafter BCT) included the Dow-Jones Commodity *Cash* Index in the market proxy, giving it a weight of 6.3% and the S&P 500 Index a weight of 93.7%. BCT report

> "As Marcus predicts, we obtain lower beta estimates than CRS. Moreover, the beta estimates we obtained are not significantly

> different from zero, which supports Dusak's results" (1985, p. 124).

So (1987) used a random coefficient approach to estimate the risk premium of commodity futures and obtained results consistent with those of Dusak. He argued that commodity futures are not risky assets in CAPM terminology.

Elam and Vaught (1988) estimated the levels of systematic risk for cattle and hog futures for the period 1975 - 85, using the weighting for the market proxy suggested by Marcus. Elam and Vaught's study is the first in the CAPM, futures literature to address the possibility of time to maturity influencing futures returns. Given a fixed delivery date, the time to maturity of each contract will change over time. As Chang, Chen and Chen (hereafter CCC) argue

> "Conceivably, failure to fix the maturity of the return time series may reduce the statistical significance of the beta estimates" (1990, p. 32).

In order to try to deal with this issue Elam and Vaught divide returns on cattle and hog futures contracts into six groups based on the time to maturity of the contract. The estimates of beta are all positive and small (although only 5 out of 12 are significantly different from zero). The average beta for cattle is 0.2 and for hogs 0.24.

CCC (1990) moved the analysis of futures returns within a CAPM framework beyond returns on agricultural commodities, by investigating returns on copper, platinum and silver futures. Like Elam and Vaught they try to deal with the problem of time to maturity. However, they do this by generating time series price data for artificial futures comprising a weighted average of two futures quotations for each commodity. The estimated betas are all positive and significant, with longer maturity betas having lower systematic risk. CCC therefore conclude that

> "all three metal futures . . . can be viewed as risky financial assets when they are held as part of a large portfolio of assets" (1990, p. 36).

A number of important points emerge from the above review of empirical work. Firstly, the choice of the market proxy is particularly important, since it appears that the proxy chosen can influence the estimated betas. Secondly, the results, while differing in terms of whether futures are risky in systematic risk terms, nonetheless suggest that futures pricing is consistent with the CAPM. Those futures which have low systematic risk offer low returns and those with higher systematic risk offer higher returns. Indeed, the finding that different futures have different levels of systematic risk is consistent with the CAPM. Thirdly, the time to maturity of a contract does appear to affect the extent of systematic risk of a futures contract.

However, there do appear to be shortcomings associated with these studies. Firstly, within the area of applying the CAPM to futures contracts there has been a concentration of research on commodity futures, rather than on the risk return trade-off associated with financial futures. Given that financial futures are more obviously akin to other financial assets than are commodity futures, this lack of research is surprising. Secondly, all of the studies which have used this methodology relate to futures markets in the USA. Thirdly, there is now considerable evidence indicating that there exists a day of the week effect, such that returns differ depending on the day of the week that they are realised. In particular, returns to Mondays and Fridays appear to differ from those to midweek days (see, for example, Dyl and Maberly (1986a, 1986b), Cornell (1985), Phillips-Patrick and Schneeweis (1988)). None of the studies applying the CAPM framework have attempted to address this issue. Given that any test of efficiency involves a joint test with an asset pricing model, and any test of an asset pricing model involves a joint test with market efficiency, it is surprising that this issue has not been addressed also. The final and most important shortcoming concerning the studies reviewed here relates to the methodology which has been used to examine futures within a CAPM framework. By estimating the market model for futures contracts and examining the risk and return characteristics these studies are essentially adopting the approach used first by Black, Jensen, and Scholes (1972) (hereafter BJS). This approach has been subject to considerable criticism by Roll (1977), who argued that the approach adopted by BJS (and subsequently by many others) is essentially tautological. This arises, argues Roll, because the same sample period is used both for estimation and for investigation and drawing inferences. This criticism applies to all of the studies reviewed in this section.

Given that stock index futures clearly provide a means by which investors can take up a position in the stock market it is important to further extend the CAPM framework beyond the bounds of agricultural and metal commodity futures. In addition, the shortcomings mentioned here need to be taken into account, as do the issues raised by previous studies.

B1.3 Futures Trading and the Underlying Spot Market.

In section A it was established that futures can be used as a means of investment and that the main advantages which futures contracts offer in this regard arise because of the low cost of participating in market index movements using futures, and because changes in market position can be implemented rapidly. While futures markets can be seen to be enhancing economic welfare by allowing investors to achieve higher indifference curves, they have been criticised for encouraging speculation. Goss and Yamey (1978b) point out that futures markets make a distinctive contribution to speculation since they allow individuals to undertake speculative activity without them having to become involved in the production, handling or processing of the commodity or asset.

In addition to this distinctive contribution, futures facilitate specialisation in speculation because of the standardised nature of futures contracts, as opposed to, for example, forward contracts. Further, transactions costs and the amount of funds which have to be committed are very low with futures. Due to the ease with which market participants can engage in speculation in futures markets, there has been considerable concern regarding the impact that futures markets might have on prices in the underlying spot market. Indeed, this concern dates back almost to the inception of futures trading.

One of the main reasons for this concern has been the popular belief among participants in the spot market that speculators in futures contracts will have a destabilising impact on spot prices. In contrast there have been a number of economists who have argued that the activities of speculators will have a stabilising impact on spot market prices. These arguments are examined shortly. In addition to generating much discussion at the theoretical level on the impact of futures trading, the issue has also been the subject of considerable empirical analysis and has received the repeated attention of policymakers.

One of the results of this close scrutiny is that futures markets in the USA have been subjected to substantial regulation (including, for example, the prohibition on trading in onion futures). In spite of the volume of research into this issue and the long history of conflict concerning the question of whether futures trading destabilises or stabilises the cash market, futures trading is still viewed with considerable suspicion by spot market participants and policymakers alike. For example, in the search for explanations of the stock market crash of October 1987 a number of culprits have been suggested. Among these have been program trading and futures trading. For example, the U.S. Securities and Exchange Commission (SEC) acknowledged that futures trading and strategies involving the use of futures contracts were not the sole cause of the crash, but argued that

> "Nevertheless, the existence of futures on stock indexes and the use of various strategies involving 'program trading' (i.e. index arbitrage, index substitution and portfolio insurance) were a significant factor in accelerating and exacerbating the decline." (U.S. Securities and Exchange Commission, 1988, p3-11).

Such suspicion has led to suggestions that futures trading should be further regulated, including, for example, higher margins. For example, the Brady Commission argues

> "...low futures margins allow investors to control large positions with low initial investments. The clear implication is that margin requirements affect intermarket risk and are not the private concern of a single market place... To protect the intermarket system, margins on stock index futures need to be consistent with margins for professional market participants in the stock market." (Report of the Presidential Task Force, 1988, p65).

Similarly, the SEC report on the crash called for higher margins. However, further regulation may have a negative impact on the working of financial markets and hence on economic welfare and it is therefore important to carefully consider whether such action is beneficial. Concern over the impact of speculators on the volatility of market prices predates the introduction of futures trading. The classical view of the impact of speculators is that they play a useful role and help to stabilise prices. For example, John Stuart Mill, in discussing the progress of society argues that

> "The safety and cheapness of communications, which enable a deficiency in one place to be supplied from the surplus of another...render the fluctuations of prices much less extreme than formerly...This effect is much promoted by the existence of large capitals, belonging to what are called speculative merchants...[T]he tendency of this operation [by speculators] is to equalise price, or at least to moderate its inequalities. The prices of things are neither so much depressed at one time, nor so much raised at another, as they would be if speculative dealers did not exist. Speculators, therefore, have a highly useful office in the economy of society" (1871[12], p276-7).

Mill goes on to suggest that this view of speculators is 'contrary to common opinion'.

Discussion of the impact of speculators intensified with the arrival of futures trading. The main reason for this is the fact that futures trading encourages speculation. Indeed, it can be argued that futures markets require speculators, to enable hedgers to transfer risks which they wish to avoid. In futures markets, transactions costs are low, capital requirements small (due to trading on margin) and delivery of the underlying commodity or instrument need not occur. Since futures prices have a very close relationship to prices in the underlying spot market, yet impose far fewer costs on speculators than would trading in the spot market, they are very attractive to those seeking to engage in speculative activity.

The opposing views on the impact of speculators are discussed by Kaldor (1960)[13], and Friedman (1953). Kaldor points out that traditionally speculation has been viewed as a process which evens out price fluctuations. This followed from the assumption that

> "...speculators are people of better than average foresight who step in as buyers whenever there is a temporary excess of supply over

> demand, and thereby moderate the price-fall; they step in as sellers, whenever there is a temporary deficiency of supply, and thereby moderate the price-rise." (Kaldor, 1960, p17-8).

This view of speculators clearly conforms to that of Mill, discussed above. Kaldor goes on to state that the idea that speculative activity might increase price fluctuations was not considered in traditional theory since this would require that speculative activity resulted in losses; selling when prices are low and buying when high. However, he argues that this view of the impact of speculative activity implies that speculative demand or supply accounts for only a small part of total demand or supply. If this is not true then while successful speculators must possess above average foresight, success can be achieved by the speculator forecasting the forecasts of other (less successful) speculators.

> "If the proportion of speculative transactions in the total is large, it may become...more profitable for the individual speculator to concentrate on forecasting the psychology of other speculators, rather than the trend of the non-speculative elements...[T]he losses of a floating population of unsuccessful speculators will be sufficient to maintain permanently a

> small body of successful speculators". (Kaldor, 1960, p19).

Thus it is possible for speculative activity to produce a net loss, with *some* speculators gaining, and at the same time destabilise the market. While Friedman (1953) accepts this point he argues that

> "Despite the prevailing opinion to the contrary, I am very dubious that in fact speculation... would be destabilizing... People who argue that speculation is generally destabilizing seldom realize that this is largely equivalent to saying that speculators lose money...[W]hile this may happen, it is hard to see why there is any presumption that it will; the presumption is rather the opposite." (Friedman, 1953, p175).

In spite of this 'presumption' criticism continues to be levelled at futures markets for encouraging speculation and, therefore (the argument goes), destabilising prices in the underlying spot market.

Given the situation as described above, it is necessary to turn to empirical evidence to try to ascertain whether futures trading stabilises or destabilises the underlying spot market. We therefore now review previous empirical studies examining the impact of futures trading on spot price volatility. The review is not exhaustive, given the large volume of studies which have been undertaken. Rather it seeks to identify the most important work in this area, together with the main techniques used to address the issue.

Literature exists which considers whether activity in futures markets has any impact on spot price volatility in periods of excessive price movements, such as the 1987 crash. However, in this thesis we are concerned with the impact of futures trading on spot price volatility for the whole period for which futures trading has taken place and not with specific events. As such comparisons are made of spot price volatility pre- and post-futures trading. Hence, the review of previous studies, in line with the review of theoretical issues above, does not include any discussion of the impact of futures trading on speculative bubbles, contagion, or specific events such as the 1987 stock market crash.

Due to the relatively short time for which financial futures have been available the earlier studies relate to commodity futures trading. However, given the focus of this thesis we will confine our review to financial futures. In addition, it should be noted that the attention of previous work in this area has been focussed almost exclusively on US futures markets.

The general approach which has been adopted when addressing this issue is to examine spot price volatility prior to the onset of futures trading and then to make comparisons with the volatility of spot prices post-futures. The general conclusion to emerge from these studies is that futures trading has either led to more stable spot prices or has had no discernable impact on spot prices. Research into the impact on spot price volatility of financial futures trading has concentrated on two instruments: Government National Mortgage Association (GNMA) certificates, and Stock Index futures. We will deal with these in turn.

Froewiss (1978), in an early study of the GNMA market, regressed the weekly percentage change in GNMA spot prices on the weekly percentage changes of Government bond prices to determine the variability of GNMA prices relative to that of bond prices. He argues that a rise in the coefficient after the beginning of futures trading will suggest that futures destabilise spot prices. The test for equality of coefficients suggests no change after the introduction of futures trading which Froewiss interprets as evidence of no change in the stability of spot prices post-futures. Froewiss goes on to use univariate Box-Jenkin analysis to further analyse the issue. Again the results suggest that spot price volatility had not been altered by the introduction of futures.

Figlewski (1981) constructs a monthly volatility series and regresses these volatilities on four factors: volatility in related markets (proxied by the 10-year bond volatility), market liquidity, the level of prices and futures market activity. In contrast to Froewiss, Figlewski concludes that futures trading in GNMA securities has led to increased price volatility in the cash market.

Simpson and Ireland (1982) investigated the spot price volatility of GNMA certificates before and after the introduction of futures by using standard regression analysis and a multivariate time series model with an intervention term. The regression analysis was carried out for both daily price changes and weekly price changes, with a dummy variable for futures trading being included in the equations. Tests of structural change were employed to ascertain whether the onset of futures trading had impacted on the dependent variable. The results of the analysis suggested that futures trading did not affect the volatility of spot prices either on a daily or a weekly basis.

A time series-intervention approach was adopted by Corgel and Gay (1984) to analyse the impact of futures trading on the GNMA spot market volatility. Corgel and Gay argue that intervention analysis is an appropriate technique for examining the impact of futures trading, since it

> "...allows direct focus on the dynamic characteristics of the response to the intervention [the introduction of futures trading] , such as the speed of adjustment, as well as the degree and nature of any over- or under-reaction." (1984, p181).

The results are in line with those of Froewiss (1978) and suggest that the introduction of futures trading has had a long-run stabilising effect on the volatility of the spot market.

Moriarty and Tosini (1985) use the same volatility measure and regression model employed by Figlewski (1981) to examine the validity of his results. Whereas Figlewski examined the period up to February 1979, Moriarty and Tosini extend the period of analysis to July 1983. In contrast to Figlewski (whose findings they refer to as 'unique in the futures literature') their results suggest that there is no evidence that the introduction of GNMA futures caused the volatility of the cash market to increase. They conclude that

> "...the GNMA cash and futures markets...experienced fundamental change during

this period [up to 1983] and that, as a consequence, the strength and significance of certain price relationships depend critically on the subperiod analyzed" (Moriarty and Tosini, 1985, p634).

While Figlewski and Moriarty and Tosini used monthly volatility measures, Bhattacharya et al (1986) calculated weekly volatility series for spot and futures prices. They sought to examine the influence of GNMA futures volatility on spot volatility using Granger's definition and methodology for testing for causality. While their results suggest that futures market volatility has some causal influence on cash market volatility, they say nothing about the question of whether futures trading has stabilised or destabilised the spot market.

Edwards (1988a and 1988b) analysed the impact of stock index futures trading on stock price volatility by examining the volatility of the stock market before and after the inception of futures trading. Volatility was measured as the variance of close-to-close percentage daily price changes. Edwards' results suggest that volatility had decreased post-futures for the S&P 500 and was not significantly different post-futures for the Value Line index, leading to the conclusion that there is no evidence that futures trading has had a long-run destabilising effect on the stock market.

Aggarwal (1988) regressed the returns on the stock index on the returns on the over the counter composite index and dummies relating to 'early and mature' futures periods. In addition, the regressions are repeated using return squared deviations in place of returns. The results suggest that while the post-futures period is more volatile, this is true for all markets and hence stock index futures may not be the primary cause of this increase.

Cross-sectional analysis of covariance methods are used by Harris (1989) to test for changes in stock index volatility since the onset of index futures trading. While the results are

> "...consistent with the hypothesis that trade in index futures...markets increases cash market volatility [s]upport for this conclusion...is circumstantial" (Harris, 1989, p1170-3).

Harris argues that other index related phenomena, such as the growth in foreign ownership of American equities and the growth in index funds, could account for the results.

A statistical method designed to highlight potential outliers is used by Becketti and Roberts (1990) to determine whether stock index futures have led to an increase in the frequency of jumps in daily stock returns. They find little or no relationship between stock market volatility and either the existence of, or the level of activity in, the stock index futures market.

Brorsen (1991) argues that stock price autocorrelation should be reduced by the introduction of futures trading, since such trading reduces market friction leading to prices adjusting more rapidly to new information. Using the Ljung-Box Q statistic results are obtained which are consistent with this argument. In addition, Brorsen argues that reducing market frictions increase the variance of short-run price changes. Homogeneity of variance for time periods before and after futures trading is tested. While the variance of daily price changes are significantly different, there is no significant difference in the variances of 5 and 20 day price changes.

Baldauf and Santoni (1991) have used an Autoregressive Conditional Heteroskedastic (ARCH) model to test for increased volatility in the stock index following the introduction of futures trading and program trading. They model the squared differences in the log of daily price changes as an ARCH process for periods before and after the onset of futures trading and test for changes in the parameters of the model. No evidence is found of a shift in the model's parameters suggesting that the inception of futures trading and program trading had no significant effect on volatility.

A number of serious problems relate to the studies reviewed above. Firstly and most importantly, the studies have tended to view the question about the impact of futures trading on spot price volatility from a narrow stabilising/destabilising stand-point. Crucially, with rare exceptions, these studies have not attempted to question why futures trading might impact on spot market price volatility and, in particular, have not examined the link between information and volatility. Indeed, while a number of different methodologies have been adopted to examine this stabilisation/destabilisation issue, it is questionable whether any of them are capable of addressing the link between information and volatility.

Another problem which emerges from the work of Figlewski (1981) and Moriarty and Tosini (1985), is that when using certain techniques to analyse the issue, the choice of time period for analysis may affect the results obtained. This arises due to problems of heteroskedasticity. It is therefore necessary to use a technique for analysing the impact of futures trading on spot price volatility which explicitly takes account of this problem.

Finally it is evident from the above review that it is necessary to filter out any market wide factors which might impact on spot market volatility in order that the impact of futures can be clearly identified. It is therefore necessary to adopt an approach which is capable of fulfilling this requirement.

B1.4 Price Discovery and Futures Market Efficiency.

It was argued earlier that futures markets have a crucial role to play in regard to price discovery. Prices in futures markets impart information regarding expected future spot prices. In addition, we have seen in the previous discussion that information is important in relation to spot market volatility.

If futures markets are to play a useful role in price discovery, in that they provide forecasts of future spot prices, then two conditions must hold. Firstly, market participants must, in aggregate, be risk neutral. If this condition holds then futures prices would be expected to provide unbiased estimates of future spot prices. If it does not hold then prices may follow a pattern of either normal backwardation or contango. Secondly, it is necessary that futures markets are efficient in that futures prices incorporate all relevant information. If they are not efficient, then even if the futures price does provide a market forecast of the expected future spot price, that forecast could be biased. Hence, in order to be able to assess the price discovery role of futures markets it is necessary to examine the question of futures market efficiency[14].

The issue of unbiasedness in futures prices and the efficiency of futures markets has been widely addressed for commodity futures and for foreign exchange forward contracts. However, there has been limited investigation of these issues for financial futures and, to the knowledge of the author, none of the efficiency/unbiasedness of stock index futures. Even for those markets which have received considerable attention, the question of efficiency remains unresolved due to differences in methodology and time periods examined. In addition, recent advances in econometrics have called into question the findings and implications of many of the previous studies. Nonetheless, in order to understand these problems and the issues which they raise it is necessary to briefly review previous studies.

A standard test of futures market efficiency involves regressing the spot price at maturity on the futures price some time prior to maturity, as in equation 1.3:

$$S_{t+n} = a + bF_{t,t+n} + e_t \qquad (1.3)$$

The joint test of market efficiency and the unbiasedness hypothesis implies that a=0 and b=1 in equation 1.3. Traditionally, this test of market efficiency and the unbiasedness hypothesis has been carried out using standard regression procedures, ordinary least squares. However, there are problems associated with using these tests due to the non-reliability of standard statistical tests in the presence of nonstationary data. These problems will be discussed more fully in chapter 4 when describing the approach to be used in this thesis for testing for the efficiency of the FTSE-100 stock index futures contract. The result of these problems is that more recently the cointegration procedure has been used to test for futures markets efficiency. This procedure will also be discussed in detail in chapter 4.

The joint test of market efficiency and the unbiasedness hypothesis applies equally to forward markets as well as to futures markets. Many studies of this joint hypothesis have been carried out with respect to forward foreign exchange rates. In addition, many of the early studies of both forward and futures markets efficiency were conducted using standard regression analysis (see, for example, Frenkel (1977, 1979), Geweke and Feige (1979), and Huang (1984)). Given the problems associated with standard regression analysis and the focus of this thesis on futures markets, the review of previous studies of the unbiasedness hypothesis and efficiency will concentrate on tests that fall into one or both of two categories: firstly, more recent studies which examine the joint hypothesis for *futures* markets will be reviewed, even when OLS has been used and; secondly, studies of forward market efficiency which use the cointegration procedure will be covered.

Goss (1981, 1986a)[15] explores the hypothesis that futures and spot prices are unbiased predictors of subsequent spot prices for four non-ferrous metals (copper, tin zinc and lead) traded on the London Metal Exchange (LME). The periods covered are 1971 - 1978 (in the 1981 paper) and 1966 - 1984 (1986a). He uses OLS and, in the case of serial correlation, instrumental variables estimation procedures. In the earlier paper he finds that the hypothesis of efficiency is accepted for the tin, copper and zinc markets, but not for the lead market. However, in the later paper for the longer period he finds that the unbiasedness hypothesis should only be rejected for the zinc market, at the 5% level of significance. At the 1% level the unbiasedness hypothesis is accepted for all four markets. Goss concludes

"The implications of this result are that agents using London Metal Exchange copper, tin and lead futures prices for decision purposes are as well off on average as if they had known the subsequent cash price in advance." (Goss, 1986a, p168).

Canarella and Pollard (1986) also examine the efficiency of the London Metal exchange. The period covered by the analysis is 1975 - 1983. Three approaches are adopted to test for market efficiency. Firstly, they use standard OLS to test the unbiasedness hypothesis. Secondly, using overlapping data they explicitly model the moving average process in the error structure using autoregressive moving average (ARMA) procedures. Thirdly, they use the full information maximum likelihood technique. The analysis is carried out in relation to the same metals as those studied by Goss. The results from all tests are consistent. Canarella and Pollard state

"The findings point to a convergence of empirical results, in that each separate test indicates that for all the commodity markets considered the hypothesis of speculative efficiency is not statistically rejected by the data. This suggests that any other variables...used to forecast spot prices contain

> no additional information beyond that contained in the value of the futures price." (Canarella and Pollard, 1986, p592).

Elam and Dixon (1988) argue that the standard OLS procedure is inappropriate for testing the joint hypothesis of efficiency and unbiasedness. The reason for this is that the time series used to test the hypothesis is non-stationary. This leads to the standard F-test of the restrictions $a=0$ and $b=1$ being inappropriate. They support their suggestions with evidence from Monte Carlo simulations. The issue of OLS being an inappropriate technique for carrying out the test of the joint hypothesis is discussed further in chapter 4. However, the points raised by Elam and Dixon are important and subsequently considerable work on the joint hypothesis has been undertaken using the cointegration technique. Use of this technique avoids the problems identified by Elam and Dixon.

MacDonald and Taylor (1989) investigate the presence of time-varying risk premia in the price series of the four metals traded on the LME which were investigated by Goss, conditional on the assumption of rationality. They argue that the problem of testing the standard joint hypothesis is that rejection of the hypothesis does not enable researchers to identify which part of the joint hypothesis is rejected. They argue that

> "Given that typical market participants in commodity markets are highly motivated, highly professional individuals with instant access to potentially vast information sets, it is perhaps natural to question the assumption of risk-neutrality rather than non-rationality....[However,] the evidence for the presence of time-varying premia was found to be weak, although some support *was* found for the presence of time-varying premia for tin and zinc." (MacDonald and Taylor, 1989, p151).

With the exception of Elam and Dixon (1988) all of the studies reviewed so far suffer from the fact that they use traditional hypothesis-testing procedures and do not test for stationarity of the data, a crucial assumption underlying the standard OLS procedure. However, the criticisms raised by Elam and Dixon have been addressed in more recent studies of the joint test of efficiency and the unbiasedness hypothesis.

Hakkio and Rush (1989) use the cointegration procedure to test the joint hypothesis of risk neutrality and the rational use of all available information in foreign exchange markets. They test to see if the series of spot prices at time t+1 cointegrates with the series of forward prices at time t. They point out that if the two series are not cointegrated then with probability one they will drift apart. The data used relates to spot and forward rates for the British pound and the German mark over the period July 1975 to October 1986. The authors report that the results of the tests

> "...generally lead us to believe that the spot and forward rates are cointegrated, which is consistent with the market being efficient." (Hakkio and Rush, 1989, p81).

However, by using error-correction equations they reject the joint hypothesis of no risk premium combined with efficient use of information for both the United Kingdom and Germany.

Barnhart and Szakmary (1991) also test the joint hypothesis using the cointegration procedure. They demonstrate that the conflicting results found in the literature depend upon the econometric specification used. The finding that spot and forward exchange rates for the United Kingdom, Germany, Japan and Canada over the period 1974 to 1988 have unit roots and are cointegrated rules out the use of certain standard econometric procedures. While the spot and forward series are found to cointegrate Barnhart and Szakmary reject the unbiasedness hypothesis on the basis of error correction models.

Lai and Lai (1991) also use the cointegration procedure to test for market efficiency in forward foreign exchange markets. However, unlike the two previous studies which have been reviewed, Lai and Lai utilise the Johansen approach to cointegration. This has the substantial advantage over the Engle and Granger procedure, which had previously been used, in that it allows formal testing of restrictions in the cointegrating regression. Thus unlike Hakkio and Rush and Barnhart and Szakmary, Lai and Lai are able to formally test the restriction that a=0 and b=1 in the cointegrating relationship.

Tests are carried out in respect of five currencies: the British pound, the Deutsche mark, the Swiss franc, the Canadian dollar and the Japanese yen. The period under analysis is July 1973 to December 1989. For all five currencies for which analysis is undertaken, the results suggest that the spot price at time t+1 and the futures price at time t are cointegrated. However, tests of the hypothesis that a=0 and b=1 indicate that the hypothesis is rejected for all five currencies at the 5% significance level. Thus, Lai and Lai report that the forward rate appears to be a biased predictor of the future spot rate.

Chowdhury (1991) addresses the hypothesis that the markets for copper, lead, tin and zinc in the LME are efficient by using the cointegration procedure. The sample period is July 1971 to June 1988. The empirical results indicate the presence of unit roots in the spot and futures prices for all four metals. Chowdhury points out that this raises serious concern regarding most of the previous studies of market efficiency for the LME which have used levels price series. The hypothesis that a=0 and b=1 in the cointegrating equation is rejected in each of the four markets. The futures price thus appears to be a biased predictor of the future spot price. These results are in sharp contrast to the findings of Goss and illustrate the need to account for non-stationarity in time series.

Antoniou and Foster (1992a) carry out tests of the unbiasedness hypothesis for coffee and cocoa futures using the Johansen cointegration procedure. Unlike previous studies they use three tests of market efficiency for different values of t-i for the futures contracts. The first test involves determining whether the spot and futures price series cointegrate, for the spot series at time t and the futures series at time t-i, where i=1, 2, 3, 6, and 8. For all values of i used and for both commodities tested the series cointegrate. They then test to see if b=1 in the cointegrating relationship. This second test of market efficiency is also accepted.

Antoniou and Foster argue that while these two findings suggest that futures prices are unbiased predictors of future spot prices in the long-term, this ignores the possibility of there being substantial deviations from this relationship in the short-term. They therefore argue that it is necessary to use error correction models to determine whether there is short-term efficiency. When restrictions on parameters of the error correction models are tested, the efficiency/ unbiasedness hypothesis is only accepted for one and two months prior to maturity for coffee and one month from maturity for cocoa. Antoniou and Foster argue on the basis of these results that all three tests of the joint hypothesis need to be carried out to determine whether futures prices provide unbiased predictors of future spot prices. They argue that previous studies, such as those by Chowdhury and Lai and Lai are deficient in that they miss out an important test of market efficiency.

This review of the empirical literature testing the efficiency of futures markets highlights a number of important points. Firstly, it is essential that the stationarity or otherwise of the price series is established before determining the estimation procedure to be used in analysing the issue of market efficiency. Secondly, if the price series are non-stationary then cointegration provides an appropriate technique by which to test for market efficiency. However, it is also evident from the above discussion that a finding of cointegration between the futures and spot price series, while being a necessary condition for market efficiency, is not a sufficient condition. It is also necessary to test for the restriction of the parameters in the cointegrating relationship to determine whether a=0 and b=1. This condition is also a necessary condition for futures market efficiency. However, Antoniou and Foster have also demonstrated the need to test for short-term efficiency by testing restrictions of the parameters in the error correction model. Failure to test for such restrictions may lead to the acceptance of efficiency and unbiasedness when there are in fact substantial deviations in the short-term.

Another point to emerge from the literature review of market efficiency and the unbiasedness hypothesis is that the approach to testing this joint hypothesis has been rather narrow. Emphasis has almost exclusively focussed on the question of whether a=0 and b=1 in equation 1.3. In recent years considerable attention has been given to price volatility in examining market efficiency (see, for example, Shiller (1979, 1981a, 1981b) LeRoy and Porter (1981), Kleidon (1986) and Mankiw, Romer and Shapiro (1985, 1991)). Evidence on price volatility has been used to reject the notion of market efficiency. For example, Shiller (1981a) argues that

> "measures of stock price volatility over the past century appear to be far too high... to be attributed to new information about future real dividends... The failure of the efficient markets model is thus so dramatic that it would seem impossible to attribute the failure to such things as data errors, price index problems, or changes in tax laws." (Shiller, 1981a, p433-4).

Given the widespread use of volatility or variance-bounds tests to examine stock market efficiency, it is surprising that similar tests have not been employed to examine the spot price - futures price relationship. Such tests would appear to offer an important additional means by which to examine the joint hypothesis of market efficiency and unbiasedness in futures markets. Therefore, in examining the joint hypothesis in relation to the FTSE-100 stock index futures contract in chapter 4, two approaches are adopted. Firstly, the cointegration procedure is employed to examine efficiency in both the long-term and the short-term. Secondly, variance-bounds tests are developed in relation to futures prices and used to test the joint hypothesis. This second means of testing the joint hypothesis will bring a new dimension to the testing of futures market efficiency in that it enables the important link between information and price volatility to be examined.

B1.5 Hedging with Stock Index Futures.

We now turn to an examination of the primary role of futures contracts, namely hedging. It was demonstrated in section A that hedging is the main reason for the existence of futures trading. Given this, it is not surprising to find that much research has been undertaken concerning the hedging performance of commodity futures and financial futures contracts. However, given the large volume of work in this area, this review will focus on studies of the hedging performance of stock index futures. All of these studies relate to stock index futures traded in the USA, reflecting the fact that stock index futures have been traded for a longer period in the USA than elsewhere and that the USA offers the largest market for these contracts.

Figlewski (1984) provides the starting point for research into the hedging performance of stock index futures. He is concerned with the issue of how effectively the Standard and Poor's 500 futures contract could be in hedging the risk associated with portfolios underlying five major stock indexes. The holding period of the hedges is one week and the period analysed is from 1 June 1982 to 30 September 1983. The five indexes differ in that while they all represent diversified portfolios, two include only the largest capitalization stocks, two include smaller companies and one is much less diversified than the other four, containing only 30 stocks of very large firms.

Figlewski constructs series of weekly returns for the five portfolios. Unlike many subsequent studies he includes dividends in these returns. The futures contract nearest to expiration was used in the analysis. This is common practice amongst researchers examining hedging performance due to this contract being the most liquid of the contracts traded. The minimum variance hedge ratio and the beta hedge ratio are calculated for hedging each of the five stock indexes.

For all five indexes, hedge performance is less good using the beta hedge ratio than the minimum variance hedge ratio, with mean return being smaller and residual risk larger. For the three indexes which have underlying portfolios of large capitalization stocks, risk is reduced by between seventy and eighty percent as a result of using a minimum variance hedging strategy. Returns using this hedging strategy are in the region of the risk free rate. For the indexes which include smaller stocks, and hence more unsystematic risk, hedging effectiveness is considerably reduced.

Figlewski also examines whether the exclusion of dividends from the returns data affects hedging performance, whether the holding period of the hedge is important and whether the time to expiration of the futures contract influences hedging performance. He finds that dividend risk is of little significance, probably due to dividends being relatively stable. As far as hedge duration is concerned, hedging performance is less good for overnight hedges than for one week and four week hedges. However, four week hedges are not noticeably more effective than one week hedges. For times to expiration of the futures contract of between zero and one month and one and two months hedging performance changes little. However, for hedges where time to expiration is between two and three months hedging effectiveness is reduced.

The issue of hedging with stock index futures is also examined in Figlewski (1985). In this paper he examines the hedging performance of three stock index futures contracts (those relating to the Value Line Composite Index, the S&P 500 Index and the NYSE Composite Index) over holding periods varying from one day to three weeks. The portfolios to be hedged are the same as those in Figlewski (1984), but the time period covered only relates to the last seven months of 1982, thus eliminating the very earliest time period in which the futures contracts were being traded. While there are 153 observations for overnight hedges, for the analysis of three week hedges there are only 10 observations.

Figlewski finds that for the two major index portfolios beta hedges of very short durations (1, 2, and 3 days) were not very effective, but that risk reduction improved as the holding period extended to a number of weeks. Interestingly, there was no clear advantage between futures contracts as regards hedging the indexes. In other words, the contract underlying its own index was no better at hedging than was the contract underlying another index. For both beta and minimum variance hedges three-week hedges perform less well than two-week hedges. Figlewski attributes this finding to sampling error due to the small number of observations.

As in his earlier paper the hedging effectiveness of the futures relating to the indexes including smaller stocks is less good and the futures for the portfolio of only 30 stocks was most effective. Figlewski also finds that the risk minimising hedge ratio is well below the beta. Hedge ratios tended to increase and unhedgeable risk to decrease with longer duration hedges.

Junkus and Lee (1985) test the applicability of four traditional commodity hedging models to stock index futures contracts for three exchanges in the USA. The models tested are: the classic 'one-to-one' hedge; the Working hedge strategy; the Johnson minimum variance strategy and; the Rutledge utility hedge strategy[16]. The period examined is 31 May 1982 to 1 March 1983. Hedge ratios were estimated using three different contract maturities: the closest to maturity, the farthest from maturity and an intermediate contract. The portfolio to be hedged is assumed to be the index portfolio underlying the futures contract. Considerable differences were found between the four hedging strategies, with some of the behaviour resembling speculation. Indeed, the classic hedge sometimes resulted in a larger variance position than the unhedged portfolio. While Junkus and Lee argue that hedging motivation is of crucial importance in determining hedging strategies and hence hedge ratios, they find that the Johnson strategy is the most effective of the four examined in reducing the variance of the long portfolio position.

Peters (1986) derives risk-return equations for hedged portfolios by combining the single-index market model for the spot market with the cost of carry model for the futures position. He finds that the minimum variance hedge ratio minimises overall risk, in contrast to the beta hedge ratio which maintains full exposure to basis risk. As in the paper by Figlewski (1984) the hedging performance of the minimum variance hedge ratio is examined, using the S&P 500 futures contracts. The three portfolios with the stocks with largest capitalisation used in the Figlewski study are used here, for the period 15 March 1984 to 31 March 1985. Peters points out that this period is one of lower volatility than the period analysed by Figlewski. Daily returns are used, rather than weekly returns. The theoretical argument concerning the superiority of the minimum variance hedge ratio over the beta hedge is confirmed by the empirical results. Peters argues that the results imply that for practitioners who want to hedge an equity portfolio the beta is not a true hedge ratio.

Graham and Jennings (1987) examine the hedging performance of the S&P 500 futures contract when used to hedge equity portfolios of ten stocks. Random sampling techniques are used to form portfolios which differ in terms of systematic risk and dividend yield. The data relates to the period from April 1982 to December 1983, yielding 87 weekly observations. Three hedging strategies are compared: the one-to-one hedge, the beta hedge, and the minimum variance hedge. Hedge durations of 1, 2, and 4 weeks are examined for 90 cash equity portfolios.

As far as return retention is concerned, the minimum variance hedging strategy dominates for all hedge periods for all portfolios, i.e more of the unhedged return is retained using this hedge strategy. The 4 week hedge retains more of the returns than the shorter hedges. In relation to risk reduction, the minimum variance hedge ratio is best for 1 week hedges in all beta/dividend yield categories. For 2 week hedges the minimum variance hedge is again superior except for high beta portfolios, where the one-to-one hedge dominates. The results for the 4 week hedge are similar to those for the 1 week hedges. The other main findings of the study are that stock index futures are less than half as effective at hedging nonindex portfolios as they are at hedging indexes and that the hedge ratios vary considerably depending upon the level of systematic risk and dividend yield.

Malliaris and Urrutia (1991) argue that previous studies of the hedging performance of futures markets are subject to criticism because they implicitly assume that the estimated hedge ratio is stable over the period analysed. They suggest that there is evidence that foreign currency futures hedge ratios are unstable and therefore believe that the stationarity of both hedge ratios and measures of hedging effectiveness needs further investigation. To achieve this end they test the hypothesis that hedge ratios and measures of hedging effectiveness for futures contracts follow a random walk. The hypothesis is tested for the S&P 500 futures contract and five foreign currency futures contracts. In order to test for random walk it is first of all necessary to estimate series of hedge ratios and measures of hedging effectiveness. This is done by running OLS regressions of the change in the spot price on the change in the futures price using the moving window regression procedure. Estimates of hedge ratios and measures of hedging effectiveness (R^2's) are estimated initially for a one year period and subsequently reestimated every quarter using the moving window procedure. For the stock index futures the time period under investigation is 1 January 1984 to 27 December 1988. The holding period of the hedges are two weeks. Having thus obtained the series, they are tested for random walk using both the Dickey-Fuller methodology and the variance ratio test of Lo and MacKinlay.

The authors find that for stock index futures the hedge ratios and measures of hedging effectiveness estimated by means of the moving window regression procedure, deviate substantially from the averages estimated for the whole sample period. They argue that this is indicative of instability over time. Both tests of random walk confirm this impression, suggesting that both hedge ratios and measures of hedging effectiveness follow a random walk. (This is true for the stock index and foreign currency futures tested.) Malliaris and Urrutia argue that the major implication of their results is that it is not possible to place perfect hedges and therefore hedgers need to continuously readjust their positions. However, they point out that such a dynamic hedging strategy may actually be more costly than traditional hedging because continual readjustment of the futures position will lead to higher transactions costs. Hence, it is necessary to compare the increased transactions costs with the costs of non-perfect hedging due to the use of static hedge ratios.

Lindahl (1992) also addresses the question of the stability of the hedge ratio. She examines hedge ratio stability for the MMI and S&P 500 stock index futures contracts with respect to hedge durations and the time to contract expiration. Hedge durations of 1, 2 and 4 weeks are compared and these are further broken down by the number of weeks remaining to contract expiration. Hedges lifted between 0 and 12 weeks prior to expiration are examined. As in other studies, minimum variance hedge ratios are estimated by regressing spot price changes against futures price changes. The hedges are nonoverlapping and the data relates to 1985 - 1989 for the MMI futures and to 1983 - 1989 for the S&P 500.

Lindahl's results suggest that both the hedge ratios and the measures of hedging effectiveness increase as duration increases. In addition, the hedge ratios increase towards one (the beta hedge ratio) as hedges are lifted closer to expiration. However, the values of R^2 show no increasing pattern as expiration approaches. Multiple regression results confirm the pattern demonstrated in the simple regressions, with lower values of the minimum variance hedge ratio the farther away the hedge is from expiration. The results hold for both the MMI and the S&P 500 futures contracts.

Previous empirical studies illustrate a number of issues of interest in examining the hedging performance of stock index futures contracts. Firstly, there is no evidence that dividends play an important part in the risk associated with a hedged position. Hence, it is now accepted practice to estimate hedge ratios without including dividends. Secondly, it has been established that the minimum variance hedge ratio is superior to the beta hedge ratio in terms of risk reduction and returns retention. In addition, there is clear evidence that hedge ratios are not stable over time. Of particular importance in this regard is the duration of the hedge and the time left between lifting the hedge and the expiration of the futures contract.

While these issues have been examined in relation to stock index futures traded in the USA, similar analysis has not been carried out in relation to the FTSE-100 stock index contract. In addition, a major shortcoming can be identified in relation to *all* of the previous studies. In every study which examines the hedging performance of stock index futures, the effectiveness of the *optimal* hedge (in terms of minimising risk) is evaluated. In doing this it is implicitly assumed that the hedger has perfect foresight with respect to the spot and futures prices (and thus the basis) and can thus estimate the optimal hedge for the coming period.

However, as Malliaris and Urrutia (1991) show, hedge ratios change over time. In deciding upon the hedge strategy to implement in the coming period, the decision maker only has historical information. It is therefore important to consider how a hedger might choose a hedging strategy for the coming period in the absence of perfect foresight. In addition, it is of considerable interest to compare the hedging effectiveness of a hedging strategy based on historical information, with the performance of the optimal (perfect foresight) hedge strategy. Unlike all previous studies, this issue is examined and comparisons made in chapter 5.

B1.6 Conclusion.

In this chapter we have examined the main economic functions of futures markets and identified issues relating to those functions which require further investigation. The functions have been examined in terms of both the theoretical issues and previous empirical research in the area. Futures markets have been shown to introduce negative correlation, reduce uncertainty, move markets towards completeness and enable investors and speculators to increase their utility and thus attain higher indifference curves. In none of the areas of interest which have been identified has there been research undertaken on the FTSE-100 stock index futures contract. In addition, the issues identified are of direct relevance to investors, regulators, the government and the general public.

One of the major functions of futures contracts relates to risk reduction. In addition, it has been demonstrated that stock index futures play an important role as a means of investment and changing market timing. It is therefore evident that the risk return relationship is of central importance when examining futures contracts. The CAPM approach has been adopted to investigate this relationship for commodity futures traded in the USA. However, no such work has been carried out in relation to financial futures and none for futures traded in the UK. It therefore appears worthwhile to examine the FTSE-100 stock index futures contract within a CAPM framework. This is done in chapter 2. In addition, there is evidence of a day of the week effect in futures prices. We therefore also investigate this phenomenon within the CAPM approach in chapter 2. This issue has not previously been addressed in this manner. Finally, the methodology adopted in previous studies has been called into question by Roll (1977). In addition to carrying out work along similar lines to that carried out for commodity futures in the USA, an alternative methodology which overcomes this criticism is also employed in chapter 2.

The question of the impact of the onset of futures trading on the underlying spot market is a matter of considerable concern and conflict with a long history. The concern emanates from the belief by some that futures trading affects the volatility of spot prices. The debate about this issue is characterised in terms of futures trading either stabilising or destabilising spot prices. Previous studies of this issue have failed to use techniques which can deal with problems of heteroskedasticity in the data. More importantly, however, they have failed to take account of the link between information and volatility. In chapter 3 we investigate the impact of the onset of trading in the FTSE-100 futures contract on the underlying spot market, a market which has not previously been examined in this regard. In doing this a technique is employed which is capable of dealing with the problems caused by heteroskedasticity, and more importantly which allows direct consideration of the link between information and volatility. In view of the controversy surrounding the impact of futures trading and the calls for further regulation following the crash of 1987, this issue is of direct concern to policymakers and market participants alike.

The efficiency of futures markets has been shown to be of crucial importance to the price discovery role which futures play. In addition, it has implications for the confidence of investors in using the instruments to hedge the risks they face. In this regard, a number of studies have been undertaken to examine the joint hypothesis of efficiency and unbiasedness. However, many of these studies can be criticised for using techniques which fail to take account of non-stationarity in the price series data and as a consequence the results of these studies are unreliable. More recently, investigations of the joint hypothesis have been undertaken using the cointegration technique which does allow reliable results to be obtained in the presence of non-stationary data. However, these studies do not test all of the implications of the joint hypothesis and as such do not tell the whole story.

In chapter 4 we investigate the joint hypothesis for the FTSE-100 contract, using the Johansen cointegration technique. This joint hypothesis has not previously been tested for this contract. In addition, we extend the tests of the joint hypothesis by developing and utilising variance-bounds tests which have not previously been applied to futures contracts.

Arguably the most important function of futures contracts relates to the reduction of risk through the adoption of hedging strategies. The hedging effectiveness of futures is therefore of central concern to the question of whether a particular contract is a success. This is an issue which has been widely examined for stock index futures in the USA. However, the hedging performance of the FTSE-100 contract has not been examined. In chapter 5 the hedging performance of this contract is evaluated. The impact of time to maturity and hedge duration on hedging effectiveness is examined, as is the stability of hedge ratios through time. However, in addition, we examine the effectiveness of hedging strategies based on historical information and compare these with the performance of optimal hedges. This is an issue which has not been examined in any earlier study.

It is evident from the above discussion that the investigation carried out in the next four chapters makes a significant original contribution to the literature. In addition to undertaking research which has not previously been carried out in relation to the FTSE-100 stock index futures contract, where previous research forms the base for the work carried out here, the problems relating to that research are addressed. The work in this thesis uses techniques which overcome many of the problems associated with previous work. Furthermore, for each issue addressed significant developments are made in relation to earlier work.

Footnotes.

1. Knight (1921) distinguishes between risk and uncertainty on the basis of whether or not the probability of each possible outcome is known. If the probabilities are known, this describes a situation of risk. If they are not known, then a situation of uncertainty is said to exist. However, in the economics literature in general, and the finance literature in particular, this distinction is ignored and the terms risk and uncertainty are used interchangeably.

2. Futures contracts and forward contracts have strong similarities. Essentially, a forward contract is a 'made to measure' contract, whereas a futures contract is 'off the peg'. Unlike forward contracts, futures are characterised by:
   (a) standardised contracts;
   (b) trading through organised exchanges;
   (c) the existence of a clearing house; and
   (d) specific margin requirements.

   All of these characteristics assist the liquidity of futures markets. These distinguishing characteristics are discussed in many good texts. See, for example, Kolb (1988) and Tucker (1991).

3. A futures contract on the FTSE Eurotrack index was introduced in 1991. However, this contract relates to a portfolio of major european securities.

4. The FTSE-100 index is a weighted arithmetic index of the 100 largest listed firms by capitalisation. It has been specifically designed to mirror real investment portfolios and to this end includes service and manufacturing companies. The FTSE-100 was introduced in January 1984 specifically to enable futures and options contracts on a stock index to be established in the UK. The FTSE-100 is officially updated every minute and some security houses update the index continuously. The FTSE-100 index is now the most widely used benchmark of the UK equity market.

5. The month in which the contract expires or matures is known as the delivery month, even though with stock index futures cash settlement takes place, rather than delivery of the underlying asset.

6. For an index value of 2600 the initial margin represents 3.8%, i.e. 2500/(25x2600).

7. The basis is the difference between the price of the futures contract and the price of the instrument in the spot market.

8. The arbitrage arguments concerning stock index futures and the reasons why futures prices might deviate from their theoretical level, thus creating an arbitrage window, are explained in detail in Yadav and Pope (1990).

9. Ross refers to marketed capital assets such as shares of stock and bonds as primitives (1976a, p76).

10. The market is complete when the rank is full. This requires that there be as many linearly independent securities as there are states of the world. Linear independence can be established by examination of the determinant of the matrix. Given that the determinant of this matrix is not equal to zero, the matrix is nonsingular and hence there is linear independence.

11. If a risk premium has to be paid to speculators to encourage them to go net long then the futures price will be below the expected future spot price. This is known as normal backwardation and is associated with the view of Keynes (1930) and Hicks (1946). In contrast, if a risk premium has to be paid to encourage speculators to go net short, the futures price will be above the expected future spot price. This is referred to as contango. These patterns of prices are demonstrated in figure 1.4.

12. This passage is unchanged from the first edition published in 1848.

13. Chapter 1 of this book was first published in the Review of Economic Studies, 1939.

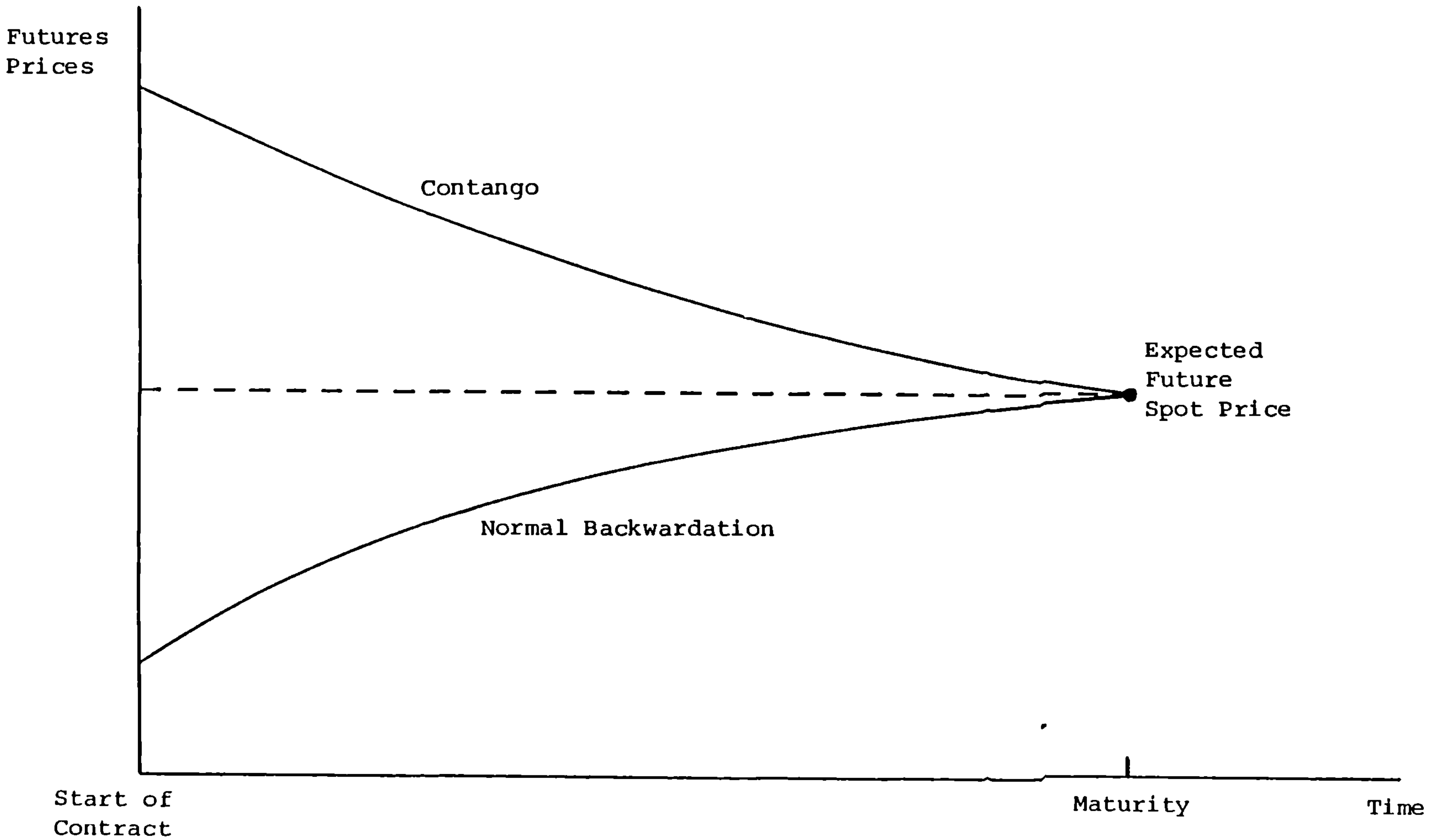
14. For a thorough and extremely interesting discussion of the issues of market efficiency and the efficient markets hypothesis see Fama (1970, 1991).

15. The 1986 paper by Goss is an updated version of that of 1981, including an extended sample period. Otherwise the two papers are very similar.

16. The Rutledge hedge is explained on page 276.

Figure 1.4

Patterns of Futures Prices



Chapter 2: Risk and Return in Stock Index Futures.

2.1 Introduction.

In chapter 1 it was seen that the risk return relationship in futures markets is of considerable interest, and that, following Dusak (1973), the CAPM framework has provided a means by which to investigate this relationship in a manner which is compatible with modern finance theory. The literature review of CAPM studies of commodity futures highlighted a number of important points and also demonstrated that there are a number of shortcomings associated with previous studies.

In this chapter we investigate the risk return characteristics of the FTSE-100 stock index futures contract over the period 1985 to 1990, taking account of the major shortcomings of previous studies. The main purpose of this analysis is to establish whether this contract can be viewed as a risky asset within a CAPM framework by estimating the market model, as adapted for futures. If it is found that such a relationship does exist then the FTSE-100 stock index contract can be viewed as a risky asset in systematic risk terms and it would suggest that the unbiasedness hypothesis may not hold.[1] If on the other hand, no such relationship is found, then it is more likely that the unbiasedness hypothesis will hold. Black (1976) makes this point arguing that if the covariance of returns on the futures contract with returns on the market portfolio is zero, the expected change in the futures price will be zero and the futures price will be an unbiased predictor of the future spot price. However, Black goes on to argue that even if there is a non-zero beta, investment decisions could be taken as if beta were zero. While acknowledging that with a non-zero beta it is necessary to know the value of beta (β^*) to estimate futures price changes, and thus spot prices at maturity, he argues that

> "A farmer may not want to know the mean of the distribution of possible spot prices at time t^* [contract maturity]. He may be interested in the discounted value of the distribution of possible spot prices. In fact, it seems plausible that he can make his investment decisions as if β^* were zero, even if it is not zero. He can assume that the β^* is zero and *that the futures price is the expected spot price*." (Black, 1976, p174, emphasis added).

The reason for this is that by taking up an appropriate offsetting position in the futures market the farmer (or indeed, an investor) can establish an overall portfolio with a beta of zero. Hence, evidence of a non-zero beta is not evidence of normal backwardation or contango. For that reason, following on from the findings of this chapter, a direct test of the expectations approach and market efficiency is presented in chapter 4.

Given the evidence relating to possible day of the week effects in futures markets, this chapter estimates the market model for weekly returns to Monday, Wednesday and Friday. By doing so it is hoped to identify any differences in the returns to the stock index futures contract relating to day of the week. In addition, the market model is estimated for futures contracts with different times to maturity to see if there are any differences between contracts which differ in terms of this characteristic. The sample period is also partitioned into sub-periods relating to before and after October 1987 to investigate whether there are differences resulting from the stock market crash of that time. Finally, Roll's (1977) criticism of the Black, Jensen and Scholes (BJS) approach to empirical tests of the CAPM is addressed. In addition to following the procedure for testing the CAPM which has been used in all previous studies of futures markets, an alternative methodology is also adopted. This methodology follows that of Fama and MacBeth (1973). Such an approach has not previously been employed for studying the risk return relationship in futures contracts.

The chapter proceeds as follows. The next section discusses the CAPM as appropriate to futures markets.

Section 2.3 presents the data used in this analysis, and section 2.4 sets out the methodology and the reasons for employing the approach used. Section 2.5 examines preliminary results relating to returns, risk and time to maturity. This is followed by the major empirical results in section 2.6. A conclusion follows which also details issues raised in this chapter to be discussed later in the thesis.

2.2 The Capital Asset Pricing Model and Futures Markets.

In a seminal article published in 1964 Sharpe developed a model for pricing assets held as part of a widely diversified portfolio. Sharpe argued that

> "Through diversification, some of the risk inherent in an asset can be avoided so that its total risk is obviously not the relevant influence on its price; unfortunately little has been said concerning the particular risk component which is relevant." (Sharpe, 1964, p426).

Sharpe addresses this lack of theory and puts forward a model of the determination of capital asset prices. The CAPM was subsequently developed further by Lintner (1965), Mossin (1966) and Black (1972). Sharpe derives a linear relationship between the expected return of an asset and the systematic (non-diversifiable) risk associated with that asset. That linear relationship is known as the CAPM and can be written as:

$$E(R_i) = R_f + [E(R_m) - R_f]\beta_i \qquad (2.1)$$

where R_i is the return on asset i, $E(R_i)$ is the expected value of that return, R_f is the risk-free rate of interest, R_m is the return on the market portfolio which contains all assets, $E(R_m)$ is its expected value and β_i is a measure of the systematic or non-diversifiable risk and is measured as $Cov(R_i,R_m)/Var(R_m)$.

The CAPM says that the return on any capital asset is made up of a risk-free rate of return plus an additional return to compensate for risk. This additional return comprises the risk premium $(E(R_m) - R_f)$ multiplied by the level of systematic risk, β_i. In terms of futures markets the CAPM implies that holders of futures contracts will only earn above the risk-free rate of return if there is positive systematic risk associated with those contracts, i.e. if there is positive covariance between the returns on futures and the returns on the market portfolio.

Dusak (1973) was the first to recognise this arguing that

"...futures markets are no different in

> principle from the markets for other risky portfolio assets... differences in form should not obscure the fundamental properties that futures market assets share with other investment instruments: in particular, they are all candidates for inclusion in the investor's portfolio." (Dusak, 1973, p1388).

Dusak therefore set out to examine whether futures markets provide a risk premium within the context of the CAPM. However, she points out that

> "One difficulty in applying the Sharpe model of capital asset pricing to the risk-return relation on futures contracts is that of defining the appropriate capital asset and its rate of return." (Dusak, 1973, p1390-1391).

This difficulty arises because futures are traded on margin, meaning that the purchaser of a futures contract will typically only have to provide 5 to 10 per cent of the value of the contract as a deposit. However, this deposit is not a down payment, but rather it is 'good-faith' money to demonstrate that the contractual obligations will be adhered to. In addition, the margin can be deposited in the form of interest-bearing assets. Consequently, at the time the contract is entered into, the party to the contract is not having to put up capital in the normal sense of the phrase and hence is not forgoing any risk-free rate of return. As a result equation 2.1 needs to be modified before it can be applied to futures. Equation 2.2 presents the appropriate form for the CAPM as applied to futures:

$$E(R_i) = \beta_i[E(R_m) - R_f] \qquad (2.2)$$

As can be seen, the only difference between equations 2.1 and 2.2 is that the latter does not have the intercept term R_f.[2]

However, equation 2.2 cannot be estimated directly. Rather it is necessary to transform equation 2.2 from an *ex ante* model to a model which is capable of determining βs through empirical estimation. This is achieved by firstly taking the market model, adapted for futures:

$$R_{it} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + \varepsilon_t \qquad (2.3)$$

Where R_{it} is the return for futures contracts. Note that this is equivalent to the normal market model except that the left hand side of equation 2.3 has total returns rather than returns in excess of the risk free rate.

Taking expectations of equation 2.3 yields:

$$E(R_i) = \alpha_i + \beta_i E(R_{mt} - R_{ft})$$

Thus:

$$E(R_i) - \alpha_i - \beta_i E(R_{mt} - R_{ft}) = 0$$

Adding this equation to the right hand side of 2.3 and rearranging yields:

$$R_{it} = E(R_i) + \beta_i[(R_{mt} - R_{ft}) - E(R_{mt} - R_{ft})] + \varepsilon_{it}$$

Substituting for $E(R_i)$ from equation 2.2 and rearranging yields:

$$R_{it} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + \varepsilon_t \qquad (2.3)$$

which is an ex post form of the CAPM model.

Within a CAPM framework the finding of a β value significantly positive and different from zero suggests that futures are a risky asset in systematic risk terms. Therefore if CAPM is correct, assets with a significant positive β should offer a positive return. In other words, it would be expected that futures prices, on average, rise over the life of a contract. Clearly, although the CAPM framework approaches the question from a different stand-point, if significant systematic risk is found, then this would appear to be consistent with the concept of normal backwardation. However, it should be noted that when Keynes considered rising futures prices as a result of futures being risky assets he was considering total risk, rather than nondiversifiable risk.

It is equation 2.3 which has been estimated by the studies reviewed in the previous chapter, with inferences being drawn on the basis of the estimated beta values. However, this approach is subject to the criticism put forward by Roll (1977) that tests based on the approaches of Black, Jensen and Scholes (1973,) and Fama and MacBeth (1974, hereafter FM) are tautological. However, the FM approach has been defended against this criticism. To understand these arguments it is important to distinguish between the two methodologies.

With the BJS approach betas and average rates of return are computed in the same periods of time. This is consistent with the approach adopted by Dusak and others.[3] However, with the FM approach betas and returns are computed for different sample periods. Betas are estimated for one period and these estimated values are then used to predict rates of return in a subsequent period. While Roll's criticism that tests are tautological may be relevant to the BJS approach, it is not true of the FM methodology. The reason for this is that tautologies are definitional and as such will have no predictive ability. In contrast, the FM approach tests the CAPM by using estimated betas from one period to predict future returns. In this study both the BJS and the FM approach are therefore adopted.

2.3 Data.

In this study betas are estimated for the LIFFE FTSE-100 stock index futures contract using the market model adjusted for futures (equation 2.3). There are three stages in the analysis in this chapter. These are discussed in the next section. Here we set out and discuss the data used in these three stages.

In all three stages the model is estimated for weekly returns. The CAPM provides no insight into what the appropriate interval for analysis should be. It therefore becomes a matter of practicality. It is clearly possible to use any interval for which data is available. Thus, for the analysis carried out here, it would have been possible to use daily, weekly, biweekly, triweekly, monthly or even longer intervals. There has been considerable discussion of whether the length of intervals affects the beta estimates.[4] Levhari and Levy (1977) calculated betas for stocks over the period 1948 to 1968 using intervals of between one and thirty months. They found very considerable differences in estimated betas as the interval varied. Hawawini (1983) carried out estimates of betas for shorter intervals, ranging from one day to one month. The period analysed was 1970 to 1973. He similarly found considerable differences in the estimated betas. Thus, it is clear that beta estimates may be sensitive to the interval used in the analysis.

Monthly intervals have frequently been used in studies of stocks. However, given that one of the concerns in this chapter is to investigate the possibility of day of the week effects, the use of monthly (or longer) returns is inappropriate. As far as daily returns are concerned, these too seem inappropriate given the fact that hedgers would not typically hold their position for periods of less than one week. Weekly returns therefore appear to be the most appropriate for the analysis to be carried out here. One of the main reasons for not using weekly (or shorter interval) data in studies of individual stocks has been that some stocks are not widely traded and thus week end data can therefore be an inappropriate measure of true price. This is not a problem with the data to be used here.

There are four FTSE-100 Index futures contracts traded in each year with settlement taking place in March, June, September and December. Closing prices for Monday, Wednesday and Friday were obtained for these contracts over the period January 1985 to December 1990. This data was then used to construct three series of *weekly* returns relating to the three days of the week under consideration. The closing futures prices were transformed into returns data according to equation 2.4:

$$R_{it} = \ln(P_{it}/P_{it-1}) \qquad (2.4)$$

where P_{it} and P_{it-1} are the closing futures prices for contract i at times t and t-1, respectively. Thus, R_{it} is the log relative weekly return for futures contracts.

In addition to the interval used for estimating betas being of potential impact on the values estimated, other factors can influence the values obtained. In particular, there are potential problems relating to the proxy for the risk free rate, the measurement period and, most importantly in this case, the proxy for the market portfolio. Each of these is now considered in turn.

As far as the risk-free rate is concerned Harrington (1987) states

> "The risk-free rate (R_f) is the least discussed of the three CAPM factors. Whether in academic research or in practical applications of the CAPM, the 90-day Treasury bill rate has been

virtually the only proxy used for the risk-free asset. Remember that this rate is only a proxy for the risk-free rate, which must be estimated, just as beta and the market return must be." (p149).

Harrington goes on to argue that there are both theoretical and practical problems associated with using the Treasury bill as a proxy. With regard to theoretical problems she points out that the risk-free proxy should have no variance and no covariance with returns from the market. Zero variance can, however, only exist for a one-period world. With more than one time period, there will be variances in risk-free returns and there will thus be some reinvestment risk. As far as practical problems are concerned the Treasury bill rate is not a pure market rate (it is partly influenced by the government through control of either interest rates directly or the money supply) and rates are volatile, partly due to changes in inflation.

In spite of these criticisms, Harrington acknowledges that there is no clear answer to the question relating to which proxy to use. She points out that the 30- and 90-day Treasury bill rates are the most widely used proxies and that the choice of proxy is up to the practitioner.

While acknowledging the problems of using short-term Treasury bill rates, there does not appear to be a superior alternative to be used. For this reason, in this study we use the UK Treasury bill one-month middle rate adjusted to a weekly figure as a proxy for the risk-free interest rate. By choosing the one-month rate, an interest rate for an interval closest to that over which betas are being estimated is obtained.

As far as the measurement period is concerned, it is necessary to ensure that enough observations are available to allow a statistically significant sample. In addition, the period should not be too long as this might mask significant changes throughout the period. The period for which analysis is carried out in this study is from 4 January 1985 to 28 December 1990. The first eight months for which futures on this contract were traded (May 1984 - December 1984) are excluded from the analysis to ensure that there is no bias due to possible mispricing in the early months of the contract. With the exception of these eight months of data, all the data available at the time the analysis was carried out is used. This yields approximately 300 observations. In addition, following tests for structural breaks, the data is partitioned at the crash of October 1987, to allow for differences in betas in different time periods. This sub-period analysis is undertaken with sample sizes of at least one hundred and forty.

The final problem to be considered here relates to the market proxy. Roll (1977) has demonstrated the considerable problems associated with choosing a proxy for the market portfolio. The market portfolio is a portfolio comprising *all* risky assets, both marketable and nonmarketable. In practice not only do market indexes, such as the FT All Share index, fail to incorporate all risky assets, but it is impossible to establish a measure which would incorporate all such assets and hence would be a true reflection of the market portfolio. Indeed, it is impossible to observe the true market portfolio.

In spite of this criticism estimates of betas and tests of CAPM have continued. CAPM has proved to be a very influential model both academically and amongst practitioners, and in order to operationalise the notion of systematic risk a proxy has to be found. For this reason, while stock market indexes do have shortcomings, they probably represent the best set from which a proxy can be drawn. Given the nature of the market portfolio, of those stock market indexes available the one with the widest coverage is the most appropriate. In this study we therefore use the FT All Share index.

This is comparable with the market proxy used by Dusak (1973), namely the value-weighted S&P 500 Index. In the previous chapter it was seen that this proxy was criticised by Carter, Rausser and Schmitz (1983) who suggested an alternative proxy giving equal weight to the S&P 500 stock index and the Dow-Jones commodity futures index and that, in turn, Marcus (1984) criticised this choice. The main point of contention related to the inclusion or otherwise of commodities in the market proxy. However, even giving a small weight to commodities, as suggested by Marcus and used by BCT, may be misleading. Black argues that

> "To the extent that stocks of commodities are held by corporations, they are implicitly included in the market portfolio." (Black, 1976, p172)

By using the FT All Share index we avoid the potential problem of double-counting and also avoid problems of possible under-representation of certain assets, including commodities, from using a restricted index such as the FT30 or FTSE-100.

There is one other very important point regarding the market portfolio proxy in relation to this study. Previous studies of futures contracts within a CAPM framework have examined agricultural and metal commodities. Thus they are focusing on futures on individual nondiversified assets. The futures contract under investigation in this study is that written on the FTSE-100, which is itself a broadly diversified portfolio. Thus, the underlying asset is likely to have little diversifiable risk, and, more importantly here, is likely to be highly correlated with the chosen market proxy. Unfortunately, this problem cannot be overcome, since this correlation is likely for any suitable market proxy. However, it does suggest that a beta in the region of unity is to be expected. Given that current futures prices are believed to be more volatile than are current spot prices, and that the market proxy is likely to be highly correlated with the spot asset, a beta in excess of unity may be expected. In addition, given the correlation between the asset underlying the futures contract and the market proxy, any results must be interpreted with caution.

For the risk-free proxy and for the market portfolio proxy, data relates to Monday, Wednesday and Friday closing figures, as appropriate. Returns data for the market portfolio is constructed along similar lines to the returns on futures and all returns data are in logs. All data were obtained from Datastream.

2.4 Methodology.

As stated in the previous section, there are three stages to the analysis undertaken. The first two are comparable in approach to previous studies (i.e. the BJS approach). However, additional factors to those examined in previous studies are analysed. The third stage adopts the FM methodology.

2.4.1 The standard (BJS) approach.

In the first part of the analysis using this approach, data relating to contracts with settlement in June and December only are utilised. The market model (equation 2.3) is estimated using the ordinary least squares method for the three series of weekly returns: to Mondays, Wednesdays and Fridays. In this part of the analysis no account is taken of time to maturity. The data comprise weekly returns over the last six months of each June and December contract. Thus it includes returns in the last week before contract expiration and returns in the week up to six months prior to expiration. In addition to undertaking analysis for the whole period (1985-1990) each category of estimate was carried out on two sub-periods, up to October 1987 and from November 1987. Data relating to the month around the 1987 crash was omitted from this sub-period analysis.

The second part of the study uses data on the four futures contracts for each year (i.e. with settlement in March, June, September and December). For reasons set out in section 2.6 closing prices for Wednesdays only are used. In this part of the analysis the data were partitioned along similar lines to that used by Elam and Vaught. Two time-series were created; one relating to weekly returns on contracts with less than 3 months to maturity and the other to weekly returns on contracts with between 3 and 6 months to maturity. Thus, for example, for January 1986 Wednesday closing prices for the March 1986 and June 1986 contracts are used. Those relating to the March contract are utilised for the time-series for contracts having less than 3 months to maturity and those to the June contract, for contracts having between 3 and 6 months to run. For April 1986, the relevant data are prices on the June contract for the first time-series and the September contract for the second. By comparing the results of the second part of the analysis to those of the first part, the impact of time to maturity on futures returns should be established, something which has not previously been done.

There are good grounds for believing that there may be differences in the risk return relationship with respect to time to maturity. Firstly, as was noted in chapter 1 the hedging performance of futures may be influenced by time to maturity. In addition, it is to be expected that the vast majority of hedging activity takes place using the nearby contract. As a result, futures contracts with more than three months to maturity may have different risk return characteristics to those for the nearby contract. Similarly, it is likely that futures prices further from maturity will be less good predictors of future spot prices.

More importantly, however, the volume of futures trading in any contract varies substantially throughout the life of the contract. In particular, since most hedging activity is carried out using the nearby contract, trading in contracts with substantially more than three months to maturity is typically very thin. It is only as investors move out of the nearby contract close to maturity of that contract, that activity in the contract next nearest to maturity picks up. So, for example, in late March as the maturity of the March contract approaches, market participants will close out their positions in the March contract. At the same time those, wishing to maintain an open futures position are likely to move into the June contract. As a result both trading volume and open interest change markedly over the life of a futures contract.

This view is borne out by figures 2.1 to 2.10. Figures 2.1 to 2.5 show the pattern of trading volume over the life of the FTSE-100 stock index futures contracts. Figure 2.1 relates to average trading volume for up to 120 days[5] prior to maturity for all FTSE-100 stock index futures contracts traded over the period December 1984 to September 1992[6]. Figures 2.2 - 2.5 show the same information for each contract month. Thus, for example, figure 2.2 relates to volume of trading for March contracts and figure 2.3 to that for June contracts. Figures 2.6 - 2.10 provides information on open interest on the same basis.

A clear pattern emerges from these diagrams. For the period relating to between approximately 120 to 80 trading days prior to maturity trading volume and open interest are very low. In the period from about 80 to 60 days prior to maturity both volume and open interest increase as one contract matures. There is then a substantial rise in both of these variables as the contract comes to dominate for the remaining months to maturity. Figures 2.2 - 2.5 and 2.7 - 2.10 demonstrate that there is no discernible difference in these patterns between contracts maturing in different months. These patterns clearly give grounds for the view that the risk return relationship should be examined separately for contracts with differing times to maturity. Ideally, it would be interesting to carry out analysis for more sets of data based on time to maturity. For example, it would be desirable to examine the risk return relationship for contracts with less than one month to maturity, between one and two months, etc. However, given that the futures for this contract only mature quarterly such analysis could only be

Figure 2.1

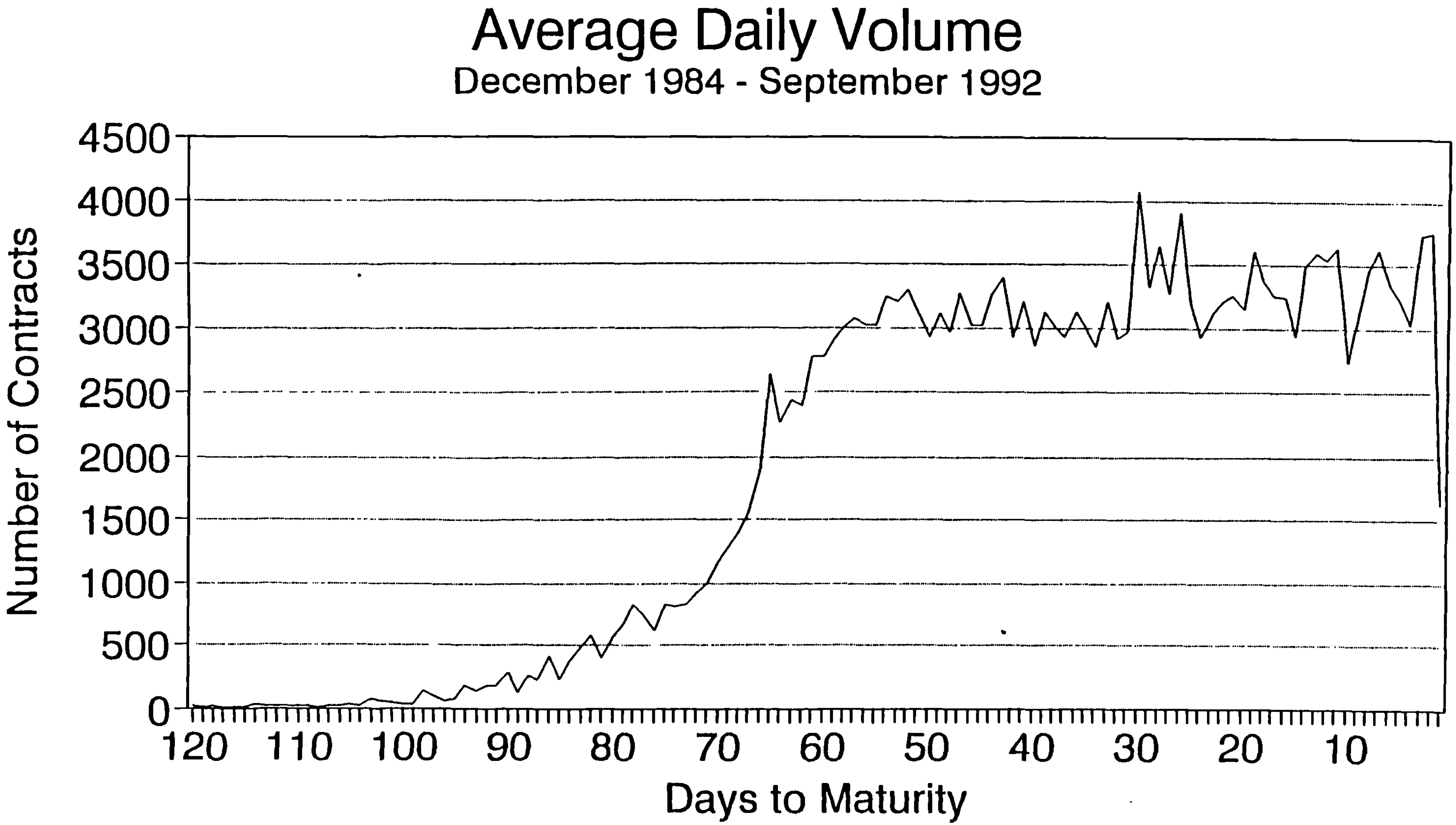

Average Daily Volume
December 1984 - September 1992
Number of Contracts
4500
4000
3500
3000
2500
2000
1500
1000
500
0
120
110
100
90
80
70
60
50
40
30
20
10
Days to Maturity

Figure 2.2

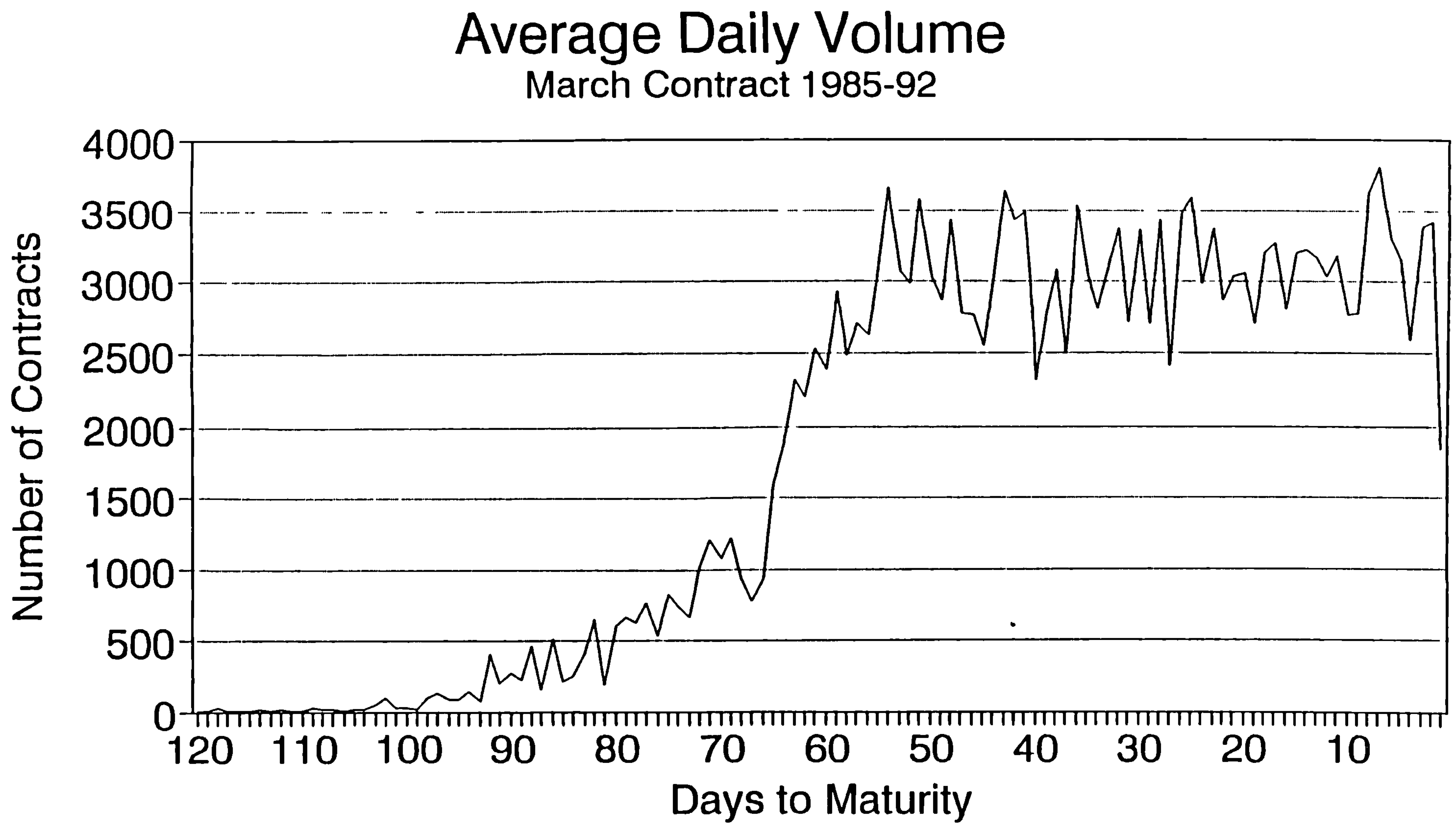
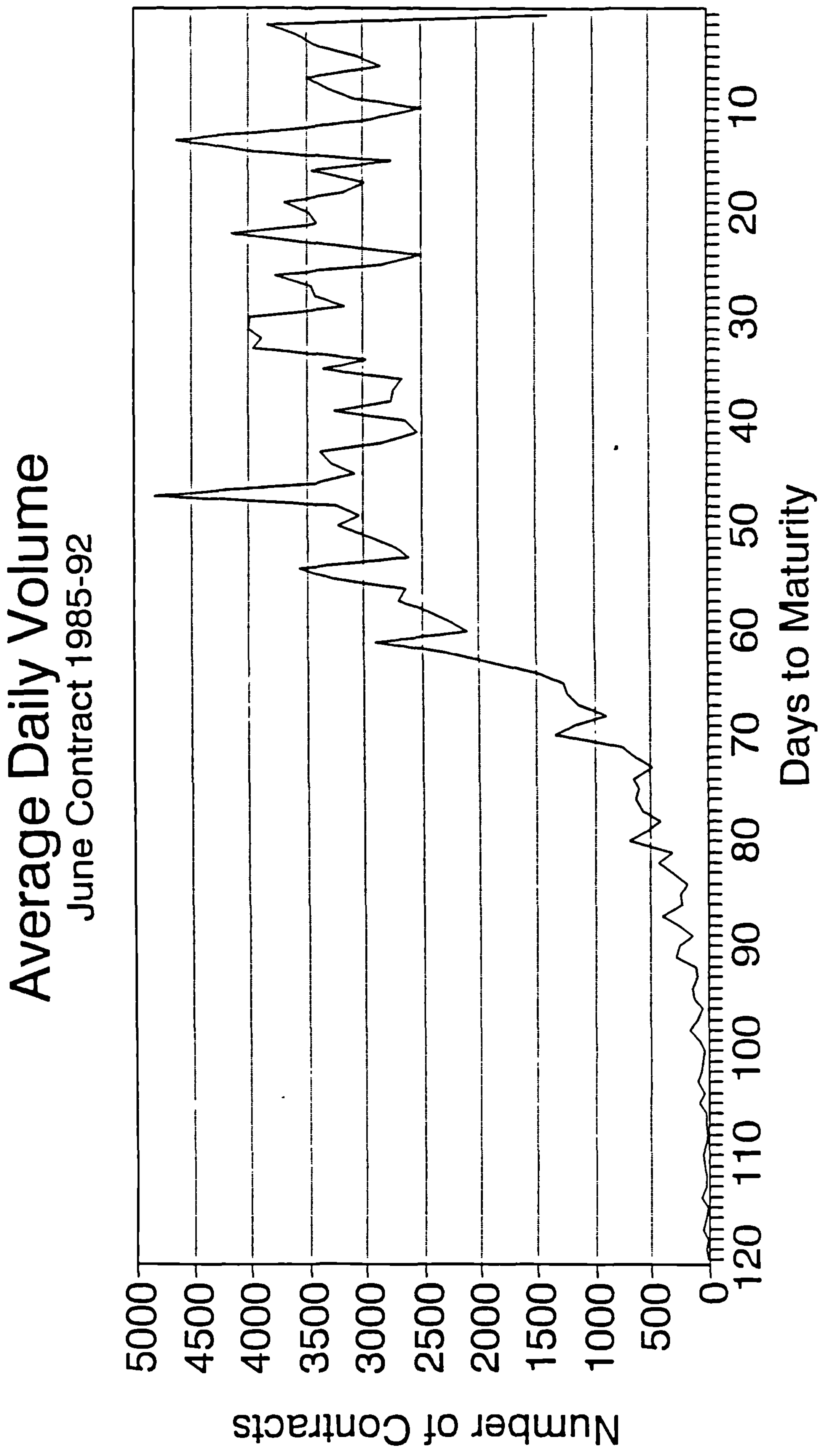

Average Daily Volume
March Contract 1985-92
Number of Contracts
4000
3500
3000
2500
2000
1500
1000
500
0
120
110
100
90
80
70
60
50
40
30
20
10
Days to Maturity

Figure 2.3



Average Daily Volume
June Contract 1985-92
Number of Contracts
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
120
110
100
90
80
70
60
50
40
30
20
10
Days to Maturity

Figure 2.4

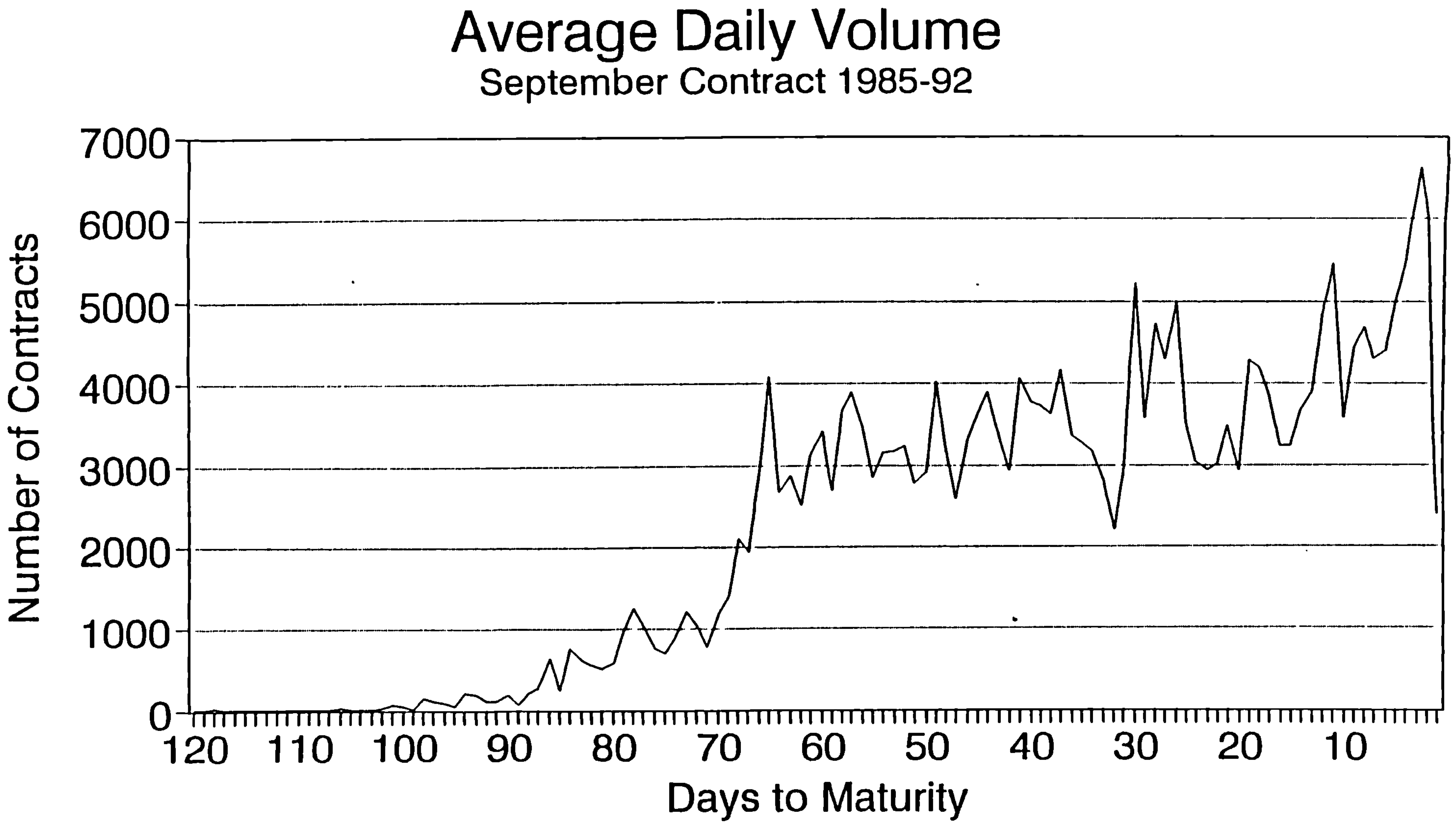

Average Daily Volume
September Contract 1985-92
Number of Contracts
7000
6000
5000
4000
3000
2000
1000
0
120
110
100
90
80
70
60
50
40
30
20
10
Days to Maturity

Figure 2.5

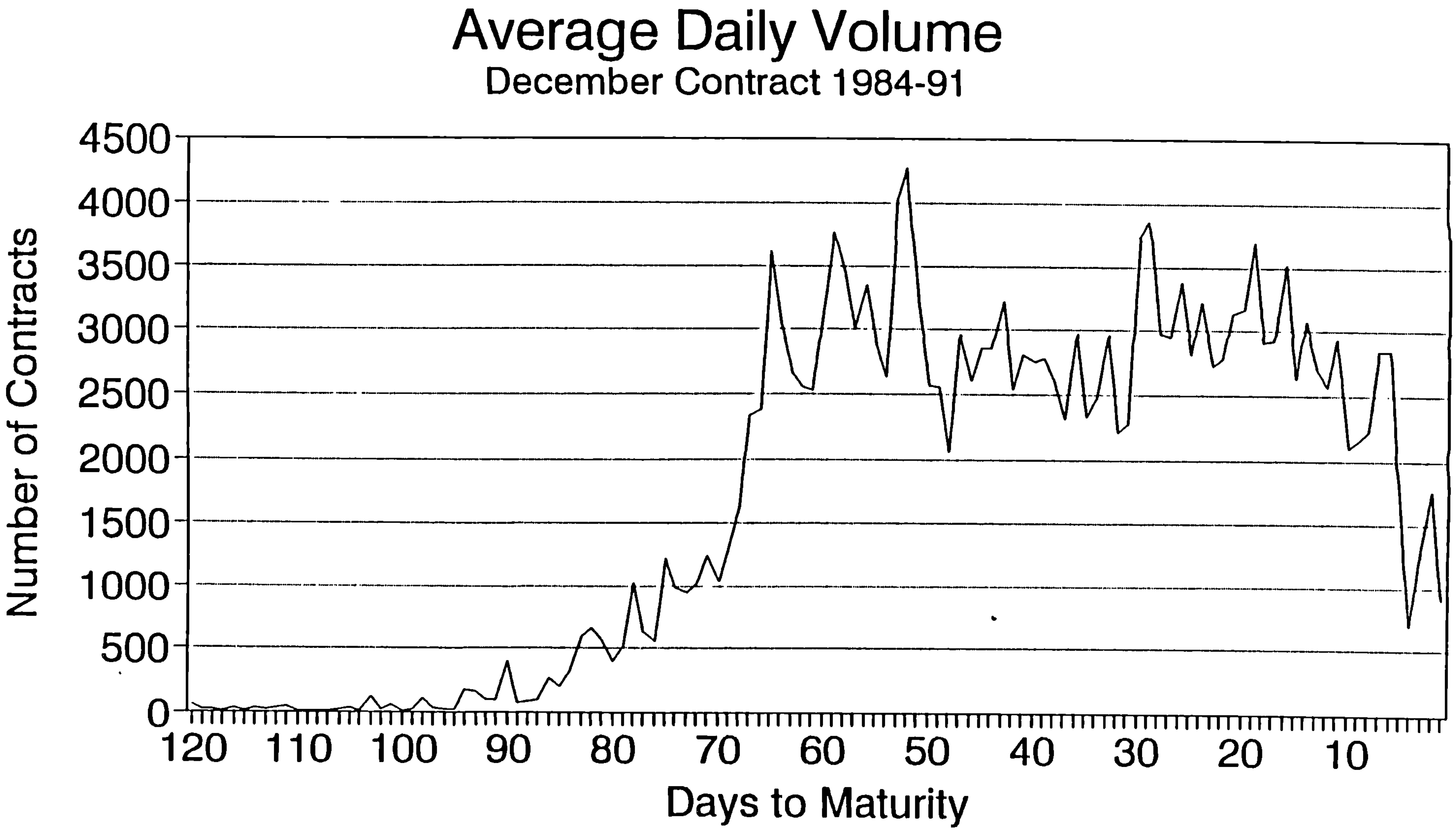

Average Daily Volume
December Contract 1984-91
Number of Contracts
4500
4000
3500
3000
2500
2000
1500
1000
500
0
120
110
100
90
80
70
60
50
40
30
20
10
Days to Maturity

Figure 2.6

Average Open Interest

December 1984 - September 1992

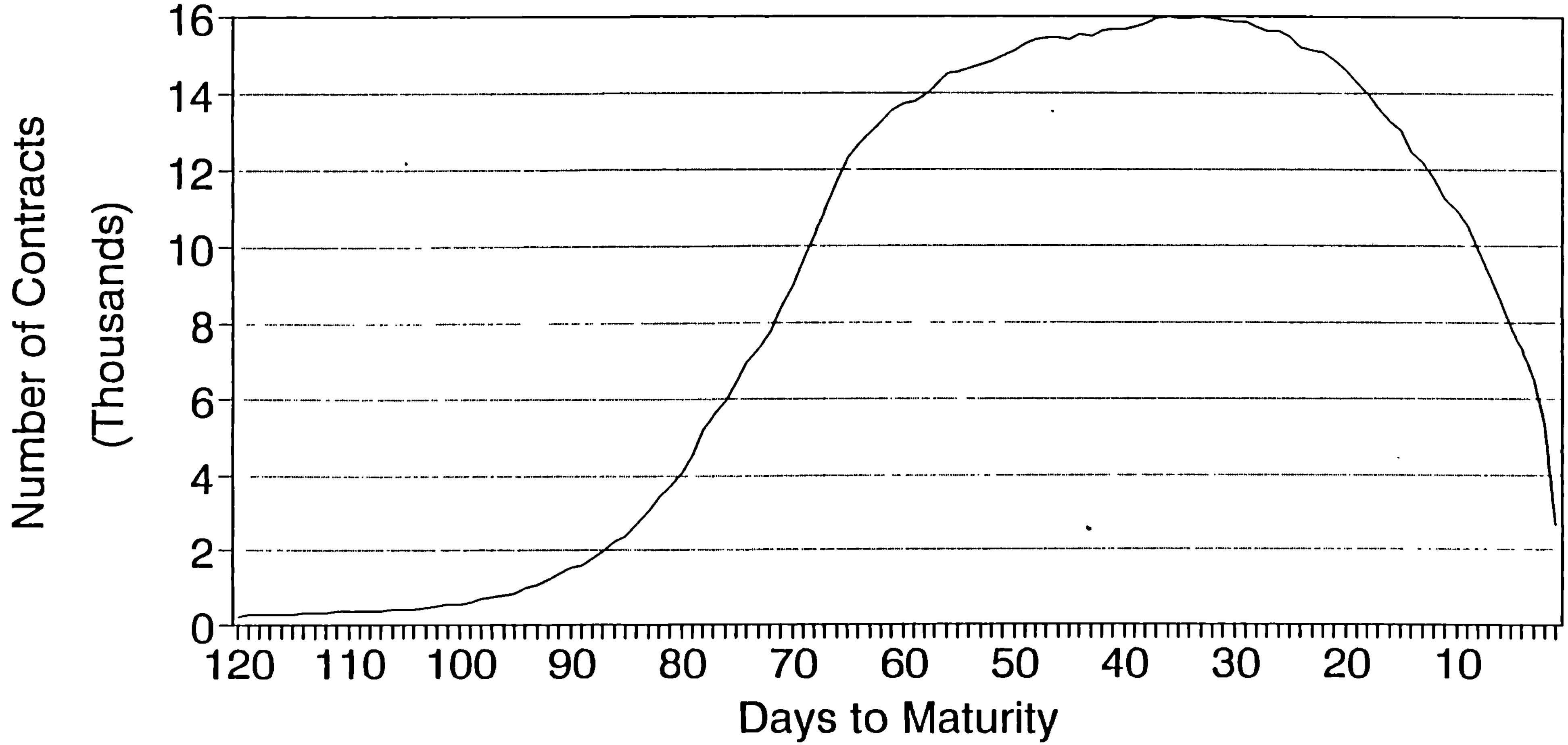


Figure 2.7

Average Open Interest
March Contract 1985-92

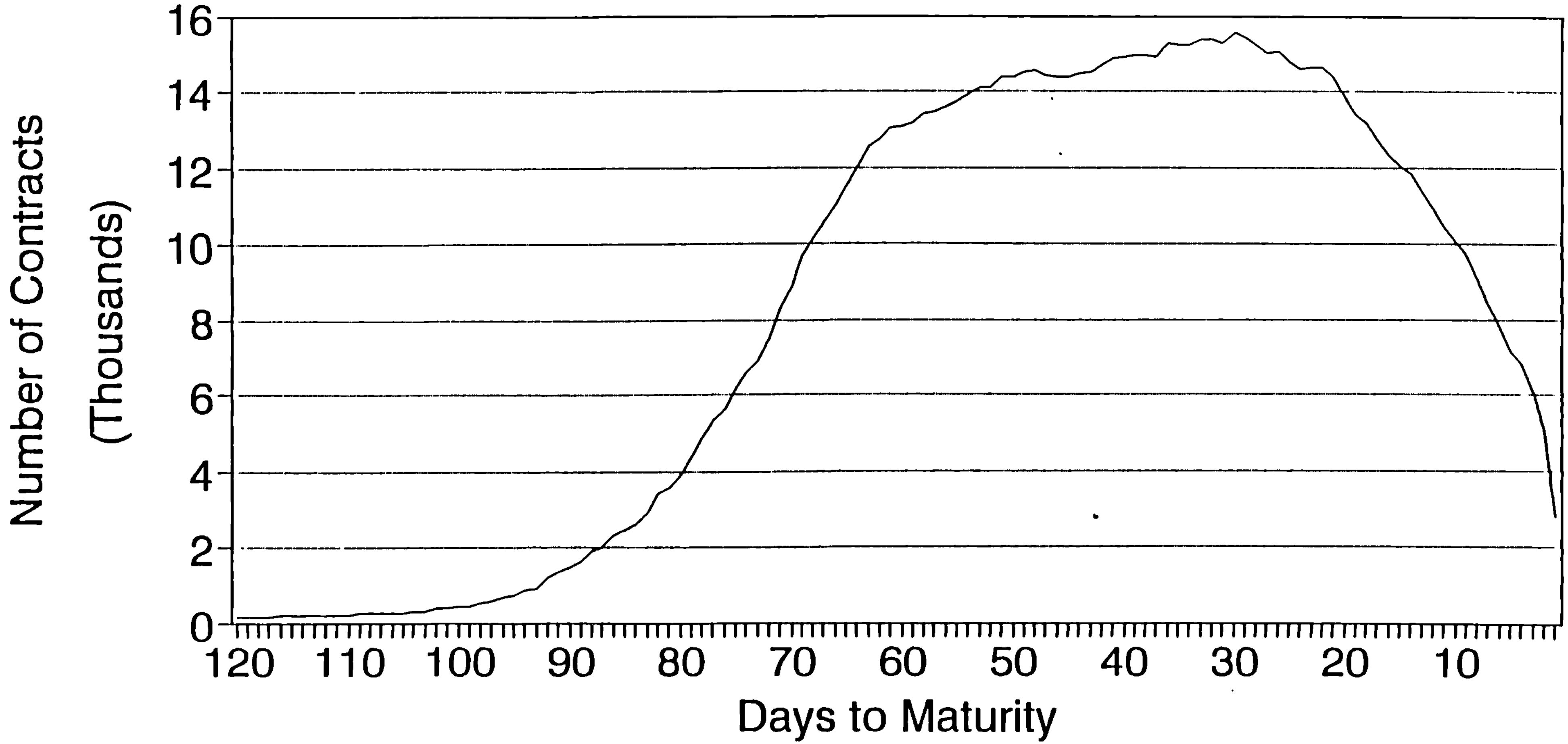


Figure 2.8

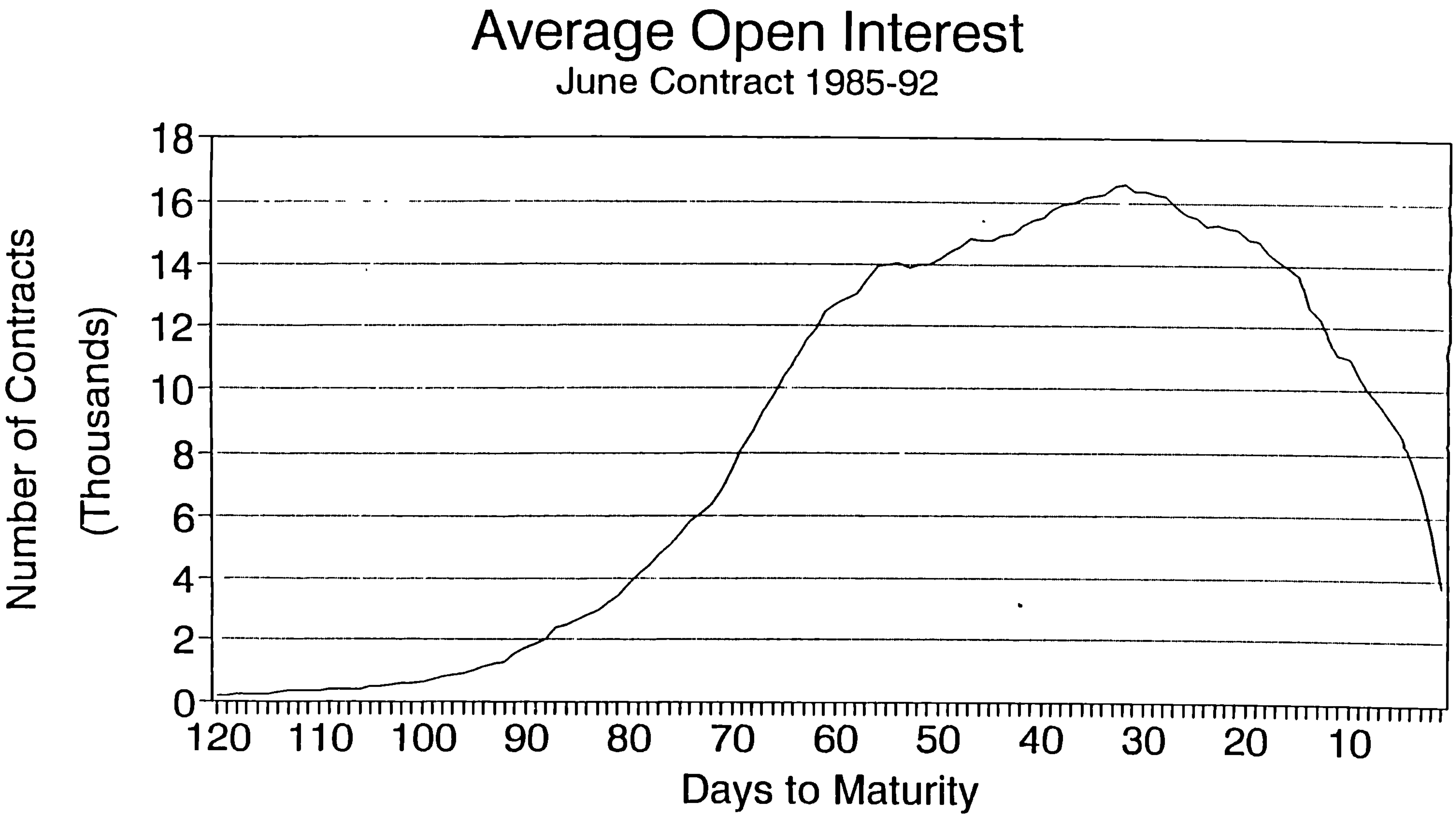

Average Open Interest
June Contract 1985-92
Number of Contracts
(Thousands)
18
16
14
12
10
8
6
4
2
0
120
110
100
90
80
70
60
50
40
30
20
10
Days to Maturity

Figure 2.9

Average Open Interest

September Contract 1985-92

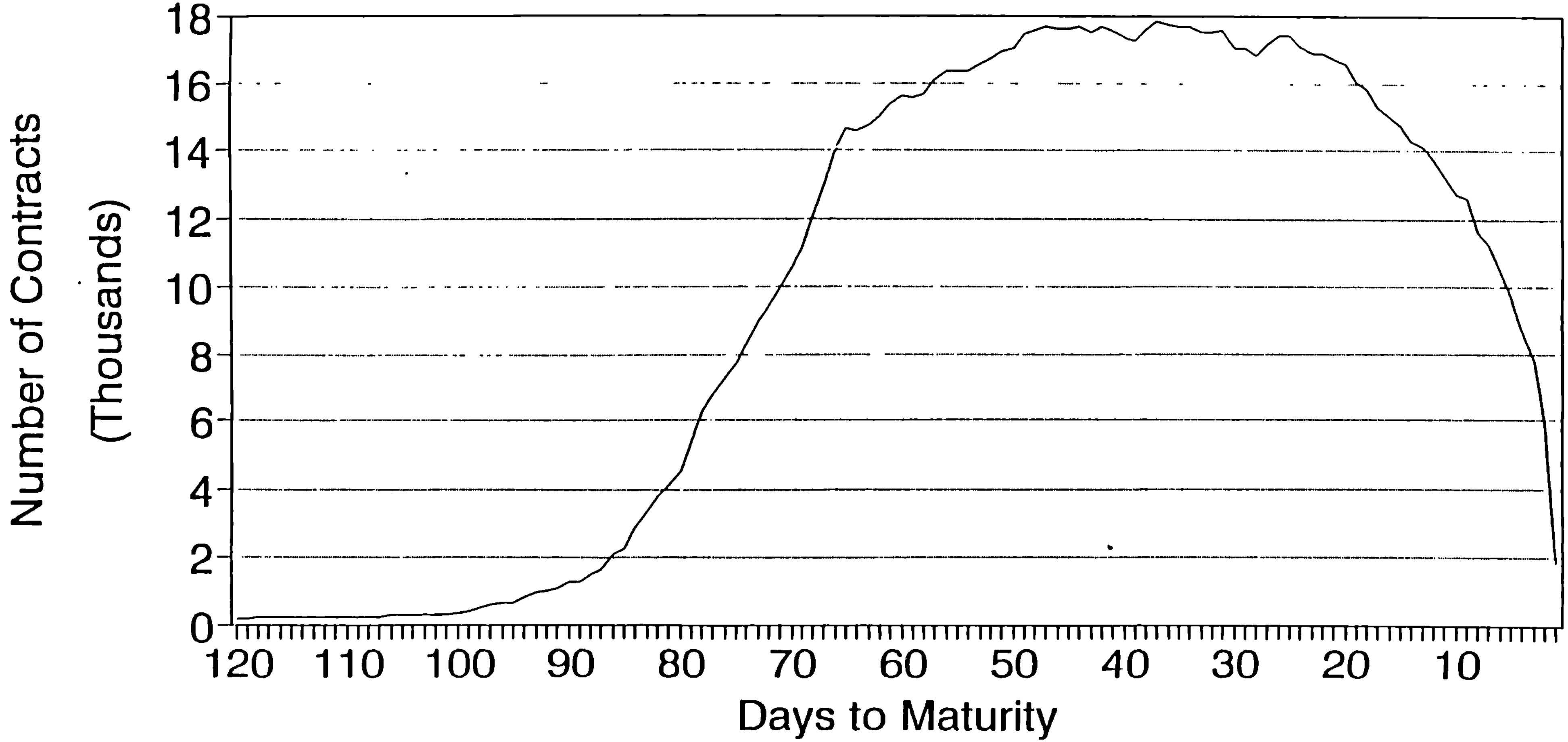
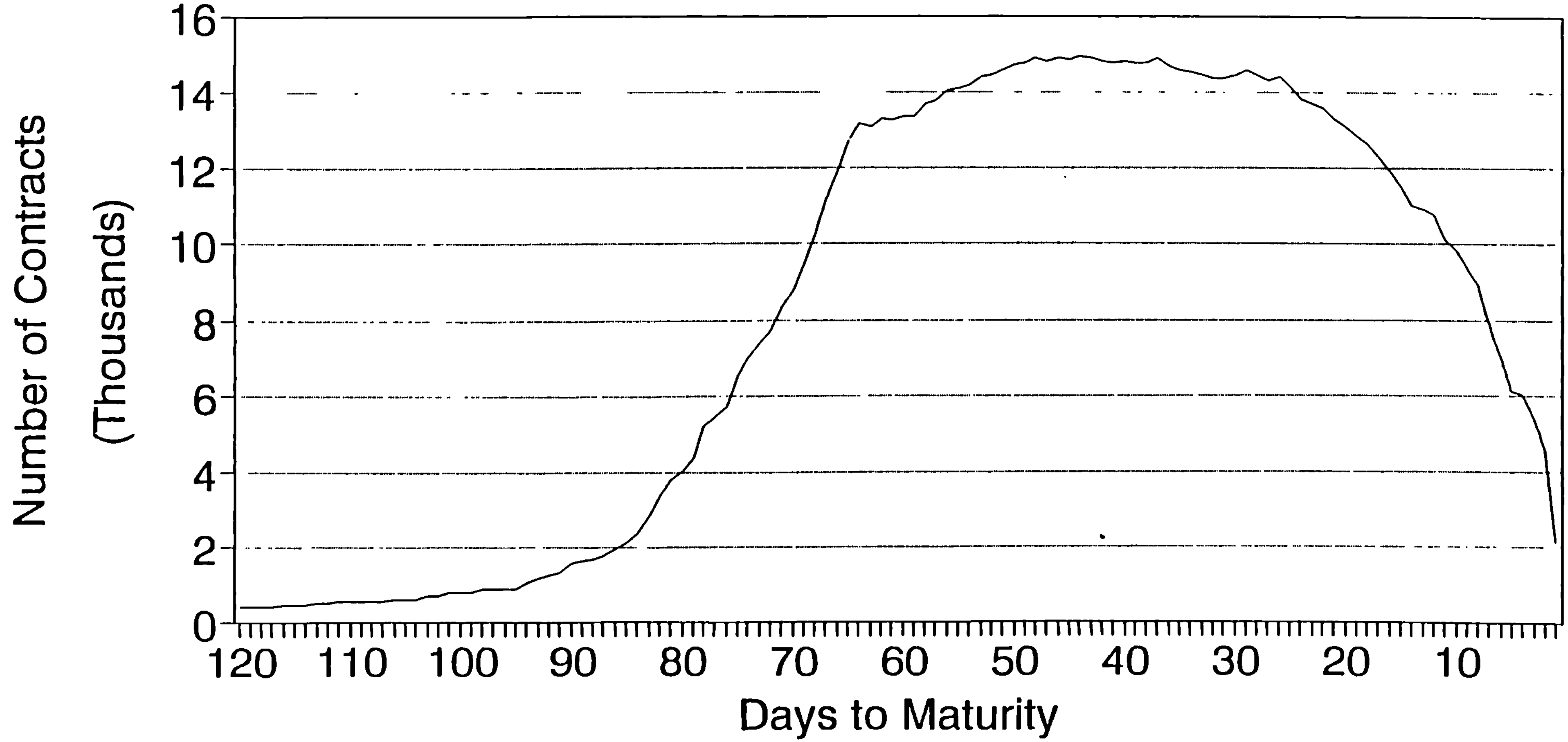


Figure 2.10

Average Open Interest
December Contract 1984-91



carried out by using noncontinuous or artificially constructed data. It was therefore decided to carry out analysis based on the nearby contract (0-3 months to maturity) and the next but one contract to maturity (3-6 months from maturity). Once again, analysis is carried out for the whole period and for the two-sub-periods.

In all of the analysis which adopts this methodology the hypothesis to be tested is that returns on the stock index futures contract will be systematically linked to the returns on the market portfolio. In addition, if the CAPM adequately explains returns on the futures contract then the intercept term (alpha in equation 2.3)) will be insignificantly different from zero.

2.4.2 The predictive (FM) approach.

The third stage of the analysis involves further partitioning of the data. The two sub-periods relating to before and after the October 1987 crash are investigated separately. In this stage the market model is estimated for the first seventy observations (weeks) for the first sub-period and the first eighty observations for the second sub-period. The estimated betas are then used to predict weekly returns for the remaining weeks of the sub-periods. The predicted returns are then compared with the actual returns for the period and inferences drawn. This comparison is made by subtracting the predicted returns from actual returns to yield 'excess returns'. The hypothesis that excess returns are equal to zero is then tested.

In testing for returns predictability on the basis of beta estimates, only data relating to weekly returns to Wednesdays for the nearby contract are utilised (i.e. with less than three months to maturity). The reason for restricting the data set to Wednesdays is the same as that for the analysis of time to maturity. Given that the vast majority of trading takes place in the nearby futures and that the purpose of this analysis is not to explicitly examine the time to maturity effect, only the nearby contract data is utilised.

2.5 Preliminary Results.

Tables 2.1 and 2.2 present the mean and standard deviation of weekly returns, together with the number of observations used in the analysis for the whole period and for the two sub-periods. In addition, t statistics relating to the test of whether the mean returns are significantly different from zero are also included. Table 2.1 relates to weekly returns to Monday, Wednesday and Friday, taking no account of time to maturity. Table 2.2 presents information for weekly returns to Wednesday, for contracts with less than 3 months and 3-6 months to maturity. In all cases returns for the whole period and for the second sub-period are considerably smaller than for the first sub-period, reflecting the

Table 2.1: Means and standard deviations of weekly returns to Mondays, Wednesdays and Fridays.

	Mean	SD	t statistic	n
Week to:		1985 - 1990		
Monday	0.0008	0.0287	0.4848	301
Wednesday	0.0006	0.0261	0.4167	301
Friday	0.0010	0.0287	0.5921	304
		1985 - Oct. 1987		
Monday	0.0037	0.0202	2.1659	140
Wednesday	0.0035	0.0192	2.1830	140
Friday	0.0039	0.0204	2.2569	141
		Nov. 1987 - 1990		
Monday	0.0004	0.0277	0.1972	157
Wednesday	0.0006	0.0228	0.3513	157
Friday	0.0011	0.0240	0.5542	159

t statistics relate to the test of whether mean returns are significantly different from zero

Table 2.2: Means and standard deviations of weekly returns according to time to maturity.

	Mean	SD	t statistic	n
Months to maturity:		1985 - 1990		
< 3 months	0.0006	0.0257	0.3971	302
3-6 months	0.0009	0.0261	0.6037	279
		1985 - Oct. 1987		
< 3 months	0.0039	0.0191	2.3593	135
3-6 months	0.0047	0.0191	2.7875	130
		Nov. 1987 - 1990		
< 3 months	0.0004	0.0218	0.2206	163
3-6 months	0.0004	0.0219	0.2070	145

t statistics relate to the test of whether mean returns are significantly different from zero impact of the October 1987 crash and relatively low returns thereafter. There is evidence of differences in returns to different days of the week, although all returns are relatively low. For the whole period the weekly returns correspond to annual returns of only 4.2%, 3.1% and 5.2% to Mondays, Wednesdays and Fridays respectively. Indeed, mean returns for the whole period and for the period after the crash are insignificantly different from zero at the 5% confidence level.

As is to be expected, the standard deviation of returns are also greater for the whole period and for the second sub-period. In contrast to CCC (1990) there is no clear evidence of contract maturity impacting on the standard deviation of returns. As far as a day of the week effect is concerned weekly returns to a Wednesday have a lower standard deviation than do those to Mondays and Fridays and the mean return is also less (with the exception of weekly returns to Monday post October 1987).

2.6 Empirical Results.

In table 2.3 we present the results of the estimation of the market model for weekly returns to Monday, Wednesday and Friday. The first set of results in table 2.3 relates to the whole period and the other results to the two sub-periods. Strong similarities are evident across the estimations. All of the R^2s are high. The

Table 2.3: Estimated market model coefficients for weekly returns to Mondays, Wednesdays and Fridays

Week to:	α_i	SE(α_i)	β_i	SE(β_i)	R^2	F_{sc}^x
			1985 - 1990			
M	.0013+	.0005	1.0607*	.0203	.9140	11.7503@
W	.0013*	.0004	1.0660*	.0188	.9151	2.7359
F	.0013*	.0004	1.1104*	.0179	.9272	18.9694@
			1985 - Oct. 1987			
M	.0006	.0006	1.0652	.0432	.8754	19.1193@
W	.0006	.0005	1.0459	.0293	.9142	2.4507
F	.0007	.0005	1.0170	.0261	.9160	6.4762$
			Nov. 1987 - 1990			
M	.0019*	.0005	1.1175*	.0229	.9389	8.5827@
W	.0019*	.0007	1.0971*	.0359	.8575	3.5997
F	.0019*	.0005	1.1328*	.0258	.9246	5.2705$

* Denotes α significantly different from 0 or β significantly different from 1 at 1% level
\+ Denotes α significantly different from 0 or β significantly different from 1 at 5% level
x F_{sc} denotes the F-statistic for the test of serial correlation
@ denotes significant at the 1% level
$ denotes significant at the 5% level
M, W, F relate to Monday, Wednesday and Friday respectively.

estimated βs are all significantly different from zero at the 1% level and all fall within the range 1.01 to 1.14. Given the nature of the futures contract under consideration and the market proxy used it was to be expected that βs would approximate unity. However, there is a difference in the values of the estimated betas for the periods before and after the crash of 1987. For the period up to October 1987 the betas are insignificantly different from unity at the 5% level of confidence. However, for the period post-October 1987 the estimated betas are significantly different from unity. This suggests that the FTSE-100 stock index futures contract has become a riskier asset in systematic risk terms following the stock market crash.

The estimated values of alpha are also worthy of note. For the three estimations within each period there is evidence of consistent values of alpha. However, while the values of α for the whole period and for the second sub-period are positive and significantly different from zero, they are not significant for the first sub-period. Thus it appears that prior to the crash of 1987 the market model is adequately specified and that systematic risk explained returns to the futures index contract, but that post-October 1987 the futures index offered excess profits. This result could be explained by the fact that in the wake of the crash, a number of smaller brokers and analysts ceased business, resulting in a reduction in the search for information. This in turn could lead to pricing inefficiency with the consequence that unexploited arbitrage opportunities led to abnormal returns being earned. While the question of efficiency is beyond the scope of this chapter, this finding does suggest that the efficiency of the market for the futures index contract does need to be addressed. It is therefore examined in chapter 4.

The final column in table 2.3 presents the statistic for the test of serial correlation. The test statistic is F distributed and shows that for Mondays and Fridays there is evidence of serial correlation. However, for Wednesdays the test statistic reveals no evidence of serial correlation. Clearly, there are a number of reasons why serial correlation may be observed. However, given the above findings, a reasonable interpretation would appear to be that a day of the week effect is in evidence with some misspecification being evident for the estimations for Mondays and Fridays. This may be related to higher volumes of activity in futures trading taking place on Mondays and Fridays as fund managers adjust their portfolios to avoid any possible beginning and end of week effects. Again, further investigation of this issue is beyond the scope of this chapter, but the findings again call into question the efficiency of trading in the futures index.

Table 2.4 presents the results of estimations taking account of time to maturity. In the light of results presented above, estimations were only carried out for weekly returns to Wednesday. In terms of the size and significance of the betas the results are consistent with the findings presented in table 2.3. The betas for contracts with three or more months to maturity are marginally lower than for those with less than three months to maturity. While this might suggest that contracts with longer time to maturity are less risky in terms of systematic risk, the differences are very small. However, they do conform to the findings of CCC (1990) for metal futures. In all cases the beta estimates are significantly different from unity at the 5% level, with the exception of the beta for contracts with between three and six months to maturity pre-October 1987.

The general pattern of alpha coefficients is not affected by the partitioning, with significant values for the whole period and the latter sub-period, but not for the first sub-period. However, the extent of excess returns appears to be higher for contracts with longer time to maturity. Nonetheless, these findings of little difference between contracts with different times to maturity is surprising given the evidence presented above of very thin trading in contracts with more than three months to maturity.

Table 2.4: Estimated market model coefficients for Wednesday weekly returns according to time to maturity.

Months to maturity:	α_i	$SE(\alpha_i)$	β_i	$SE(\beta_i)$	R^2	$F_{sc}{}^x$
			1985 - 1990			
<3	.0010*	.0003	1.0705*	.0149	.9451	1.1040
3-6	.0014*	.0004	1.0624*	.0153	.9459	0.4713
			1985-Oct. 1987			
<3	.0004	.0004	1.0632+	.0268	.9220	3.2473
3-6	.0009	.0005	1.0533	.0280	.9173	4.0598$
			Nov 87-90			
<3	.0014*	.0005	1.0973*	.0245	.9259	2.8931
3-6	.0018*	.0004	1.0931*	.0248	.9314	1.6283

Footnotes as table 2.3

Table 2.5 presents the results of analysis using the FM approach. The first two columns show beta values and the standard error of the beta values estimated for the first part of each of the two sub-periods. The other columns relate to the second part of each sub-period. For these periods returns are predicted on the basis of the estimated beta values from the earlier period. The difference between actual returns in the second part of each sub-period and the predicted returns are referred to as excess returns. The three columns show the mean value of these excess returns, the standard deviations of the returns and the t statistic relating to the hypothesis that mean excess returns are zero.

The results presented in table 2.5 from the analysis using the FM approach confirm the findings of the analysis using the BJS approach. Before the October 1987 crash the excess returns to the stock index futures contract are not significantly different from zero. Thus futures returns compensate for the systematic risk and are as predicted by the CAPM. This evidence of no excess returns suggests that pre-crash the contract is priced efficiently. However, post-crash there is evidence of excess returns. The mean of the excess returns is significantly different from zero for this period. In particular, actual returns post October 1987 are higher than those predicted by the CAPM, suggesting that the market may be inefficient.

Table 2.5 Estimated beta values, and mean and standard deviation of excess returns for Wednesday weekly returns.

Sample Period (weeks)	β_i	SE(β_i)	Excess returns Mean	σ	t^+
1 - 70	1.0354	.0332			
71 - 135			-.00036	.00623	-.0462
140 - 219	1.0571	.03867			
220 - 302			.00182*	.00557	2.9690

* Denotes mean excess returns significantly different from zero at the 1% level.
\+ t statistic relates to the null hypothesis mean excess returns are zero.

2.7 Conclusions and Implications for Further Research.

This chapter has considered the risk and return associated with the LIFFE FTSE-100 stock index futures contract within a CAPM framework over the period 1985-90. This has been done against a background of a lack of study in this area in terms of using UK data and analysing financial futures. In order to examine the possibility of a day of the week effect, weekly returns to Mondays, Wednesdays and Fridays have been examined. In addition, although the issue of a possible impact on returns of the time to maturity has been acknowledged, previous studies had failed to analyse returns when both accounting for time to maturity *and* making no allowance for time to maturity. This study has sought to rectify this position. In addition, previous studies suffer from only using the BJS approach to testing the CAPM. This approach has been strongly criticised by Roll (1977). In this study we not only adopt the BJS approach, but also employ the FM methodology for testing the CAPM.

A number of interesting results have emerged from this analysis:

(1) In all of the analysis carried out the beta values were found to be in the range 1.01-1.14. This relative closeness to unity (even given that post-October 1987 betas were statistically different from unity) conforms to expectations about beta values on a stock index

futures contract. Indeed, the results suggest that a portfolio comprising the market portfolio and selling the futures index in approximately equal proportions would lead to a situation of near zero systematic risk.

(2) While the findings suggest that futures index returns are adequately explained by the CAPM up to October 1987, after the crash returns in excess of those due to systematic risk could be earned from the futures index. In addition, for weekly returns to Mondays and Fridays there are serious problems of serial correlation. These results raise doubts regarding the efficiency of trading in the futures index. Clearly, this issue is worthy of further examination.

(3) As far as the time to maturity of a contract is concerned, it does appear to have some impact on futures returns. In particular, contracts further from maturity appear to be associated with less systematic risk and offer higher excess returns. Given the evidence on trading volume and open interest presented in figures 2.1 - 2.10 this finding is not surprising. Indeed, a finding of excess returns in thinly traded markets is consistent with findings for stock markets (see, for example, Butler and Malaikah (1992) and Wong, Hui and Chan (1992)).

(4) The results of the analysis using the FM methodology are broadly in line with those using the BJS approach. This suggests that the criticism raised by Roll concerning the tautological nature of tests of the CAPM may not be of great practical significance[7].

There are various implications of the analysis carried out and reported in this chapter. Firstly, there is clear evidence that the stock index contract is a risky asset in systematic risk terms. This would suggest that the asset should offer a risk premium. However, as was noted earlier, there will be strong correlation between the returns on the market portfolio used in this study and the asset which underlies the futures contract under investigation. It is to be expected that the futures price will be systematically related to the spot price. Thus while there is evidence of a systematic relationship between futures returns and market returns, this may be due more to a relationship between changes in spot and futures prices. Thus the finding that returns on the FTSE-100 futures contract vary systematically with returns on the market must be interpreted with caution. This finding *may* be due to futures being treated as any other investment instrument within a CAPM framework. On the other hand, as the market index is not substantially different from the spot asset underlying the futures contract, the finding does not necessarily imply such a conclusion. Further, as Black (1976) points out, a positive beta does not necessarily imply that investors will treat the asset as if it has a positive beta. In this case evidence of systematic risk is not evidence of a risk premium.

For these reasons, further investigation is necessary before conclusions about the applicability of CAPM to this futures contract can be drawn. In particular, it is necessary to explicitly test for the existence of a risk premium. This is undertaken in chapter 4 by testing the unbiasedness hypothesis. If the unbiasedness hypothesis is found to hold, then it would suggest that a risk premium does not exist for this asset and the CAPM may not be an appropriate framework within which to examine the FTSE-100 stock index futures contract.

A second issue to emerge from this investigation is that the market for the FTSE-100 stock index futures contract may be inefficient. This point is raised by the finding of serial correlation in returns for Monday and Friday weekly returns and by the finding of positive alpha values. Since any test of a pricing model is a joint test of that model and efficiency, the test of the unbiasedness hypothesis to be carried out in chapter 4 is therefore also a test of efficiency.

However, before going on to examine the unbiasedness hypothesis and market efficiency in chapter 4, another issue arises from this analysis which is also of considerable importance. In particular, given the evidence from this chapter of excess returns on futures over the period investigated, it is possible that speculators were encouraged into the market. As was demonstrated in chapter 1, there is considerable concern among spot market participants that the activities of this group of market participants could have an impact on the market for the underlying asset and it is therefore important to investigate the volatility of the spot market pre- and post-futures trading. This investigation is undertaken in the next chapter.

Finally, the evidence of betas near to unity suggests that futures on the stock index will allow market participants to achieve a zero beta portfolio. Given that the underlying asset has practically no diversifiable risk, this suggests that this futures contract will be extremely useful in hedging risk faced in the stock market. The hedging effectiveness of futures is investigated in chapter 5.

Footnotes.

1. The unbiasedness hypothesis was mentioned in chapter 1 and is discussed in detail in chapter 4.

2. The concept of a rate of return is somewhat problematic when no actual investment has been made. Dusak views the rate of return as the change in price over the period as a proportion of the price at the beginning of the period (i.e. $(p_{t+1} - p_t)/p_t$).

3. While the approach adopted by Dusak and others to examine futures within a CAPM framework is not identical with that adopted by BJS, the two approaches are consistent in that in both cases betas and average rates of return are computed for the same period.

4. At one level the actual beta estimates found in this study are not particularly important. Rather, what is important is whether the futures contract under consideration is a risky asset in systematic risk terms. Nonetheless, the sizes of the betas estimated will be of interest

5. There are approximately 60 to 65 trading days between contract maturities. Thus a 120 trading day period represents slightly less than a six month period.

6. The period for which volume data is shown is greater than that used in the analysis in this chapter. This is because analysis carried out in later chapters uses data for longer periods than that used here. The evidence on volume presented here is relevant to some of that later analysis.

7. It is recognised that the concern over previous tests of the CAPM being a tautology represents only a minor strand of his critique of tests of the CAPM. Nonetheless, it is a criticism which subsequent studies have sought to address and the finding here suggests that this may not be a major source of problems.

Chapter 3: Futures Trading, Information and Spot Price Volatility.

3.1 Introduction.

In chapter 1 it was shown that the impact of futures trading on the volatility of prices in the spot market has been an area of concern from the earliest days of futures trading. This concern stems from the belief of spot market participants that the activities of speculators in futures markets will destabilise spot prices. It was argued that previous studies suffer from having taken too narrow a focus. In particular, previous studies have failed to recognise the link between information and volatility.

The question of the volatility of market prices has also been an area of active concern in the efficient markets literature in recent years. For example, DeBondt and Thaler (1985, 1987) have argued that stock markets overreact to information, with the implication that those markets are inefficient. The results of DeBondt and Thaler suggest that those stocks which generate high returns (they refer to these stocks as winners) in one period tend to underperform in a subsequent period, and those which underperform in one period (losers) outperform in a subsequent period. The implication of these results is that stock prices which overshoot will have a reversal which is predictable from past return data alone, violating the weak form of the efficient markets hypothesis.

The results of DeBondt and Thaler have been questioned by, among others, Chan (1988) and Ball and Kothari (1989). They argue that the results obtained by DeBondt and Thaler are due to a failure to adjust returns for the level of risk. Nonetheless, the issue of stock market volatility is still of active concern to researchers. The volatility of prices also lies at the heart of the variance bounds literature discussed in chapter 1 and examined more fully in chapter 4. It is therefore important, in examining the role of stock index futures, to analyse the impact on the underlying market of the introduction of futures trading on the FTSE-100 stock index contract. In doing this, however, it is essential that the methodology adopted allows examination of the link between information and volatility.

The impact of futures trading on spot price volatility is the subject of this chapter and the link between information and volatility is examined here by use of the generalised autoregressive conditional heteroskedasticity (GARCH) family of statistical techniques. In the next section theoretical issues relating to the link between information and volatility are discussed. The methodology adopted in this chapter is set out in section 3.3. This is followed in section

3.4 by a description of the data used in the study. Section 3.5 presents and discusses the empirical results emerging from the study and the final section presents concluding remarks.

3.2 Theoretical Considerations.

The past debate about the role of speculators and the impact of futures trading on spot price volatility, discussed in chapter 1, has characterised increased volatility as undesirable, or 'bad', and a reduction in volatility as desirable. However, this view is misleading in that it fails to take account of the connecting link between information and volatility. The debate about the impact of speculators and futures trading on price volatility can more fruitfully be examined within the context of the efficient markets hypothesis (EMH). The EMH tells us that prices in a market depend upon the information which is currently available in that market. When new information becomes available in an efficient market, prices will adjust to reflect that new information[1]. Thus price movements, and hence price volatility, are directly related to information in an efficient market.

Cox (1976) argues that there are two reasons why futures trading can alter the amount of available information. Firstly, futures trading attracts an additional group of traders to a market, namely speculators, who might otherwise not participate in the market. Marshall (1923) argued that it was in the interests of speculators to be well informed. Hence, in pursuing their own interest they are bringing good quality information to the market. However, the link between this information and volatility is not made. On the contrary, Marshall argues in relation to speculators in futures that

> "Their influence certainly tends to lessen the amplitude of price variations from place to place and from year to year." (Marshall, 1923, p262).

Clearly, this is in contrast to the view of the impact of information within the EMH literature.

The second reason why futures trading can alter the amount of available information is that since futures trading incurs less transactions costs than does trading in the spot market, when new information does become available it may be transmitted to the market more quickly. This is the standard argument of operational efficiency (low transactions costs) assisting allocational efficiency.

From the point of view of the efficiency of financial markets it is reasonable to argue that if futures trading does increase the amount of information available, then spot price volatility will increase. As Stoll and Whaley argue

> "...we must distinguish between message and messenger. Financial markets are the economy's messenger... Competing markets play an important role in determining that the messenger does not manipulate, distort, or delay the message... [F]utures and other recent financial innovations expand the routes over which messages may travel, which increases the likelihood that the correct message gets through." (1988, p20).

However, Cox argues that while the additional traders brought to the market by the introduction of futures contracts may be better informed about future prices than are traders in the spot market, equally they may be less well informed. Hence, again from a theoretical point of view the impact of futures trading is not unambiguous. Indeed, Goss and Yamey state

> "In principle, futures markets are neutral as to the effects of speculation on prices and price movements. Careful analysis and examination of the evidence are necessary to establish its effects in particular markets." (1978b, p30)

Similarly, Marshall argues that

> "...the power of selling the future command of a thing, not yet in possession, is liable to abuse. But, when used by able and honest men, it is beneficial: as is shown by the havoc, caused by unorganized speculation". (Marshall, 1923, p264).

However, in well developed markets such as the London Stock Exchange and LIFFE, which are largely dominated by institutional investors, it is difficult to believe that speculators will be ill-informed. Indeed, the description by MacDonald and Taylor (1989) of commodity market participants as highly motivated, highly professional individuals with instant access to vast information sets (see quotation on page 57 in chapter 1) seems equally, if not more, applicable to those participating in the market for stock index futures.

If the view that the additional traders brought to the market by the introduction of futures trading are well informed is accepted, then a direct link between information and volatility can be established. The arguments of Cox that futures trading might increase available information does not necessarily imply that information becomes available which would not otherwise. Rather, it may simply be that information becomes available earlier. Thus the rate of flow of information increases, as does the rate at which the information is impounded into prices. Hence, volatility of prices will increase.

The above argument is essentially intuitive. Ross (1989) presents a formal theoretical connection between information and volatility. He is concerned with the relationship between the timing of the release of information and price volatility. Ross uses the no arbitrage methodology developed by Ross (1976b) and Cox and Ross (1976), and subsequently extended by Ross (1978), Harrison and Kreps (1979) and others.

Ross (1989) begins by assuming an arbitrage-free economy, with prices generated by a martingale process and a pricing standard (or asset pricing model), q. By letting:

$$\frac{dp}{p} = \mu_p dt + \sigma_p dz_p \qquad (3.1)$$

where p is price, a two parameter random variable, with mean μ_p and standard deviation σ_p, and z is unit normal.

Ross demonstrates (theorem 1) that expected returns satisfy the following generalised security market line equation:

$$\mu_p - r = - \operatorname{cov}(p,q) \qquad (3.2)$$

where r is the rate of interest.

He then assumes that information is generated by a process of the form:

$$\frac{ds}{s} = \mu_s dt + \sigma_s dz_s \qquad (3.3)$$

where this process is used to predict the value of s at a future time T, s_T. Equation 3.3 describes the change in the rate of flow of information, s. By further assuming that s follows a lognormal process and that an asset exists with a value at time T which is given by s_T:

$$p_T = s_T \qquad (3.4)$$

the following pricing relation is obtained:

$$p = se^{(\mu s - r + \operatorname{cov}(q,s))(T-t)} \qquad (3.5)$$

From this we have:

$$\frac{dp}{p} = \frac{ds}{s} - [\mu_s - r + \operatorname{cov}(q,s)]dt \qquad (3.6)$$

Substituting in from equations 3.1 and 3.3 gives:

$$\mu_p dt + \sigma_p dz_p = [r - cov(q,s)]dt + \sigma_s dz_s$$

which, from equation 3.2, implies:

$$\sigma_p dz_p = \sigma_s dz_s$$

and:

$$\sigma_p = \sigma_s \qquad (3.7)$$

Equation 3.7 corresponds to Ross's theorem 2 which states that the variance of price change equals the rate (or variance) of information flow. This theorem implies that if the volatility of prices is not equal to the rate at which information arrives then arbitrage is possible. Thus Ross formally demonstrates the intuitive argument discussed above and concludes that

> "In an arbitrage-free economy, the volatility of prices is directly related to the rate of flow of information to the market." (Ross, 1989, p16).

In the context of the impact of futures markets on spot market volatility, if futures trading does increase the rate of flow of information, then we would expect spot prices to exhibit increased volatility. Thus, in examining spot price volatility pre- and post-futures, it is important to use a technique which is capable of examining this link.

3.3 Methodology.

3.3.1 Introduction.

This chapter examines the impact of the introduction of futures trading on the FTSE-100 stock index contract on the volatility of prices in the underlying spot market. By examining this issue it will be seen whether the introduction of futures trading has increased or decreased spot price volatility or had no discernible impact on volatility. However, the central theme of this chapter is not whether futures trading has stabilised or destabilised spot prices (although this will be made clear). Rather, the concern here is to investigate the extent to which the introduction of futures contracts on the FTSE-100 index affected the *nature* of volatility in the underlying spot market. It will thus be possible to draw inferences concerning the link between information and volatility.

It has been shown in chapter 1 that there is disagreement between different researchers as to whether the introduction of futures markets can be expected to stabilise or destabilise the underlying spot markets. The theoretical debate fails to provide a definitive answer concerning this issue and it is therefore a matter for empirical investigation. However, empirical research has also led to disagreement amongst researchers about the impact of futures on spot prices.

Three factors are important in explaining this disagreement:

1. differences exist in the methodologies used to examine the issue;

2. researchers have used different sample periods; and

3. the markets analysed have been different.

The first of these points is of particular importance. Most previous empirical studies have analysed the question of whether futures stabilise or destabilise the underlying spot market by using constructed measures of volatility in a time series analysis. However, Board and Sutcliffe (1991) have shown that studies of volatility are sensitive to the measures of volatility used. In addition, studies based on constructed measures of volatility make the implicit assumption that price changes in spot markets are serially uncorrelated and homoskedastic.

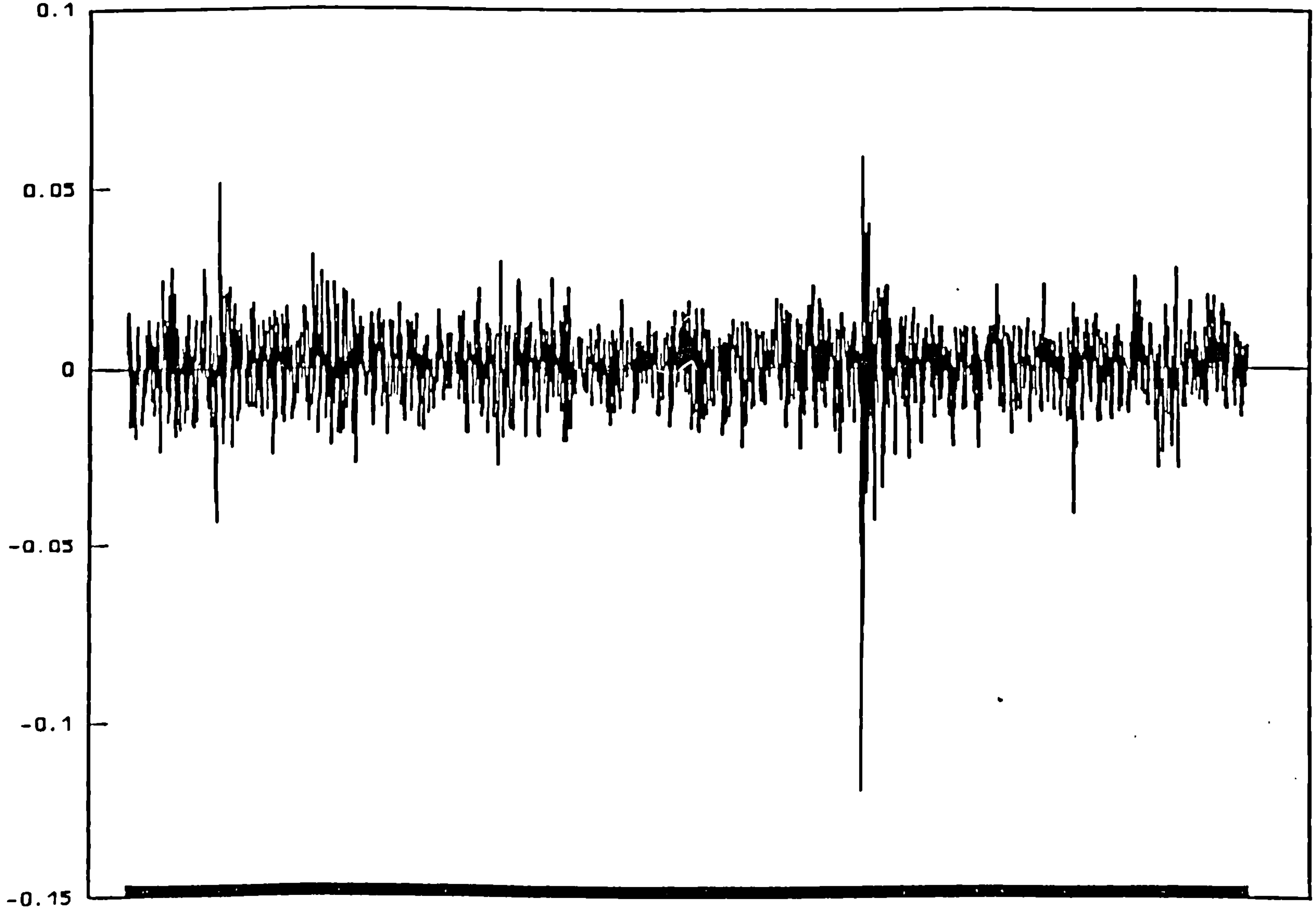
Figure 3.1 shows the log of daily price changes (daily returns) for the FT 500 stock index for the period November 1980 to October 1991 (the period investigated in this chapter)[2]. As can be seen from figure 3.1 large changes in returns appear to be followed by large changes, and small changes by small changes[3] and hence, the assumption of homoskedasticity may well be violated. This causes a problem for analysing such data since inferences drawn from studies which fail to control for such dependence are unreliable. In particular, while observed differences in volatility may be due to the introduction of futures contracts, it is possible that they are simply the result of return dependence and have nothing to do with the introduction of futures. In other words, the time period chosen for investigation may significantly alter the results (compare, for example, the results of Figlewski 1981 and Moriarty and Tosini, 1985). If the time period analysed is one where there are a predominance of small price changes prior to the introduction of futures trading and large price changes after, the impression will be given that futures trading has led to an increase in volatility. However, by extending the period analysed it is possible that different results will emerge.

More importantly, however, previous studies which investigate the impact of futures trading on spot price volatility have failed to recognise the connecting link

Figure 3.1

Daily Returns for FT 500 Stock Index

November 1980-October 1981



between information and volatility. In order to address this issue it is necessary to utilise techniques which allow examination of both the structure and characteristics of volatility. To this end this chapter employs the GARCH family of statistical techniques in modelling the conditional variance. As well as allowing examination of the structure and characteristics of volatility, this approach has the additional advantage that it explicitly addresses the issue of time dependence in the variance and therefore overcomes problems associated with heteroskedasticity in the data.

Traditional regression techniques require that the error term, ε, be homoskedastic. The assumption of homoskedasticity states that the error term, ε, is a random variable with a probability distribution that remains the same over all observations of the explanatory variable. In particular, homoskedasticity requires that the variance of each ε_i is the same for all values of the independent variable:

$$\text{var}(\varepsilon) = E[(\varepsilon_i - E(\varepsilon)]^2 = E(\varepsilon_i)^2 = \sigma_\varepsilon^2 \qquad (3.8)$$

Equation 3.8 states the assumption of the traditional regression technique that the error term has a constant variance. If this assumption is violated then the ε_i's are said to be heteroskedastic and we have:

$$\text{var}\ (\varepsilon_i) = \sigma_{\varepsilon i}{}^2 \tag{3.9}$$

where the subscript i denotes the fact that the individual variances may be different. Figure 3.1 above suggests that equation 3.9 might be a more appropriate representation of the error term for daily price changes than equation 3.8.

Engle and Rothschild argue that

> "Scholars and practitioners have long recognized that asset returns exhibit volatility clustering; only in the last decade have we had statistical models which can accomodate and account for this dependence...the ARCH (or AutoRegressive Conditional Heteroskedasticity) model rests on the presumption that forecasts of the variance at some future point in time can... be improved by using recent information. In particular, volatility clustering implies that big surprises of either sign will increase the probability of future volatility." (1992, p1).

Thus ARCH and GARCH models are ideally suited to the study of volatility in a time series which is heteroskedastic. This point has been demonstrated by Engle (1982), Engle and Bollerslev (1986) and Bollerslev (1986, 1987). In order to understand why this is the case it is necessary to have an understanding of the ARCH and GARCH processes.

3.3.2 ARCH and GARCH.[4]

The ARCH model of Engle (1982) and subsequent extensions have proved to be extremely useful tools by which to characterise the time varying variance associated with speculative prices. Following Engle (1982) an ARCH model is any discrete time stochastic process (ε_t) of the form:

$$\varepsilon_t = z_t \sigma_t \qquad (3.10)$$

$$z_t \quad \text{i.i.d.}, \quad E(z_t) = 0, \quad \text{var}(z_t) = 1 \qquad (3.11)$$

where σ_t is a time-varying, positive and measurable function of the information set at time t-1. By definition, ε_t is serially uncorrelated, with zero mean. However, the conditional variance of ε_t is equal to σ_t^2, which may change over time. ε_t corresponds to the disturbance term for some other stochastic process, say y_t:

$$y_t = f(x_{t-1};b) + \varepsilon_t \qquad (3.12)$$

where $f(x_{t-1};b)$ denotes a function of x_{t-1} and the parameter vector b. This is known as the mean equation.

Where $f(z_t)$ is the density function for z_t and θ is the vector of all the unknown parameters in the model, the log-likelihood for the sample $\varepsilon_t, \varepsilon_{t-1}, \ldots, \varepsilon_1$ is:

$$L(\theta) = \sum_{t=1}^{T} [\log f(\varepsilon_t \sigma_t^{-1}) - \log \sigma_t] \qquad (3.13)$$

The form of equations 3.10 and 3.11 is very general, allowing for a wide variety of models. However, the most popular representations of these equations are in a linear form. The earliest suggested parameterisation of σ_t was that of Engle (1982) who proposed the variance could be modelled as a linear function of past squared values of the process. This is the simple linear ARCH (q) model, shown in equation 3.14.

$$\sigma_t^2 = \omega + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 = \omega + \alpha(L)\varepsilon_t^2 \qquad (3.14)$$

where $\omega>0$ and $\alpha_i>0$ or $\alpha_i=0$, and L denotes the lag operator. The advantage of the linear ARCH (q) model is that it captures the tendency in financial data for volatility clustering.

For z_t normally distributed, the conditional density entering the likelihood function in 3.13 takes the form:

$$\log f(\varepsilon_t \sigma_t^{-1}) = -0.5\log 2\pi - 0.5\varepsilon_t^2 \sigma_t^{-2} \qquad (3.15)$$

Engle (1982) suggests maximum likelihood based inference procedures for the ARCH class of models under this distributional assumption. Several tests of the hypothesis that the alpha values equal zero have been proposed, as have alternative means of estimating ARCH models (see Bollerslev, Chou and Kroner (1992) for details in relation to both of these issues).
Bollerslev, Chou and Kroner (1992) point out that

> "In many of the applications with the linear ARCH(q) model a long lag length of q is called for. An alternative and more flexible lag structure is often provided by the Generalized ARCH, or GARCH(p,q), model" (1992, p9).

The GARCH model was proposed by Bollerslev (1986) and is of the form:

$$\sigma_t^2 = \omega + {}_{i=1}\Sigma_q \alpha_i \varepsilon_{t-i}^2 + {}_{j=1}\Sigma_p \beta_j \sigma_{t-j}^2$$
$$= \omega + \alpha(L)\varepsilon_t^2 + \beta(L)\sigma_t^2 \qquad (3.16)$$

While p and q can be of any order, in most applications p = q = 1 is found to be satisfactory. For a GARCH (1,1) process to be well-defined it is necessary that both α_1 and β_1 are nonnegative.

GARCH explicitly allows for heteroskedasticity of the error term, with the variance of the error term being modelled as a linear function of the lagged squared errors and the past residual variances.

Engle et al (1987), proposed the GARCH-in-mean (GARCH-M) as an extension of the GARCH model, while the integrated GARCH (I-GARCH) was put forward by Engle and Bollerslev (1986). Both of these are examined here. GARCH-M extends GARCH by including the conditional variance (σ_t^2) as an explanatory variable in the mean equation. Hence, the conditional variance may directly explain the dependent variable:

$$y_t = f(x_{t-1}, \sigma_t^2; b) + \varepsilon_t \qquad (3.17)$$

With I-GARCH the model specification is characterised by nonstationary variables, such that any shock to the variance of a process is permanent. For a process to be identified as I-GARCH the parameters α_i and β_j in equation 3.16 must together sum to unity. This implies that there is present an approximate unit root in the autoregressive polynomial. Where an approximate unit root is present, current information remains important for forecasts of the conditional variances for all horizons.

3.3.3 GARCH, Volatility and the FTSE-100 Stock Index Futures Contract.

In this chapter the impact of futures trading in the FTSE-100 contract on the volatility of the underlying market is investigated by estimating a model for a period which covers the time before and after the introduction of futures, in line with previous studies. However, unlike previous studies a GARCH model is used here.[5] Using GARCH, the impact of the onset of futures trading is captured by the introduction of a dummy variable in the variance equation 3.16, representing the time period before and after futures trading.

As was seen in chapter 1, in order to isolate the impact of futures trading on the volatility of spot price changes, it is necessary to account for market wide influences as far as is possible. For this purpose a proxy variable for which there is no related futures contract is included in the mean equation. Specifically, the mean equation (generalised as 3.12 above) for the analysis carried out here is:

$$SPC_t = a + bUPC_t + \varepsilon_t \qquad \text{where } \varepsilon_t \sim N(0,h_t) \qquad (3.18)$$

where SPC_t is the natural logarithm of the daily spot price change, UPC_t is the natural logarithm of the daily price change for the proxy variable for market wide influences and h_t is the variance of the error term (previously referred to as σ_t^2).

The variance equation for the analysis carried out here (generalised as 3.16 above) is:

$$h_t = \omega + {}_{i=1}\Sigma_q \alpha_i \varepsilon_{t-1}^2 + {}_{j=1}\Sigma_p \beta_j h_{t-1} + \gamma_1 DF \qquad (3.19)$$

where DF is a dummy variable with value 0 for the pre-futures period and 1 for the post-futures period, and all other variables are as previously defined.

Thus spot price changes are regressed on a proxy variable which is intended to capture market wide influences on price changes (for example, changes in interest rates) in equation 3.18. What is left unexplained in this model will be spot price changes which are due to influences specific to this market. Remember that the proxy variable relates to a market for which there is no futures trading, while the dependent variable relates to a market for which there is (at some point in the period analysed) futures trading. Hence, one of the influences specific to the spot market for which price changes are being analysed relates to the existence of futures trading. This influence is clearly not captured by the mean equation, but rather by the GARCH equation, equation 3.19. If, in this functional form, the futures dummy is found to be statistically significant, it can be inferred that the introduction of futures trading has impacted on spot market volatility.

However, as explained above, the central issue of concern in this chapter is the relationship between information and volatility, and not simply whether futures trading has led to an increase or decrease in volatility in the spot market. To address this issue the period under investigation is partitioned into two sub-periods relating to before and after futures trading began. GARCH models are estimated for both sub-periods. The GARCH models estimated in this analysis are identical to equations 3.18 and 3.19 except that the dummy variable for the existence of futures trading is not included.

Comparisons are then made of the order of the GARCH models and of the estimated coefficients, and inferences drawn. By proceeding in this manner it is possible to examine not just the impact of futures trading in terms of increasing or decreasing spot price volatility, but also the impact of futures trading on the nature of volatility. In examining these issues using GARCH it is the GARCH equation 3.19 which is of central interest, because this relates to spot price changes unrelated to market wide influences. Specifically, we are concerned with whether the order of GARCH or the magnitude of the GARCH coefficients changes post-futures. In addition, the persistence of market specific factors which cause spot price changes is examined by testing for unit roots in the autoregressive polynomial, i.e whether the estimated alphas and betas sum to unity. This test is carried out both for the pre-futures period and the post-futures period and comparisons made.

3.4 Data.

The data used in this study consists of daily closing price indices for the period November 1980 to October 1991. The FTSE-100 stock index was introduced in January 1984 to support the futures contract on its introduction in May of that year. Hence, data is not available for a sufficiently long period on the FTSE-100 index for the purposes of comparing the volatility of spot market prices before and after futures trading began. It is therefore necessary to use a proxy variable for the FTSE-100 index in order for this comparison to be made in the analysis presented in this chapter.

The possible candidates to be used as a proxy for the FTSE-100 are the FT All Share index, the FT 500 index and the FT30 index. The construction of the FT30 is different in nature from that of the FTSE-100. In addition, it clearly does not cover such a range of stocks as does the FTSE-100 and is thus not such a good proxy for the market. The use of the FT30 as a proxy is, therefore, inappropriate. The two indexes based on a wider range of stocks must therefore be considered. Both are potentially appropriate as proxies for the FTSE-100. However, the non-synchronous trading problem is most severe for the FT All Share index. In addition, the correlation coefficient between it and the FTSE-100 was lower than that for the FT 500 and the FTSE-100 over the period analysed in this study since the introduction of the FTSE-100. For these reasons the FT 500 was used as a proxy in this analysis.

As stated in the previous section it is necessary to remove market wide influences on spot price changes by incorporating a proxy variable in the mean equation. None of the FT share indexes are suitable for this purpose since they are all highly correlated with the FTSE-100 and it is necessary to have a proxy which is not associated with a futures contract. Therefore, to capture market wide influences on price volatility the index on the Unlisted Securities Market (USM), as provided by Datastream, was used[6].

After the exclusion of non-trading days the daily time series for the whole sample consists of 2709 observations. Of these 883 related to the period prior to the introduction of futures trading on the FTSE-100 stock index and 1826 to the period following its introduction.

3.5 Empirical Results.

Table 3.1 presents the means and standard deviations of the first differences of the log of the FT 500 and the USM indexes. The period for which figures are given is November 1980 to October 1991. In addition to presenting the figures for the whole period, the means and standard deviations are also shown for the two sub-periods within the whole period, relating to before and after the onset of futures trading in the FTSE-100 stock index contract. Given that the second sub-period includes the time of the stock market crash of October 1987, it is not surprising to find that the mean returns for the first sub-period are greater than those for the second. Indeed, for the USM the second sub-period generated negative returns[7]. However, it is volatility of price changes which is of central concern here. In relation to this, table 3.1 shows that the standard deviation of daily price changes for the FT 500 is higher for the post-futures trading period. However, in contrast, the standard deviation for the price changes for the USM index is lower for this period. Hence, while volatility in the market without futures trading is lower in the later period, the volatility of the spot market underlying the futures contract has increased. While this presents prima facie evidence of changes in volatility resulting from futures trading, further analysis is required. Of particular concern in interpreting this higher standard deviation for the FT

Table 3.1: Means and Standard Deviations of First Differences of the Log of the FT 500 and the USM Indexes.

Daily Data: November 1980 - October 1991

Period[1]	n	FT 500 Mean	FT 500 Standard Deviation	USM Mean	USM Standard Deviation
1980-1991	2709	.00054	.00950	-.00011	.01129
1980-May '84	883	.00072	.00935	.00008	.01376
May '84-1991	1826	.00045	.00958	-.00019	.00987

1. Excluding Bank Holidays and other non-trading days.

500 as being the result of the introduction of futures trading, is the fact that the latter period includes the 1987 crash. Thus it is possible that the greater volatility in the latter period is simply the result of the time period chosen for analysis. This problem can be addressed by use of GARCH.

GARCH (p,q) and GARCH-M (p,q) equations were estimated for all combinations of p=1,2,3,4,5 and q=1,2,3,4,5. On the basis of log likelihood tests the GARCH (1,1) was found to be the most appropriate representation for the sample period and sub-periods considered[8]. Table 3.2 shows the equations estimated and the results for the whole period (pre- *and* post-futures). The model was estimated both with and without a dummy variable accounting for the October 1987 crash in the mean equation[9]. The dummy relating to the crash was included in the mean equation because the purpose of this dummy is to account for market wide influences on price changes. In addition, a dummy variable relating to Big Bang was included, but found to be insignificantly different from zero. It was therefore excluded from the final estimations. All parameters included are statistically significant at the 5% level.

The coefficient, γ_1, on the futures dummy is statistically significant and positive. This appears to suggest that the onset of futures trading has resulted

Table 3.2: GARCH Estimations with Futures Dummy.

$$SPC_t = a + bUPC_t + CD_c + \varepsilon_t$$

$$ht = \omega + \alpha_1 \varepsilon^2_{t-1} + \beta_1 h_{t-1} + \gamma_1 D_F$$

SPC_t = the natural logarithm of the daily price change for the FT 500 index.

UPC_t = the natural logarithm of the daily price change for the USM index.

D_F = a dummy with value 0 for the pre-futures period and 1 for the post-futures period.

D_c = a dummy with value 1 for the period immediately following the October 1987 crash and 0 otherwise.

a	b	c	ω	α_1	β_1	γ_1
.775*	.3384	-	.3969+	.0862	.8423	.107+
(5.32)	(25.70)		(5.49)	(9.44)	(54.97)	(2.70)
.963*	.3276	-.0504	.4350+	.0991	.8190	.117+
(6.52)	(25.30)	(-43.15)	(5.56)	(13.13)	(50.57)	(2.39)

* Coefficients multiplied by 10^3 for readability

\+ Coefficients multiplied by 10^5 for readability

All parameters are statistically significant at the 5% level
Figures in parentheses are t-statistics

n = 2709

in an *increase* in the volatility of prices in the underlying stock market. This finding is in contrast to the majority of findings relating to the impact of stock index futures trading in the USA. However, while spot price volatility may have increased as a result of the onset of futures trading, the analysis thus far does not enable us to examine the *reasons* for this change.

Table 3.3 reports the results for the two sub-periods, relating to before and after the introduction of futures trading. Once again, for the post-futures sample the model was estimated both with and without a dummy variable relating to the crash. For both pre- and post-futures trading the GARCH parameters are all significantly different from zero at the 5% level, with the exception of the constant term, ω, pre-futures. We are able to investigate further the increase in volatility suggested in table 3.2 by examining the behaviour of the parameters in the GARCH equation for the two sub-periods.

The first point to note in comparing results for before and after the onset of futures trading is that the onset of futures trading has *not* led to a change in the *nature* of volatility. For the periods before and after the onset of futures trading a GARCH (1,1) representation is the most appropriate form of the model. The large increase in ω post-futures (indeed ω is not

Table 3.3: GARCH Estimations: Period Partitioned at Start of Futures Trading.

$$SPC_t = a + bUPC_t + cD_c + \varepsilon_t$$

$$ht = \omega + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 h_{t-1}$$

	a	b	c	ω	α_1	β_1
Pre-futures n=883	.642* (2.58)	.4082 (23.62)	-	.1151+ (1.48)	.0404 (2.73)	.9384 (38.31)
Post-futures n=1826	.814* (4.43)	.2035 (7.65)	-	.6061+ (6.77)	.1099 (7.60)	.8099 (42.13)
Post-futures n=1826	.674* (3.72)	.3521 (24.25)	-.0460 (-38.70)	.5805+ (5.58)	.1298 (12.60)	.7880 (37.28)

Definitions and footnotes as in Table 2.

Augmented Dickey Fuller Statistic:

Pre-futures	- 3.33
Post-futures (without D_c)	-10.56
Post-futures (with D_c)	- 7.75

significantly different from zero pre-futures) together with the changes in α_1 and β_1 indicate that there has been an increase in the unconditional variance. The unconditional variance, given by $\omega/(1-\alpha_1-\beta_1)$, is .0000543 pre-futures and .0000756 post-futures (.0000706 with the crash dummy). This finding is consistent with the view that more information is being transmitted to the market as a result of the onset of futures trading.

Similarly, the value of α_1 has increased post-futures, again suggesting an increase in volatility as a result of futures trading. α_1 is the coefficient relating to the lagged squared error term. In the context of this analysis the lagged error term relates to changes in the spot price on the previous day which are attributable to market specific factors, i.e. non-market wide factors. Assuming that markets are efficient, then these price changes are due to the arrival in the market of items of information which are specific to the pricing of the FT 500. Hence, α_1 relates to the impact of yesterday's market specific price changes on price changes today. Given that this relates to the arrival of information yesterday, α_1 can thus be viewed as a "news" coefficient, with a higher value implying that recent news has a greater impact on price changes. Thus the increase in α_1 post futures suggests that information is being impounded in prices more quickly due to the introduction of futures trading.

Just as α_1 reflects the impact of recent news, β_1 can be thought of as reflecting the impact of 'old news'. β_1 is the coefficient on the lagged variance term and as such is picking up the impact of price changes relating to days prior to the previous day and thus to news which arrived before yesterday. The increase in the rate of information flow to be anticipated from the onset of futures trading is expected to lead to a reduction in uncertainty regarding previous news. This in turn will lead to a fall in the persistence of information. In other words, 'old news' will have less impact on today's price changes. This view is confirmed by the fall in the value of β_1 post-futures.

This interpretation of the changes in the GARCH parameters is given further support by the fact that the pre-futures model is a candidate for I-GARCH, whereas the post-futures model is not obviously so. Pre-futures α_1 and β_1 sum to .98, compared to .92 post-futures. Dickey-Fuller tests were carried out for an I-GARCH specification and revealed that while the pre-futures sample was integrated at the 1% level, the post-futures model is stationary. These results are also reported in table 3.3. This implies that the persistence of shocks has decreased since the onset of derivative trading. Hence, all of the findings regarding the changes in the parameters of the GARCH equation suggest that the spot market has become more volatile after the introduction of futures trading, but that this is the result of an increase in the rate of flow of information to the market and is not due to the 'destructive' activities of speculators as suggested in earlier studies. These results are consistent with the theoretical arguments of Ross (1989) and the view that futures trading increases the flow of information to the spot market.

The results presented in this chapter are in contrast to many of the results relating to the volatility of the stock index and GNMA spot markets in the USA post-futures. A likely reason for this relates to the frequency of the data used in the analysis. This study has shown that increased volatility is the result of the more rapid impounding of information into spot prices. Given that most financial markets in developed economies impound information into prices rapidly, the impact of the onset of futures trading in terms of the speed of the price change, while significant, is likely to be at the margin. Thus, prices which were already adjusting rapidly, adjust more rapidly with the onset of futures trading. If this change is to be identified, it is necessary to utilise data at short time intervals. Ideally, we would want data collected at very short intervals, perhaps in terms of hours or even minutes. In this study the most frequent data available to the author was used, namely daily data. This proved sufficiently frequent to identify the changes resulting from the onset of futures trading. However, it is unlikely that such changes would be identified if weekly or monthly data were used. Therefore, the findings in some previous studies that futures trading had no discernible impact on spot price volatility may well be due to the frequency of the data used.

3.6 Summary and conclusions.

There has long been a debate on the impact which speculation has on price volatility. While this debate preceded the introduction of futures markets, trading in derivative securities led to an intensification in concern over the role of speculators. The main concern about the impact of futures trading emanates from the belief among spot market participants that the activities of speculators will destabilise prices in the spot market. Previous studies have sought to examine the impact of futures trading by modelling the volatility of prices for periods before and after the introduction of futures. However, these earlier studies have not accounted for the interdependence of the time series of returns in speculative markets i.e. large changes in prices are followed by large changes, and small by small. For this reason it is more appropriate to analyse volatility using GARCH which allows for time varying variance in a process.

More importantly, however, previous studies have largely ignored the relationship between information and volatility. Thus increasing volatility has been seen as a 'bad thing' and the fact that it may be a direct result of an increase in the rate of flow of information has received little acknowledgement in this literature. Hence, previous studies have failed to distinguish between message and messenger. In addition to dealing with the problem of heteroskedasticity, the use of the GARCH technique also allows consideration of the link between information and volatility directly.

The results presented here for the impact of the introduction of the FTSE-100 stock index futures contract suggest that there has been an impact on spot price volatility. In particular, the variance in price changes for the pre-futures sample was integrated, suggesting that shocks (i.e. items of news) have a permanent effect on price changes, whereas the post-futures sample was found to be stationary. The results suggest that trading in futures markets has led to an improvement in the quality and speed of information flowing to spot markets. This is confirmed by the increase in the "news" coefficient (α_1) of the GARCH equation and the reduction in the "persistence" coefficient (β_1).

Hence the evidence presented here suggests that there has been an increase in spot price volatility on a daily basis, but that this increase has arisen due to increased information in the market and is not due to speculators having an adverse destabilising effect. Indeed, this increased volatility appears to be the result of futures trading expanding the routes over which information can be conveyed to the market.

This finding has important implications for the way in which futures markets are viewed. *Rather than seeing* increased volatility as undesirable and necessitating further regulation of futures markets, the evidence presented here suggests that futures trading is improving the operation of the underlying spot market. In particular, by attracting more, and possibly better informed, participants into the market, futures lead to the incorporation of information into spot prices more quickly. This suggests that the increased volatility of prices in spot markets are the result of the impounding of more information as a result of the onset of futures trading. Thus even those market participants who do not directly use futures markets, may benefit from this knock on effect of the introduction of futures trading.

As far as policy implications are concerned, the evidence of the analysis in this chapter suggests that findings of increased volatility post-futures should not automatically lead to increased regulation. Indeed, increased regulation is likely to slow down the rate at which information is impounded into spot prices, making them a less accurate measure of the true value of the asset.

Furthermore, it has been argued in this chapter that in order to identify the impact of futures trading on spot price volatility it is necessary to use data collected at short time intervals. If information is continually flowing into financial markets then the fact that futures speed up this flow may not be identified if the data used is weekly or monthly. The speed at which information is impounded into prices as a result of the onset of futures trading might increase by a matter of hours or, even days, but it is unlikely that, in what are already broadly efficient markets, the increase can be measured in terms of weeks.

In this chapter the relationship between information and price volatility has been examined. The finding that the rate of flow of information to the underlying spot market has increased post-futures, suggests that futures trading has improved the efficiency of that market. This strongly suggests that the futures market itself will be efficient. However, while the role of information has been investigated in this chapter, this has not been in relation to the efficiency of the FTSE-100 futures market. Given that the efficiency or otherwise of this market has important implications in terms of the price discovery role and hedging effectiveness of futures, this issue is the subject of the next chapter.

Footnotes

1. See Fama (1970, 1991) for excellent discussions of the EMH and for an interesting comparison of how the debate regarding efficiency has developed over the last two decades.

2. The reason for showing returns on the FT 500 rather than the FTSE-100 is explained below.

3. This conforms with the well established findings of Mandelbrot (1963) and Fama (1965) and, more recently, by Akgiray (1989).

4. This section draws on the excellent exposition of Bollerslev, Chou and Kroner (1992).

5. A similar approach has been adopted for the oil market by Antoniou and Foster (1992b).

6. It is recognised that there are problems associated with choosing a proxy which captures market wide volatility. However, it is felt that the USM index is the most appropriate available in this case.

7. Strictly speaking the values are not returns as they only relate to price changes and therefore exclude dividend income.

8. This is in line with the findings of many other studies, see for example Akgiray (1989) and Antoniou and Foster (1992b).

9. The dummy variable relates to the four weeks following the 19 October 1987. This length of time was chosen on the basis of a visual examination of the closing values of the stock index. Over this four week period there was excessive volatility. The equations were also estimated using dummies relating to differing lengths of time after the crash. Periods of between two and six weeks were tried. The pattern of results was unchanged with the differing lengths.

Chapter 4: Futures Markets Efficiency and the Unbiasedness Hypothesis.

4.1 Introduction.

We have seen in chapter 1 that the price discovery role of futures markets crucially depends on the efficiency of those markets. If futures markets are not efficient then they will not necessarily provide unbiased estimates of the expected future spot price. In chapter 2 the risk return relationship for the FTSE-100 stock index futures contract was examined and doubts were raised about the efficiency of the market for this contract. Chapter 3 has demonstrated the importance of information in relation to price volatility. The use of information is central to the issue of efficiency. Furthermore, efficiency impinges on hedging, the primary role of futures markets, which is the subject of the next chapter. Investors seeking to hedge risk in an efficient market will be able to accept market prices as correct. Hence, it will not be worthwhile incurring additional costs in an attempt to seek out information not already incorporated in prices. However, if futures markets are inefficient then hedgers will face an additional cost of using the markets.

Clearly then, market efficiency is of central concern to the question of whether a futures contract is successful in fulfilling the economic role ascribed to futures. In this chapter we examine the efficiency of the FTSE-100 stock index futures contracts using the cointegration procedure and variance bounds tests. In chapter 1 it was noted that the OLS procedure used in many previous studies is inappropriate when price series are nonstationary. The cointegration technique overcomes the methodological problems associated with many of these earlier studies. Variance bounds tests, while widely used to examine stock market efficiency, have not previously been employed to examine the efficiency of futures markets.

The chapter proceeds as follows. The next section discusses market efficiency and the way in which it relates to futures contracts. Section 4.3 explains the cointegration procedure and the way in which it can be used to examine futures market efficiency. In section 4.4 there is a discussion of variance bounds tests and an alternative test of futures market efficiency based on these tests is developed. Section 4.5 discusses the methodology adopted in this chapter, and the data used to test for efficiency is set out in section 4.6. Sections 4.7 and 4.8 present the empirical results relating to tests based on cointegration and variance bounds respectively. Finally, section 4.9 presents a summary and conclusions.

4.2 Market Efficiency and Futures Markets.

According to the efficient markets hypothesis (EMH) financial markets are efficient if security prices fully reflect all relevant information as soon as that information becomes available. If they do then the prices of securities are accurate signals for the allocation of resources.

Fama (1970, 1991) has done much to operationalise the notion of market efficiency. His definition of the EMH is in line with that given above

> "I take the market efficiency hypothesis to be the simple statement that security prices fully reflect all available information. A precondition for this strong version of the hypothesis is that information and trading costs, the costs of getting prices to reflect information, are always 0... A weaker and economically more sensible version of the efficiency hypothesis says that prices reflect information to the point where the marginal benefits of acting on information (the profits to be made) do not exceed the marginal costs... Since there are surely positive information and trading costs, the extreme version of the market efficiency hypothesis is surely false. Its advantage, however, is that it is a clean

benchmark that allows me to sidestep the messy problem of deciding what are reasonable information and trading costs." (Fama, 1991, p1575).

In this thesis the view will be taken that a financial market is efficient if prices 'fully reflect' all the available information which is relevant to valuation. In other words, the set of prices arrived at in the market reflects all that is known about the securities.

When it comes to testing efficiency in any market the problem of the existence of trading costs and positive information clearly arises. However, Fama argues

> "The joint-hypothesis problem is more serious. Thus, market efficiency per se is not testable. It must be tested jointly with some model of equilibrium, an asset-pricing model. This point... says that we can only test whether information is properly reflected in prices in the context of a pricing model that defines the meaning of 'properly.' As a result, when we find anomalous evidence on the behavior of returns, the way it should be split between market inefficiency or a bad model of market equilibrium is ambiguous." (Fama, 1991, p1575-1576).

Hence, in testing for the efficiency of futures markets, it is necessary to consider the way in which futures are priced. More formally, Hansen and Hodrick argue

> "Any discussion of the efficiency of a market requires a specification of the preferences and information sets of economic agents, the technology available for production, and the costs inherent in transactions." (1980, p830).

With reference to futures markets, Koppenhaver (1983) defined a market equilibrium in terms of price expectations and the existence of a risk premium greater than or equal to zero. The relationship between the current futures price and the expected value of the futures price at expiration of the contract is given in equation 4.1:

$$F_{t,t+n} = E[F_{t+n,t+n}|\phi_t] - R_t \qquad (4.1)$$

where $F_{t,t+n}$ is the futures price quoted at time t for delivery at time t+n (i.e. n periods later), $F_{t+n,t+n}$ is the futures price at maturity, ϕ_t is the information set at time t, E is the mathematical expectations operator and R_t is the risk premium which is nonnegative and depends on the systematic risk of holding a futures contract.

In the absence of arbitrage opportunities at expiration, the maturity basis will be zero and hence the spot price, S_{t+n}, at maturity will equal the futures price at maturity. Thus $S_{t+n} = F_{t+n,t+n}$. Market efficiency is commonly defined in terms of the futures price being a fair game with respect to the information set. Hence, equation 4.1 can be rewritten as:

$$E(S_{t+n}) = F_{t,t+n} + R_t \qquad (4.2)$$

Equation 4.2 implies that at time t the expected spot price at futures contract maturity (i.e. time t+n) will be greater than or equal to the futures price at time t for delivery at time t+n. With a zero risk premium equation 4.2 is a martingale process and the expected spot price at contract expiration is the current futures price for future delivery. This implies that :

$$E(S_{t+n} - F_{t,t+n} | \phi_t) = 0 \qquad (4.3)$$

Hansen and Hodrick point out that

> "If economic agents are risk neutral, costs of transactions are zero, information is used rationally, and the market is competitive, the ... market will be efficient in the sense that the expected rate of return to speculation... will be zero." (1980, p830).

Where this is the case then equation 4.3 will hold. Assuming that on average the expected spot price equals the actual spot price then we have the following:

$$S_{t+n}=E(S_{t+n}|\phi_t) + e_{t+n} \quad \text{where } E(e_{t+n}|\phi_t) = 0 \qquad (4.4)$$

Equations 4.3 and 4.4 imply that the future spot price is given by:

$$S_{t+n} = F_{t,t+n} + e_t \qquad (4.5)$$

Equation 4.5 states that the futures price quoted at time t for delivery at time t+n is an unbiased predictor of the future spot price at contract expiration, given the information set available at time t. Note that this unbiasedness hypothesis relies crucially on the assumption of their being no risk premia in futures markets, or that there is a zero net risk premium. Empirical analysis of equation 4.5 allows the joint hypothesis of market efficiency and unbiasedness in futures prices to be examined.

It is common in the literature to test the implications of equation 4.5 by regressing the spot price at maturity on the futures price some time prior to maturity:

$$S_{t+n} = a + bF_{t,t+n} + e_t \qquad (4.6)$$

Equation 4.6 is the same as equation 1.3 and from this equation market efficiency implies that a=0 and b=1. This unbiasedness hypothesis is also known as the 'simple efficiency' hypothesis (see Hansen and Hodrick (1980)) and the 'speculative efficiency' hypothesis (see Bilson (1981)). In testing for futures market efficiency it is normal to assume that, due to the nature of the information set, futures prices closer to the expiration date will provide better estimates of the future spot price, than do those further away. Thus tests are carried out for futures prices with different values of t in equation 4.6. Rejection of the restrictions on the parameters a and b has been interpreted as either the market is inefficient or there exists a non-zero risk premium in futures markets. Hence, tests of equation 4.6 are a joint test of the unbiasedness hypothesis and market efficiency and, therefore, provide a means of examining the price discovery role of futures markets.

However, while the implications of equation 4.5 are typically investigated by examining the values of a and b in equation 4.6, the variance bounds literature provides another means of examining equation 4.5. Both approaches are adopted in this chapter.

Before going on to set out the techniques used to test the joint hypothesis in this chapter it should be noted that investigation of equation 4.5 is not the only means by which futures market efficiency can be examined. Clearly, if a different pricing model were adopted then the joint hypothesis to be tested would be different. In addition, efficiency could be tested by examination of whether arbitrage opportunities exist in the markets. The approach adopted in this chapter has been chosen because of the central role of price discovery in futures markets and hence the considerable importance which is attached to the notion of futures prices being unbiased predictors of future spot prices.

4.3 Cointegration and futures market efficiency.

It has been established that a common test of market efficiency involves regressing the spot price at maturity on the futures price some time prior to maturity, as in equation 4.6. However, it was mentioned in chapter 1 that there were problems associated with testing the restrictions. The reasons for this are now discussed.

In recent years a major area of interest in relation to the analysis of financial price data has been the issue of the stationarity of a price series. In circumstances where data is nonstationary, standard statistical tests of parameter restrictions such as those discussed in relation to equation 4.6 are not reliable. This lack of reliability arises from the fact that the asymptotic distribution theory on which hypothesis tests are constructed relies critically on the assumption of stationarity. In particular, Elam and Dixon (1988) point out that financial price series are typically nonstationary, having a unit root, with the implication that the standard F-test of the null hypothesis that a=0 and b=1 is inappropriate. They point out that on the basis of Monte Carlo simulations the F-test is biased towards rejecting market efficiency incorrectly. Hence, the F-test is not a reliable test for pricing efficiency given the existence of nonstationary variables. Elam and Dixon state that

> "Fuller (1976) provides a table of tabulated values for testing the hypothesis that b=1 for a random walk. However, testing that b=1 is not a sufficient test for pricing efficiency...To our knowledge, the distribution of the F statistic for the hypothesis that a=0 and b=1...has not been derived." (1988, p369).

They go on to say that the development of an appropriate statistical procedure to test this hypothesis is an important issue for future research. Fortunately for the purposes of testing the efficiency of futures markets, such a statistical procedure has now been developed in the form of cointegration. Before going on to discuss this technique, it is appropriate to firstly discuss the concept of stationarity.

A series which achieves stationarity after differencing that series d times is said to be integrated of order d, denoted I(d). A series which is integrated of order zero, i.e. is I(0), is therefore stationary and one which is integrated of order 1, I(1), achieves stationarity after first differencing. An I(1) series is said to contain a unit root. When two price series, such as the spot and futures price series, are both integrated of the same order d, then a linear combination, Z_t, of the two series will generally also be integrated of order d, where:

$$Z_{t+n} = S_{t+n} - a - bF_{t,t+n} \qquad Z_t \sim I(d) \qquad (4.7)$$

However, as Engle and Granger (1987) point out, a linear combination of two I(d) series, although generally I(d), *can be integrated of* an order lower than d. For example, it is possible that two series which are nonstationary and contain a unit root, i.e. are I(1), can generate a linear combination, Z_t, which is stationary, i.e I(0). Such a series is said to be cointegrated and the cointegrating relationship is defined in equation 4.8a:

$$S_{t+n} - a - bF_{t,t+n} = 0 \qquad (4.8a)$$

Stationarity of Z_t is established by testing for and rejecting the null hypothesis of a unit root in the residuals of the cointegrating relationship.

Rearrangement of equation 4.8a and introduction of an error term makes the cointegrating relationship more clear:

$$S_{t+n} = a + bF_{t,t+n} + e_t \qquad (4.8b)$$

Since the market efficiency hypothesis implies that the futures price is an unbiased predictor of the future spot price, cointegration of the two price series is a necessary condition for market efficiency. If the two series were not *cointegrated*, with z_t *being* nonstationary, S_{t+n} and $F_{t,t+n}$ do not move together and will tend to drift apart over time. If this is the case then $F_{t,t+n}$ cannot be an unbiased predictor of S_{t+n}.
However, cointegration, while being a necessary condition for market efficiency, is not a sufficient condition, as demonstrated by Hakkio and Rush (1989). It is also necessary to consider the values of the parameters a and b in the cointegrating relationship. In particular, for the futures price to be an unbiased predictor of the future spot price we require that a=0 and b=1 in equation 4.8b. The procedure developed by Engle and Granger did not allow formal testing of these restrictions, as implied by Elam and Dixon (1988). However, the procedure developed by Johansen (1988) and Johansen and Juselius (1990) does allow specific testing of restrictions on the cointegrating parameters.

The acceptance of the restrictions on the values of a and b in the cointegrating relationship is a second necessary condition for market efficiency. However, the two conditions so far discussed only imply that the futures price is an unbiased predictor of the spot price in the long-run. In the short-run it is possible that there will be considerable departures from this equilibrium relationship. The short-run efficiency of the futures market can be tested by considering the dynamic relationship between spot and futures prices using an error correction model (ECM). If the spot and futures prices are cointegrated then an ECM can be specified as:

$$\Delta S_{t+n} = \alpha + \gamma \Delta F_{t,t+n} + \theta \Delta S_{t+n-1} + \rho [S_{t+n-1} - \delta F_{t-1,t+n-1}] + e_{t+n} \tag{4.9}$$

where $[S_{t+n-1} - \delta F_{t-1,t+n-1}]$ is the error-correction term. Efficiency can be tested by testing the following restrictions on the ECM in equation 4.9; $-\rho = \gamma = \delta = 1$ and α and all lagged values, θ, are zero. If these conditions hold, then equation 4.9 collapses to equation 4.5 as follows. Equation 4.9 can be rewritten as:

$$S_{t+n} - S_{t+n-1} = \alpha + \gamma F_{t,t+n} - \gamma F_{t-1,t+n-1} + \theta \Delta S_{t+n-1} + \rho [S_{t+n-1} - \delta F_{t-1,t+n-1}] + e_{t+n}$$

If $-\rho = \gamma = \delta = 1$ and $\alpha = \theta = 0$ then

$$S_{t+n} =$$

$$F_{t,t+n} - F_{t-1,t+n-1} - S_{t+n-1} + F_{t-1,t+n-1} + S_{t+n-1} + e_{t+n}$$

$$= F_{t,t+n} + e_{t+n}$$

Acceptance of these restrictions constitutes the third condition for efficiency.

Tests of these three restrictions are proposed by Antoniou and Foster (1992a). Prior to this work, tests of efficiency using the Johansen cointegration procedure had not considered the short-term dynamics using ECMs. Since tests on the parameters in the cointegrating relationship were not possible prior to Johansen, Antoniou and Foster provide the only example where all three tests of market efficiency are undertaken.

This chapter uses the three tests discussed above. However, unlike previous studies which have tested for efficiency using error correction models, in this study the diagnostic statistics relating to the ECMs are considered. Previous studies have ignored these diagnostic tests, and as a result inferences drawn on the basis of t and F tests may be unreliable. Without considering the diagnostic statistics it is possible that the standard errors are biased, leading to an increase in the possibility of a type 1 error. Thus, while a sufficient condition for market efficiency is that the restrictions on the ECM hold, it is essential that the ECM is correctly specified. Given that previous studies have not addressed this issue, the inferences drawn may be suspect.

4.4 Variance Bounds Tests of Futures Market Efficiency.

The theory relating to the use of variance bounds tests for testing market efficiency was put forward by Shiller (1979, 1981a) and LeRoy and Porter (1981), who were also the first to undertake empirical work using this approach. Although there are different versions of the variance bounds tests with some based on asset prices and others on dividends, they are all the result of the present value relation.

The idea underlying these tests can be understood by reference to the simplest of the inequalities tested by Shiller (1981a). This inequality puts limits on the standard deviation of the asset's price. Shiller argues that the efficient markets model asserts that $p_t = E_t(p_t^*)$, where p_t is the asset price and p_t^* is the present discounted value of the actual subsequent real dividends. This states that p_t is the mathematical expectation conditional on all information available at time t of p_t^* and implies that p_t is the optimal forecast of p_t^*.

Shiller defines the forecast error as $u_t = p_t^* - p_t$.

Thus:

$$p_t^* = p_t + u_t \qquad (4.10)$$

The forecast error must be uncorrelated with the forecast, otherwise the forecast could be improved. The covariance between p_t and u_t must, therefore, be zero. Elementary statistics states that the variance of the sum of two uncorrelated variables is the sum of their variances. Thus:

$$\text{var}\ (p^*) = \text{var}\ (u) + \text{var}\ (p) \qquad (4.11)$$

Shiller points out that since variances cannot be negative, equation 4.11 implies that var (p) must be less than or equal to var (p*). It is this inequality that Shiller examines to test for market efficiency. As stated in chapter 1, Shiller concludes that price volatility cannot be explained by information and therefore, he believes markets to be inefficient. Subsequent tests have similarly found evidence of excess volatility.

In spite of the widespread use of such variance bounds tests, they have not been applied to futures markets to examine the issue of futures markets efficiency. However, just as equation 4.10 can be used to establish bounds on the variance of prices, so too can equation

4.5, which is presented again for convenience:

$$S_{t+n} = F_{t,t+n} + e_t \qquad (4.5)$$

Given that in an efficient market and under the assumption of risk neutrality $F_{t,t+n}$ will be an optimal forecast of S_{t+n}, it follows that e_t must be uncorrelated with $F_{t,t+n}$. The covariance between $F_{t,t+n}$ and e_t must, therefore, be zero and an equation equivalent to 4.11 can be derived. We now have:

$$\text{var } (S_{t+n}) = \text{var } (F_{t,t+n}) + \text{var } (e_t) \qquad (4.12)$$

As Shiller pointed out variances cannot be negative. Equation 4.12 therefore implies that if the market is efficient:

$$\text{var } (F_{t,t+n}) <= \text{ var } (S_{t+n}) \qquad (4.13)$$

where <= implies less than or equal to. A test of this inequality will therefore provide a test of market efficiency. If the inequality in 4.13 does not hold then this implies that equation 4.5 does not hold and that either the futures market is inefficient or market participants are not risk neutral.

4.5 Methodology.

In this chapter the efficiency of the market for the FTSE-100 futures contract is examined using the cointegration procedure and variance bounds tests. We will discuss how these two approaches are implemented in turn. As stated above, the error based methods of cointegration, such as that developed by Engle and Granger, do not allow the testing of restrictions on parameters in the cointegrating relationship. However, the Johansen procedure does allow such tests to be carried out.

The Johansen procedure is set out in Johansen (1988) and Johansen and Juselius (1990), and in a form directly applicable to futures in Lai and Lai (1991). The procedure is in contrast to that of Engle and Granger (1987) which estimates the cointegrating relationship using regression. Rather, Johansen

> "derive[s] maximum likelihood estimators of the cointegration vectors for an autoregressive process with independent Gaussian errors, and... derive[s] a likelihood ratio test for the hypothesis that there is a given number of these." (1988, p231).

The Johansen approach is based on the multivariate technique of canonical correlations, which involves finding a linear combination of a set of variables such that the correlation among the variables is maximised. Lai and Lai note that using Johansen, the hypothesis of cointegration can be formulated as the hypothesis of reduced rank of a regression coefficient matrix. This can be estimated consistently from two vector regression equations. Based on these regressions, the likelihood ratio test for cointegration involves computing the squared canonical correlations between the regression residuals. This requires the calculation of eigenvalues.

Johansen (1988) begins by considering a process X which is of the form:

$$X_t = \Pi_1 X_{t-1} + \ldots + \Pi_k X_{t-k} + \mu + \varepsilon_t \qquad (4.14)$$

However, he reparameterises this equation so that it becomes a general vector autoregressive (VAR) model:

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \Gamma_k X_{t-k} + \mu + \varepsilon_t \qquad (4.15)$$

where X_t is an n x 1 time series vector, $\Delta = 1 - L$, where L is the lag operator, μ is some constant vector and ε_t is a vector of white Gaussian noises with mean zero and finite variance. Johansen shows that the rank of the matrix Γ_k indicates the number of cointegrating relationships existing between the variables in X_t. Lai and Lai point out that the hypothesis of cointegration between S_{t+n} and $F_{t,t+n}$ is equivalent to the hypothesis that the rank of $\Gamma_k = 1$ and that if the rank is zero, then the two variables are not cointegrated.

Once cointegration is established, the maximum likelihood estimate of the cointegrating vector, α, can be computed on the basis of eigenvalues. As far as the spot price - futures price relationship is concerned this involves estimating $\alpha' = (1, -b, -a)$ for the cointegrating relationship:

$$\alpha' X_t^* = 0 \qquad (4.16)$$

where $X_t^* = (S_{t+n}, F_{t,t+n}, 1)$. A test of market efficiency involves testing the linear restriction $\alpha' = (1, -1, 0)$ on the cointegrating vector.

Given that testing restrictions on the cointegrating relationship is necessary for the establishment of futures markets efficiency, the Johansen procedure is adopted here[1]. We begin by testing for unit roots in the spot price series, S_t, and the futures price series, $F_{t-n,t}$[2], for different values of n. The Johansen procedure is used to test for the existence of unit roots (i.e. nonstationarity) in the data. Tests are first of all carried out on the levels of the spot and futures price series. If unit roots are found then the tests are repeated for the first differenced price series.

The Johansen procedure for testing for the presence of unit roots involves testing for cointegration between one variable and a constant, i.e. testing for integration. The null hypothesis is for no cointegration, which is equivalent to the variable being not I(0). If the null is rejected then the alternative hypothesis of cointegration in one variable is accepted implying a stationary I(0) series.

If the variables are candidates for cointegration the Johansen maximum likelihood technique will be used to test for cointegration. Hall makes the point that

> "The Johansen procedure begins by constructing a general vector auto regressive (VAR) model and the estimation procedure is then contingent on the specification of the VAR....In application this raises two questions: first, what criteria should be chosen for the length of the VAR model; and second, are the results of the procedure sensitive to this choice." (1991, p318).

Hall goes on to establish that while the maximum likelihood estimates of the parameters are robust to the choice of VAR length the same is not true of the test statistics. These appear to be sensitive to the choice of VAR. It is therefore necessary to examine the effect of changes in the VAR when using the Johansen technique or to use the VAR length which has the minimum test statistic.

In applying the Johansen procedure we therefore begin by selecting the appropriate VAR length. Hall suggests that to choose the appropriate VAR length, k, an arbitrarily high value of k should be chosen and then likelihood ratio tests should be used to test for the implications of reductions in the VAR length. The correct value of k is established when a restriction on lag length is rejected. In this study likelihood ratio tests on VAR lengths of 4 to 1 are carried out.

Once the order of integration and the appropriate VAR length has been established, the Johansen procedure is used to test for cointegration between the spot price series and the futures price series. This is the first test of market efficiency mentioned above. If the series are cointegrated then tests of the restrictions in equation 4.8b are undertaken. As stated above, market efficiency requires that we do not reject the restrictions that a=0 and b=1.

Finally, if this test of efficiency is passed, we test restrictions on the parameters of the error correction model with a moving average component to account for overlapping data. Specifically, we test that α equals zero and $-\rho = \gamma = 1$. Testing of these restrictions constitutes the third test of market efficiency.

In undertaking the variance bounds tests we begin by calculating the variance of spot prices over the period t to t-i and the variance of futures prices over t-n to t-n-i, for each t in the sample. Different values of i are used to ensure that results are not dependent on the time period over which the variance is calculated.

Having calculated two series of variances, VS and VF, we define the ratio of these variances as X_{sf}:

$$X_{sf} = VS/VF \qquad (4.17)$$

From equation 4.13, X_{sf} must be greater than or equal to unity if the market is efficient. We therefore test for this by regressing X_{sf} on a constant term and testing to see if the estimated constant is less than unity.

4.6. Data.

The data used in this study consist of quarterly spot values of the FTSE-100 stock index (hereafter referred to as the spot price) and the quarterly prices for the FTSE-100 futures contract. For the purposes of the analysis, the log of the spot and futures prices are used.

Two types of data are used in the cointegration analysis. For the first type of data the spot price relates to the closing values of the index for the day relating to the last day of futures trading for each contract. Futures contracts on the FTSE-100 stock index expire in March, June, September and December of each year. Hence, there are four observations per annum. The futures prices relate to the closing prices on the last trading day of the month for various months prior to expiration (i.e various values of n). The observations relating to futures prices are divided into subsets according to their time to expiration. The first subset comprises futures prices one month prior to expiration of the contract, i.e. those relating to February, May, August and November. Similarly, subsets relating to two, three, four, five and six months prior to expiration are created. Thus n varies from 1 to 6. The data relate to the period covering the futures contracts expiring between September 1984 and June 1992. Hence, there are thirty-two observations for the spot series and for each futures subset, with the exception of six months prior to expiration for which there are only thirty-one observations.[3]

The analysis carried out in chapter 2 suggested that there was a possible day of the week effect in relation to futures returns. If such an effect is in existence then clearly this may bias the futures prices on particular days of the week. Hence, to avoid any problems relating to a possible day of the week effect a second data set was used in this analysis. The second data set is comprised of closing prices averaged over the last five trading days of each month for the series outlined above.

For the variance bounds tests only the first of these two data sets is employed. Variances are calculated using closing prices and values of i of 1, 4 and 20. Thus variances are calculated for the last trading day, the last week of trading and the last month of trading. In this analysis tests were carried out using futures prices from 1 to 5 months prior to maturity.

The sample size of thirty-two is undoubtedly small and as a consequence any results emerging from the analysis need to be interpreted with caution. However, all available relevant data relating to the FTSE-100 stock index futures contract has been used in order to test for efficiency in this study.

4.7 Results of Tests for Futures Market Efficiency using Cointegration.

In order to determine the level of integration of the time series, unit root tests were carried out on the spot price series and the six futures price series for both the last trading day data (hereafter referred to as daily data) and the five day averaged data. The results for the tests for unit roots for the levels and first differences of the daily data are presented in table 4.1a and for the five day average data in table 4.1b.

For all seven level price series for both daily and five day average data the null of no cointegration cannot be rejected. Similarly for all first differenced price series the null hypothesis is rejected. These results indicate that the series in levels are all I(1). Since spot and futures price series for all values of t-n tested are integrated of the same order, the spot and futures series are candidates for cointegration for all values of t-n.

Table 4.1a: Johansen tests for unit roots; Daily data.

Price Series	Levels	First differences
LS_t	5.5633	20.9136
LF_{t-1}	6.0052	23.8282
LF_{t-2}	7.7191	29.9792
LF_{t-3}	6.5038	21.6896
LF_{t-4}	7.0967	23.3229
LF_{t-5}	4.1971	32.1645
LF_{t-6}	6.3365	20.7948

The critical value for the test at the 5% level is 9.2430.
In all cases the value of the test statistic was the same for the likelihood ratio test based on the maximal eigenvalue of the stochastic matrix and for that based on the trace of the stochastic matrix.

Table 4.1b: Johansen tests for unit roots; Five day average data.

Price Series	Levels	First differences
LSA_t	5.7945	19.4375
LFA_{t-1}	6.8791	22.1395
LFA_{t-2}	7.2953	30.6265
LFA_{t-3}	6.9367	19.4729
LFA_{t-4}	7.6541	21.4574
LFA_{t-5}	4.3123	32.5078
LFA_{t-6}	6.9144	18.1525

The critical value for the test at the 5% level is 9.2430.
In all cases the value of the test statistic was the same for the likelihood ratio test based on the maximal eigenvalue of the stochastic matrix and for that based on the trace of the stochastic matrix.

Given that the price series are candidates for cointegration it is necessary to carry out tests to establish the appropriate VAR length. The results of these tests are reported in tables 4.2a and 4.2b. For both daily and the five day average data VAR lengths of 1 are appropriate for futures prices of 1, 2, and 4 months prior to maturity. For 3 and 5 months before maturity a VAR length of 2 is appropriate and for 6 months the VAR length is 3.

Having established the order of integration of each price series and the appropriate VAR length we can now proceed to test for futures markets efficiency. In order to do this it must first of all be established whether the spot and futures prices cointegrate.[4] As outlined above, linear combinations of the spot and futures price series which have a cointegrating vector of one indicate that their differences are stationary and satisfy the first condition for futures prices being an unbiased predictor of the future spot price.

The Johansen cointegration procedure has a null hypothesis of zero cointegrating vectors between the spot and futures price series. Rejection of the null hypothesis implies there is one cointegrating vector. Results of the tests for daily and five day average data are presented in tables 4.3a and 4.3b[5]. The tables show that in all cases the spot and futures prices

Table 4.2a: Likelihood ratio tests for appropriate VAR length; Daily data.

Restrictions on Var length	LF_1	LF_2	LF_3	LF_4	LF_5	LF_6
4-3	3.68	1.94	3.14	3.26	3.12	1.98
3-2	3.94	3.90	2.58	1.38	1.36	20.36
2-1	2.40	7.60	10.14	3.26	17.54	115.12

The critical value for the test at the 5% level is $\chi^2(4) = 9.49$
The subscript *on LF refers to months prior to maturity.*

Table 4.2b: Likelihood ratio tests for appropriate VAR length; Five day average data.

Restrictions on Var length	LFA_1	LFA_2	LFA_3	LFA_4	LFA_5	LFA_6
4-3	3.59	2.70	6.12	4.24	5.00	5.56
3-2	5.98	7.44	3.90	3.26	1.66	29.32
2-1	5.10	5.44	13.98	5.70	14.52	109.20

The critical value for the test at the 5% level is $\chi^2(4) = 9.49$
The subscript on LFA refers to months prior to maturity.

Table 4.3a: Johansen tests for cointegration of spot and futures prices; Daily data.

$$LS_t = a + bLF_{t-n,t} + e_t$$

Futures' Maturity	Test for cointegration based on: Maximal eigenvalue	Trace	a=0,b=1
F_{t-1}	19.4391	25.3669	1.61
F_{t-2}	34.7632	41.2299	0.46
F_{t-3}	16.2129	24.2245	7.54
F_{t-4}	55.0052	64.3494	2.82
F_{t-5}	40.0670	50.0396	3.25
F_{t-6}	17.9205	26.7342	9.62

The null hypothesis is that there is no cointegrating relationship between the spot and the futures prices. The critical values for the test based on maximal eigenvalues are 15.67 at 5% and 13.75 at 10%. For the tests based on the trace the values are 19.96 at 5% and 17.85 at 10%.
The column labelled (a=0,b=1) is the Johansen test of the restriction that a=0 and b=1 in the cointegrating regressions. The test is chi-squared distributed with a critical value at 5% of 5.99.

Table 4.3b: Johansen tests for cointegration of spot and futures prices; Five day average data.

$$LSA_t = a + bLFA_{t-n,t} + e_t$$

Futures' Maturity	Test for cointegration based on: Maximal eigenvalue	Trace	a=0,b=1
FA_{t-1}	16.5078	23.3802	0.87
FA_{t-2}	30.7180	36.9554	0.44
FA_{t-3}	14.1381	21.5038	7.87
FA_{t-4}	60.6726	69.6273	2.78
FA_{t-5}	33.5604	44.4628	2.53
FA_{t-6}	31.1996	38.5137	23.44

The null hypothesis is that there is no cointegrating relationship between the spot and the futures prices. The critical values for the test based on maximal eigenvalues are 15.67 at 5% and 13.75 at 10%. For the tests based on the trace the values are 19.96 at 5% and 17.85 at 10%.
The column labelled (a=0,b=1) is the Johansen test of the restriction that a=0 and b=1 in the cointegrating regressions. The test is chi-squared distributed with a critical value at 5% of 5.99.

cointegrate on the basis of trace values at the 5% level. On the basis of the maximal eigenvalue statistics all reject the null hypothesis of no cointegration at the 5% level, except for the five day average data three months prior to maturity, which is significant at the 10% level. It is reasonable to interpret these results as indicating that the spot and futures prices are cointegrated and thus meet the first necessary condition for market efficiency.

The tables also report tests on restrictions on the parameters in the cointegrating regression. The restrictions tested are that a=0 and b=1. The restriction can be tested using the Johansen test statistic which is chi-squared distributed. For one, two, four and five months prior to maturity the restrictions hold for both the daily data and the five day average data at the 5% level of significance. However, for three and six months prior to maturity the restrictions are rejected at the 5% level of significance. Thus for three and six months prior to maturity the joint hypothesis of market efficiency and risk neutrality is rejected, even though spot prices and futures prices for these dates cointegrate.

Clearly, the finding that futures prices six months prior to maturity are not unbiased predictors is not particularly surprising. As was stated in section 4.3, the further from maturity, the less likely it is that futures prices will be unbiased predictors. However, the finding that futures prices are not unbiased predictors of the spot price in the long-term for three months prior to maturity, but are unbiased predictors in the long-term for four and five months prior to maturity is both surprising and particularly interesting. One possible explanation for this finding relates to the maturity dates of the FTSE-100 stock index futures contracts. Since these contracts mature at three month intervals, dates three months prior to the maturity of one contract are actually maturity dates for earlier contracts. Indeed, the same is true for dates six months prior to maturity. Thus, for example, three months prior to the expiration of the September contract is the date of the maturity of the June contract. Similarly, six months prior to the September contract expiring, the March contract expires.

As was seen in diagrams 2.1 to 2.5 in chapter 2, the volume of transactions in futures contracts is at its greatest in the weeks immediately prior to maturity. At the same time, investors who are using futures contracts for hedging will shift between contracts as one contract matures. For example, those using the March contract to hedge will move out of that contract in March and into, say, the June or September contract. It is quite possible that this heavy volume of transactions, together with considerable switching between contracts, will lead to bias in futures prices for those months. In other words, for short periods, during times of high transactions volume, the FTSE-100 stock index futures market exhibits inefficiency.

The results of the above analysis suggest that futures prices are not unbiased predictors of future spot prices in the long-run for three and six months prior to maturity. However, it does appear from the results that futures prices are unbiased predictors of spot prices for one, two, four and five months prior to maturity, and hence that futures markets are efficient in the long-term for these time horizons. However, as explained above, while long-run efficiency is a necessary condition for efficiency, it is also necessary to consider the short-run dynamics of the relationship. In particular, it is possible that in spite of long-run efficiency there may be considerable deviations from the spot price - futures price relationship in the short-term. Hence, before drawing conclusions regarding the nature of efficiency it is necessary to consider error-correction models.

For those time periods for which there was evidence of long-run efficiency, ECMs were constructed and investigated. By doing this the third condition necessary for market efficiency is examined. The ECMs were constructed with lags on the dependent variable of between one and three. In all cases the coefficient on the lags were found to be insignificantly different from zero. We therefore only report the models for lags of zero. The results for these estimations are presented in tables 4.4a and 4.4b. Tests carried out for serial correlation, functional form, normality and heteroscedasticity confirmed the models' statistical adequacy[6]. The statistics relating to these tests are reported in tables 4.5a and 4.5b.

Of particular interest in the tables 4.4a and 4.4b are the values of α, γ and ρ. On the basis of t statistics, the restrictions that $\alpha=0$, $\gamma=1$, and $\rho=-1$ were tested separately. The estimated values of α are insignificantly different from zero for one, two and four months from maturity for the five day average data and for one and two months from maturity for the daily data at the five percent level of significance. However, the estimated value of α for five months from maturity is significantly different from zero at the five percent level for both types of data used[7]. The t statistics for the restriction $\gamma=1$ are such that the restriction cannot be rejected at the five percent level of significance for one, two and four months prior to maturity for both data types used. Once again, however, for five months from maturity the value of the t statistic is such that the restriction is not accepted at the five percent

Table 4.4a: Error correction models for spot and futures prices: Daily data.

$$\Delta LS_t = \alpha + \gamma \Delta LF_{t-n,t} + \rho[LS_{t-1} - LF_{t-n,t-1}] + e_t$$

Futures' Maturity	α	γ	ρ	χ^2 Statistic
F_{t-1}	0.0043 (0.0087)	0.8660 (0.0889)	-0.8846 (0.1883)	2.62
F_{t-2}	0.0103 (0.0130)	0.9863 (0.1708)	-1.0970 (0.2340)	0.83
F_{t-4}	0.0307* (0.0150)	0.5136 (0.3222)	-0.4783 (0.3184)	6.13
F_{t-5}	0.0360* (0.0145)	0.3250+ (0.2307)	-0.2589+ (0.2030)	20.71

Figures in parentheses are standard errors. The chi-squared statistic is for the restriction $\alpha=0$, $\gamma=1$, $\rho=-1$. The critical value at 5% is 7.81.
* denotes significantly different from zero at the 5% level.
+ denotes significantly different from unity (γ) or -1 (ρ) at the 5% level.
All ECMs have been estimated using a moving average component.

Table 4.4b: Error correction models for spot and futures prices: Five day average data.

$$\Delta LSA_t = \alpha + \gamma\Delta LFA_{t-n,t} + \rho[LSA_{t-1} - LFA_{t-n,t-1}] + e_t$$

Futures' Maturity Statistic	α	γ	ρ	χ^2
FA_{t-1}	0.0029 (0.0079)	0.9608 (0.0888)	-0.8382 (0.1953)	1.04
FA_{t-2}	0.0176 (0.0132)	0.8605 (0.1604)	-0.9220 (0.2354)	2.24
FA_{t-4}	0.0294 (0.0151)	0.5579 (0.3967)	-0.4662 (0.3653)	6.23
FA_{t-5}	0.0365* (0.0146)	0.2584^{+} (0.2234)	-0.1777^{+} (0.2034)	27.16

Figures in parentheses are standard errors. The chi-squared statistic is for the restriction $\alpha=0$, $\gamma=1$, $\rho=-1$. The critical value at 5% is 7.81.
* denotes significantly different from zero at the 5% level.
$^{+}$ denotes significantly different from unity (γ) or -1 (ρ)at the 5% level.
All ECMs have been estimated using a moving average component.

Table 4.5a: Diagnostic statistics for error correction models: Daily data.

	Months to Maturity 1	2	4	5
A: Serial Correlation	.596	1.269	.713	1.895
B: Functional Form	.985	.711	.048	.700
C: Normality	1.477	.366	3.717	.023
D: Heteroskedasticity	.247	.557	.370	.740

A: Lagrange multiplier test of residual serial correlation.
B: Ramsey's RESET test using the square of the fitted values.
C: Based on a test of skewness and kurtosis of residuals.
D: Based on the regression of squared residuals on squared fitted values.

All reported statistics are chi-squared distributed. A, B, and D have one degree of freedom. C has two degrees of freedom.
For A, B, and D the critical value at the 5% level is 3.84 and for C 5.99.

Table 4.5b: Diagnostic statistics for error correction models: Five Day Average Data.

	Months to Maturity			
	1	2	4	5
A: Serial Correlation	.101	.037	.774	2.758
B: Functional Form	1.275	.127	.153	.332
C: Normality	.534	.940	3.136	.405
D: Heteroskedasticity	.007	.600	.353	.548

A: Lagrange multiplier test of residual serial correlation.
B: Ramsey's RESET test using the square of the fitted values.
C: Based on a test of skewness and kurtosis of residuals.
D: Based on the regression of squared residuals on squared fitted values.

All reported statistics are chi-squared distributed. A, B, and D have one degree of freedom. C has two degrees of freedom.
For A, B, and D the critical value at the 5% level is 3.84 and for C 5.99.

level. Finally, the restriction $\rho=-1$ is tested. The results are the same as those for the test of the restriction on γ. The restriction holds for one, two and four months prior to maturity, but not for five months prior to maturity[8].

A formal test of all three restrictions taken together is also carried out. On the basis of the estimations reported in tables 4.4a-b the restriction that $\alpha=0$, $\gamma=1$, and $\rho=-1$ were tested using a chi-squared test. The test statistics reported in tables 4.4a and 4.4b show that for one, two and four months prior to maturity the third condition for market efficiency is accepted. However, for five months prior to maturity the restriction is not accepted. These results confirm the pattern of results from examining the restrictions separately.

The results presented here suggest that the futures price is an unbiased predictor of the future spot price in both the long and short-run for one, two and four months prior to maturity of the futures contract. However, while the futures price five months before expiration is an unbiased predictor of the future spot price at expiration in the long-run there are substantial deviations from this relationship in the short-run. This finding therefore calls into question the unbiasedness of the futures market for the FTSE-100 stock index futures contract for the period five months prior to maturity and demonstrates the importance of examining the short-run dynamics of the spot price - futures price relationship. Had these dynamics not been investigated using an ECM, the conclusion would have been incorrectly drawn that the futures price was an unbiased predictor of the future spot price for this time period. Finally, it should be noted that according to the diagnostic statistics reported in tables 4.5a-b relating to the ECMs, the models are adequately specified, making inferences drawn from them reliable.

4.8 Results of Tests for Futures Market Efficiency based on Variance Bounds Relationships.

Table 4.6 presents the results of the variance bounds tests. For all values of i (period over which the variance is calculated) consistent results are obtained for 1, 2 and 4 months prior to maturity. The results for 3 and 5 months prior to maturity vary with the period over which the variances are calculated. For 1, 2 and 4 months prior to maturity the variance bounds relationship, equation 4.13, is not violated, suggesting efficiency. For three months prior to maturity the relationship is violated for i equal to 1 and 20, but not for i equal to 4. In contrast, while there is also conflicting evidence for 5 months prior to maturity, the relationship is <u>not</u> violated for when variance is calculated over 1 and 20 days, but is violated when variances calculated over 4 days are used.

4.6: Variance bounds tests: Daily data.

Is the variance bounds relationship accepted?

Months to Maturity	Period over which variances calculated		
	1 day	4 days	20 days
1	Yes	Yes	Yes
2	Yes	Yes	Yes
3	No	Yes	No
4	Yes	Yes	Yes
5	Yes	No	Yes

No indicates rejection of the inequality in equation 4.13 at the 5% level. Yes indicates acceptance.

This evidence does suggest that variance bounds tests are sensitive to the period over which the variances are calculated. Nonetheless, the results of this analysis confirm very strongly the results of the cointegration analysis. There therefore seems strong support for the conclusion that the market for the FTSE-100 stock index futures contract is efficient for 1, 2 and 4 months prior to maturity, but not for 3 months prior to maturity, and possibly not for 5 months prior to maturity.

4.9 Summary and Conclusions.

Chapter 2 identified possible inefficiencies in the pricing of the FTSE-100 stock index futures contract and also suggested that a risk premium might be evident due to the contract being a risky asset in systematic risk terms. This chapter has investigated these issues by examining the efficiency of the FTSE-100 stock index futures market in both the long-term and the short-term using the Johansen cointegration procedure. In addition, variance bounds tests have been developed and employed to test for futures market efficiency. By doing this both the issue of efficiency of the market and the question of whether a risk premium exists are addressed. Rejection of the joint hypothesis of market efficiency and unbiasedness in prices (no risk premium) does not allow the identification of the reason for the rejection. However, acceptance of the joint hypothesis means that both parts of the hypothesis are accepted.

Previous studies of this joint hypothesis relating to futures markets have been deficient in that they either ignored the problems caused by nonstationary variables, or, if cointegration has been used, they have only considered long-run efficiency. Even if there is evidence of long-term efficiency it is possible that scope for profitable arbitrage in the short-run remains. ECMs have been used in this study to examine the short-run dynamics and the diagnostic tests relating to those models have shown them to be adequately specified. In addition, further tests of efficiency, not previously used, have been used here.

As far as long-run efficiency is concerned, futures prices appear to be unbiased predictors of spot prices for one, two, four and five months prior to maturity of the futures contract. However, they are not unbiased predictors three and six months prior to maturity. This could either be due to a positive risk premium, or to inefficiencies caused by these dates corresponding with the dates of maturity of earlier futures contracts due to stock index futures trading on a three month cycle. Given that the volume of transactions is greatest in the last weeks of a contract, and that considerable movement will take place between contracts of differing maturities at the time of contract expiration, there may be inefficiencies evident at these times.

The finding of short-run efficiency for one, two and four months prior to maturity, but not for five months prior to maturity, highlights the importance of examining the short-run dynamics of the pricing relationship using ECMs. The results of the variance bounds tests confirm the findings of the cointegration analysis.

The possibility of a day of the week effect being evident was addressed in this study by examining the unbiasedness hypothesis for data relating to both the last trading day of each month and the average of the last five trading days of each month. Analysis was carried out on this basis because of previous findings of a day of the week effect and because of the results presented in chapter 2 relating to futures markets returns. It should be noted that there was considerable consistency between the results for using last trading day data and those using the average of the last five trading days of each month. This suggests that any possible day of the week effect is not manifesting itself in the form of differences over the last week of each contract.

The results presented in this chapter throw light on the results of chapter 2 and have important implications for the users of futures markets. Direct comparison with the analysis in chapter 2 is not possible due to differences in the data used in the two studies. In particular, in chapter 2 data relates to weekly returns and to the period 1985 to 1990, whereas in this chapter, by necessity, the data used is quarterly and relates to the period 1984 to 1992. In addition, in this chapter it was possible to break down the data according to time to maturity to a greater extent than was possible in chapter 2.

Nonetheless, the evidence presented here suggests that in spite of the FTSE-100 stock index futures contracts being risky assets in systematic risk terms, the futures price is an unbiased predictor of the future spot price for one, two and four months prior to maturity. This implies that there is no risk premium to futures contracts over these periods. However, the finding that futures prices are not an unbiased predictor of future spot prices for three months prior to maturity implies that either the markets are inefficient, possibly due to the sharp change in trading volume at about this time of each contract's life, or that a risk premium is evident. Given that no risk premium is evident for one, two and four months prior to maturity, the former appears a more likely explanation.

The implications of the results of chapter 2 may be partly reconciled with those presented in this chapter by considering the differences in data between the two chapters. In particular, when time to maturity was considered in chapter 2, the data was partitioned into that relating to zero to three months prior to maturity and that relating to three to six months prior to maturity. This chapter has shown that for both of these periods there is evidence of inefficiency. In the period relating to zero to three months prior to maturity there is evidence here that the market is inefficient for three months prior to maturity. Similarly, for the other period considered in chapter 2, there is evidence here that the market is not an unbiased predictor for six months prior to maturity, and in the short-run for five months prior to maturity. Nonetheless, the results presented here do suggest the absence of a risk premium, which is not what was to be expected following the results of chapter 2. However, as mentioned in chapter 2, the evidence of betas close to unity may be due more to the relationship between the market proxy and the futures under consideration. Hence the caveat in that chapter about interpreting the results with caution. Furthermore, the arguments of Black (1976), discussed in chapter 2 are also relevant here.

As far as the users of the FTSE-100 stock index futures market is concerned, the results presented in this chapter have important implications. In particular, for those market participants who wish to pursue a strategy of 'rolling hedges' (i.e. carrying a hedge from one contract to another), it appears that the time of the expiration of the contract is not a time when the market is efficient and hence, it is not the time when the hedge should be rolled over. Given, the finding of unbiasedness for four months prior to maturity, it may be better to roll hedges over at this time rather than wait for the current contract to mature.

In relation to the other major function of futures markets, namely price discovery, it does appear that the market fulfils this function most of the time but that there are times when it fails to do so. Hence, it is important to carefully consider the information incorporated in futures prices. Finally, the finding that the futures market is possibly inefficient at some points in the contract's life suggests that they are opportunities for excess profits to be made. This could well provide an extra incentive for speculators to enter the market. However, while speculators may have entered the market, it was shown in chapter 3 that this does not appear to have led to the existence of futures markets having a detrimental impact on the underlying spot market.

Footnotes.

1. The results for tests of unit roots reported in section 4.7 relate to the use of the Johansen procedure. Tests of unit roots were also carried out using the Engle-Granger procedure and confirmed the results reported here. However, the Johansen procedure for testing for unit roots has greater power than does the Engle-Granger approach. In addition, the procedure was used for consistency with the subsequent tests of cointegration. For a discussion of the use of the Johansen approach for testing for unit roots see Cuthbertson, Hall and Taylor (1992).

2. We will use S_t and $F_{t-n,t}$ instead of S_{t+n} and $F_{t,t+n}$ in discussing the empirical work in this chapter.

3. Futures trading in the FTSE-100 stock index contract only began in May 1984. Therefore for the contract maturing in September 1984 data is not available relating to six months prior to maturity.

4. For convenience we will refer to prices as current prices.

5. Analysis of the data indicated that there was a problem of normality for three or more months from maturity. This appears to be due to the stock market crash of October 1987. For the December 1987 contract futures prices of three or more months prior to maturity relate to prices before the crash, whereas the spot price of December 1987 is clearly after the crash. The problem of non-normality in the data is overcome by including a dummy variable relating to this one observation. The results in tables 4.3a and 4.3b relate to tests including a stationary dummy variable for observation 14. Exclusion of the dummy does not alter the pattern of results. Tables 4.3c and 4.3d present the same statistics for the tests without a dummy variable.

6. Due to the problem of non-normality the ECMs were also estimated with a dummy variable for observation 14 for four and five months prior to maturity. The results reported in tables 4.4a and 4.4b relate to estimations including the dummy variable. Exclusion of the dummy does not alter the pattern of results. Tables 4.4c and 4.4d present the same statistics for the estimations without a dummy variable.

7. For the estimations excluding the dummy variable the α estimates are insignificantly different from zero for all time periods prior to maturity for which estimations were carried out.

8. The pattern of results for the restrictions on γ and ρ are the same for the estimates excluding the dummy variable.

Table 4.3c: Johansen tests for cointegration of spot and futures prices; Daily data.

$$LS_t = a + bLF_{t-n,t} + e_t$$

Futures' Maturity	Test for cointegration based on: Maximal eigenvalue	Trace	a=0,b=1
F_{t-3}	13.0396	19.3160	8.09
F_{t-4}	55.3609	61.1500	3.15
F_{t-5}	41.7789	49.6839	4.49
F_{t-6}	14.3223	23.2045	8.18

The null hypothesis is that there is no cointegrating relationship between the spot and the futures prices. The critical values for the test based on maximal eigenvalues are 15.67 at 5% and 13.75 at 10%. For the tests based on the trace the values are 19.96 at 5% and 17.85 at 10%.
The column labelled (a=0,b=1) is the Johansen test of the restriction that a=0 and b=1 in the cointegrating regressions. The test is chi-squared distributed with a critical value at 5% of 5.99.

Table 4.3d: Johansen tests for cointegration of spot and futures prices; Five day average data.

$$LSA_t = a + bLFA_{t-n,t} + e_t$$

Futures' Maturity	Test for cointegration based on: Maximal eigenvalue	Trace	a=0,b=1
FA_{t-3}	11.1523	17.5767	7.48
FA_{t-4}	61.2295	67.1590	2.99
FA_{t-5}	36.3900	45.2023	3.17
FA_{t-6}	28.0832	35.0792	22.22

The null hypothesis is that there is no cointegrating relationship between the spot and the futures prices. The critical values for the test based on maximal eigenvalues are 15.67 at 5% and 13.75 at 10%. For the tests based on the trace the values are 19.96 at 5% and 17.85 at 10%.
The column labelled (a=0,b=1) is the Johansen test of the restriction that a=0 and b=1 in the cointegrating regressions. The test is chi-squared distributed with a critical value at 5% of 5.99.

Table 4.4c: Error correction models for spot and futures prices: Daily data.

$$\Delta LS_t = \alpha + \gamma\Delta LF_{t-n,t} + \rho[LS_{t-1} - LF_{t-n,t-1}] + e_t$$

Futures' Maturity	α	γ	ρ	χ^2 Statistic
F_{t-4}	0.0172 (0.0185)	0.7662 (0.4016)	-0.7218 (0.3973)	1.32
F_{t-5}	0.0276 (0.0190)	0.1729^{+} (0.3008)	-0.2453^{+} (0.2674)	10.74

Figures in parentheses are standard errors. The chi-squared statistic is for the restriction α=0, γ=1, ρ=-1. The critical value at 5% is 7.81.
* denotes significantly different from zero at the 5% level.
$^{+}$ denotes significantly different from unity (γ) or -1 (ρ)at the 5% level.
All ECMs have been estimated using a moving average component.

Table 4.4d: Error correction models for spot and futures prices: Five day average data.

$$\Delta LSA_t = \alpha + \gamma \Delta LFA_{t-n,t} + \rho[LSA_{t-1} - LFA_{t-n,t-1}] + e_t$$

Futures Maturity	a	c	r	$\chi 2$ Statistic
FA_{t-4}	0.0168 (0.0183	0.8476 (0.4831)	-0.7535 (0.4436)	1.61
FA_{t-5}	0.0285 (0.0186)	0.0732+ (0.2820)	-0.1276+ (0.2609)	15.91

Figures in parentheses are standard errors. The chi-squared statistic is for the restriction $\alpha=0$, $\gamma=1$, $\rho=-1$. The critical value at 5% is 7.81.
* denotes significantly different from zero at the 5% level.
+ denotes significantly different from unity (γ) or -1 (ρ)at the 5% level.
All ECMs have been estimated using a moving average component.

Chapter 5: Hedging with FTSE-100 Stock Index Futures Contracts.

5.1 Introduction.

It was argued in chapter 1 that hedging is the most important function of futures markets and the main reason underlying their evolution. In this thesis the prime concern is to examine the economic role and performance of the FTSE-100 stock index futures contract. To this end chapters 2, 3 and 4 have examined the risk return relationship, the impact on the underlying market, and the efficiency of this contract. In this chapter we turn to an examination of the most important issue in relation to futures contracts by analysing the hedging performance of the FTSE-100 contract.

We have seen in chapter 4 that for periods of less than three months from maturity futures prices are unbiased predictors of future spot prices and the market for futures contracts is efficient for the FTSE-100 stock index futures contract. This has important implications for the hedging effectiveness of stock index futures, since if futures markets are to be an effective means by which investors can hedge risks, it is important that futures prices are determined in an efficient market. Given the findings relating to efficiency in chapter 4 it is to be expected that the nearby futures contract will provide an effective means by which to hedge the risk associated with holding a widely diversified stock portfolio.

In this chapter we investigate the hedging effectiveness of the FTSE-100 stock index futures contract for the period from July 1984 to June 1992. It was noted in chapter 1 that when risk is hedged using futures contracts, price risk is replaced by basis risk. It was also noted in that chapter that there are grounds for believing that the hedge ratio may change over time and may change with respect to (a) the hedge duration and (b) the time between the hedge being undertaken and the maturity of the futures contract being used to hedge. Furthermore, it was shown that while most previous studies of the hedging effectiveness of stock index futures have concentrated on the minimum variance hedge ratio, some have made comparisons with other hedge ratios. It is therefore important to give consideration to the different types of hedging strategies which have been proposed. In this chapter all of these issues are addressed.

In addition, in contrast to previous studies, hedging effectiveness is considered here in relation to hedging strategies based on historical information. Hedge ratios are estimated on the basis of such information and the hedging effectiveness compared to optimal hedging strategies which implicitly assume perfect foresight.

The next section considers theoretical issues relating to hedging, with particular emphasis on the different hedge strategies. Section 5.3 discusses the methodology adopted in this chapter to investigate the hedging performance of the FTSE-100 contract. The data to be used in the study is then discussed in section 5.4 and section 5.5 sets out the results of the study. Finally section 5.6 presents a summary and concluding remarks.

5.2 Hedging with Futures: Theoretical Issues.

In section A of chapter 1 it was shown that futures can be used to expand the opportunity set open to investors. Figure 1.3 demonstrated that by altering the value of h (the hedge ratio) different combinations of risk and return could be achieved. The exact point that an investor will choose on the risk return opportunity set will depend upon the preferences of the individual. Alternative hedging strategies have been proposed to explain this choice. Before going on to examine hedging performance it is necessary to have an understanding of these alternatives.

Four theories of hedging will be considered: the classic one-to-one hedge; the Working view of hedging; the minimum variance hedge strategy and; the beta hedge.[1] The classic hedge strategy (also known as the naive or traditional model) emphasises the potential for futures contracts to be used in reducing risk. The strategy is very simple, involving the hedger in taking up a futures market position which is equal in magnitude, but opposite in sign to the spot market position. If price changes in the spot market exactly match price changes in the futures market then price risk will be completely eliminated. However, as was noted in chapter 1 this is extremely unlikely to be the case. Thus while emphasising the avoidance of risk, the traditional approach does not guarantee a risk minimising position.

The second hedging strategy to be considered is that put forward by Working (1953). Working questioned the traditional view of hedging as a means of reducing risk. He argues that

> "...hedging is not necessarily done for the sake of reducing risks. The role of risk-avoidance in most commercial hedging has been greatly overemphasized in economic discussions. Most hedging is done largely... because the information on which the merchant or processor acts leads logically to hedging. He buys the spot commodity because the spot price is low *relative to* the futures price and he has reason to expect the spot premium to advance". (Working, 1953, p325).

Thus Working views hedging as a form of arbitrage and explicitly considers the speculative aspect of hedging. However, the generally accepted view of hedging is that it is a means of protecting or insuring a position held in the spot market, a view which is not consistent with that of the Working view of hedging. Indeed, Johnson (1960) criticises the Working view on the basis of interviews with participants in commodity markets. He argues that market participants are motivated to hedge primarily in order to reduce risk. He therefore proposed a strategy based on the concept of the minimum variance hedge ratio (mvhr), (see Johnson (1960)).

The strategy based on the mvhr is consistent with the traditional approach in that it emphasises the risk reduction properties of futures. However, unlike the traditional approach, it does not make naive assumptions about movements in the basis. Rather, Johnson defines hedging as minimising the price risk, or variance of the subjective probability distribution for prices changes, associated with holding a predetermined spot position. Following Johnson, let σ_i^2 be the variance of price change or price risk from holding one unit in the i market from time t1 to t2. The variance of return from holding x_i units is therefore equal to $x_i^2\sigma_i^2$. Likewise, the price risk of holding one unit in the j market is σ_j^2 and of holding x_j units is $x_j^2\sigma_j^2$. Finally, let cov_{ij} denote the covariance of price change between market i and market j. Thus a combination of positions in i and j has a total variance of return V(R):

$$V(R) = x_i^2\sigma_i^2 + x_j^2\sigma_j^2 + 2x_ix_j\text{cov}_{ij} \qquad (5.1)$$

The combination has an actual return, R, and an expected return, E(R), given respectively by:

$$R = x_iB_i + x_jB_j \qquad (5.2)$$

and

$$E(R) = x_iu_i + x_ju_j \qquad (5.3)$$

where B_i, B_j denotes the actual price change from t1 to t2 in i and j and u_i and u_j denote the price changes from t1 to t2 expected at t1. Johnson points out that u_i and u_j are the mean values of the probability distributions of returns in the i and j markets.

The combination of i and j which has the minimum variance of returns is found by differentiating 5.1 with respect to x_j, setting the derivative equal to zero and solving for x_j. This yields the optimal (in terms of minimum variance) value x_j^*:

$$x_j^* = -\frac{x_i\text{cov}_{ij}}{\sigma_j^2} \qquad (5.4)$$

Substituting the value of x_j^* for x_j in equation 5.1 yields:

$$V(R)^* = x_i^2\sigma_i^2 + (x_i^2 cov_{ij}^2)/\sigma_j^2 - (2x_i^2 cov_{ij}^2)/\sigma_j^2$$

or

$$V(R)^* = x_i^2(\sigma_i^2 - (cov_{ij}^2)/\sigma_j^2)$$

Given that the correlation coefficient, ρ, is equal to $(cov_{ij}/\sigma_i\sigma_j)$ then $V(R)^* = x_i^2\sigma_i^2(1 - \rho^2)$. Johnson argues

> "Generally speaking the larger the (absolute) value of the coefficient of correlation, the greater the reduction in price risk of holding x_i that can be effected by carrying the hedge x_j^*. If the... [hedger] believes at time t1 that price movements are perfectly correlated between t1 and t2, ρ is equal to 1 and over-all price risk is reduced to 0. If he believes that there is no correlation whatever, $V(R)^*$ is equal to $x_i^2\sigma_i^2$ - the variance of x_i alone. The effectiveness e of the hedge is measured by considering the variance of return $V(R)^*$ associated with the combination x_i, x_j^* in a ratio with the variance $x_i^2\sigma_i^2$ associated with the position x_i held alone". (Johnson, 1960, p143-144).

Thus:

$$e = (1 - (V(R)^*/x_i^2\sigma_i^2) = \rho^2$$

Thus Johnson proposes the square of the correlation coefficient as an appropriate measure of hedging effectiveness.

In the above discussion x_j^* is the number of units held in market j which minimises the variance of returns. In chapter 1 the hedge ratio was defined as the number of units held in the futures market divided by the number of units held in the spot market. This corresponds to x_j/x_i in the above discussion and hence, the minimum variance hedge ratio h^* will be equal to x_j^*/x_i where market j is the futures market and market i the spot market. Thus:

$$h^* = -Cov(R_s R_f)/\sigma^2_{Rf} \qquad (5.5)$$

The negative sign reflects the fact that to hedge a long stock position it is necessary to sell futures contracts. Figlewski (1984) points out that h^* is computed in practice by regressing the returns on the spot index against the returns on the futures contract, using historical data. When this is done the coefficient of determination, R^2, corresponds to Johnson's measure of hedging effectiveness.

An alternative to the minimum variance hedge ratio is the beta hedge ratio which has strong links to the classic hedge. We have seen that the classic 1:1 hedge ratio requires a futures position that is equal in size but opposite in sign to the cash position. Lindahl (1992) points out that

> "At first glance, this might be interpreted as matching the cash and futures positions dollar for dollar. However, when the cash position is a stock portfolio, the number of futures contracts for full hedge coverage needs to be adjusted by the portfolio's beta - a statistic that describes the portfolio's tendency to rise or fall in value compared to the market." (Lindahl, 1992, p35).

However, while the notion of the beta hedge in stock index futures hedging emanates from CAPM, the market portfolio to be used in determining the value of beta is not the true market portfolio (or an approximation of that portfolio such as the FT All share index) but rather the portfolio underlying the futures contract. In other words, the relationship which is of concern, is that between the stock portfolio to be hedged and the portfolio underlying the futures contract. In many cases the portfolio to be hedged will be a subset of the portfolio underlying the futures contract, and hence the beta will deviate from unity. If the portfolio to be hedged is that underlying the futures contract, the beta hedge ratio will equal unity. Thus by comparing the minimum variance hedge ratio with unity, a direct comparison is being made betwen h* and the beta hedge. Figlewski (1984) explains that in the special case of non-random dividends and the hedge being held until expiration of the futures contract, the change in the basis will be nonstochastic, resulting in h* being equivalent to the portfolio beta. This can be seen from equation 5.5 where the measure of h* is clearly consistent with the measure of beta. Indeed, where the above conditions hold and the portfolio to be hedged is the same as that underlying the futures contract, the traditional hedge, the mvhr and the beta hedge will be the same. However, Figlewski goes on to state that the basis tends not to be stable, implying that the beta hedge ratio will be sub-optimal. Indeed, Figlewski demonstrates that the minimum variance hedge ratio is superior to the beta hedge ratio, a finding which receives empirical support in later studies.

Figlewski (1984) argues that in almost all cases of hedging with stock index futures a cross-hedge is involved, i.e. the stock portfolio which is hedged differs from the portfolio underlying the futures contract. However, even when the hedge involves a position in the index portfolio itself (which means there will be no non-market risk) basis risk remains, as was shown in section A of chapter 1.

The above discussion raises two important points. Firstly, the fact that price risk is replaced by basis risk means that futures cannot be used to eliminate the risk associated with a spot position. Whatever futures hedging strategy is adopted, some risk will remain. Hence, an important point to consider is how effective a futures market for a particular asset is in reducing risk. Secondly, in practice, the minimum variance hedge ratio will depart from unity. This is due in large part to changes in the basis. Given that such changes depend in large part on the behaviour of arbitrageurs, and that this behaviour may change over time, it is reasonable to assume that the minimum variance hedge ratio will also change over time. Important empirical points to consider, therefore, relate to what is the value of h^* for a particular asset and whether h^* is stable.

In addition, it is important to consider theoretical reasons as to why h^* may change. Two major factors have been identified as being of potential influence on the value of the minimum variance hedge ratio: namely the duration of the hedge and the length of time to expiration of the futures contract.

It has been established that the relationship between the spot and futures market may be imperfect except at expiration and that futures prices will be able to deviate from their theoretical level within certain bounds. It is the imperfection between spot and futures prices prior to maturity which causes basis risk. The extent to which the two markets are related at any particular time will crucially depend upon the extent to which prices are allowed to deviate from their equilibrium relationship before arbitrageurs are enticed to enter the market to earn excess returns. As Figlewski (1984) points out, discrepancies between spot and futures prices cannot become arbitrarily large due to the activities of arbitrageurs. However, the variance of returns will increase with the length of time considered, and thus the fraction of total risk accounted for by basis risk will decrease as the holding period of any hedge increases. Thus, hedging effectiveness should increase as duration increases. Similarly, it is to be expected that the duration of a hedge will affect the value of h^*, with longer duration hedges being associated with higher values of h^*. This occurs because as the duration of the hedge increases and the basis risk falls as a proportion of total risk, the covariance of returns in the spot and futures markets will move closer to the variance of returns in the futures (and spot) market. Thus h^* increases towards unity as the duration of the hedge increases.

In addition, Figlewski (1984) argues that the attractiveness of an arbitrage opportunity depends upon the length of time that the position must be held to yield the profit. Since the equilibrium relationship between futures and spot prices must exist at expiration, the level of deviations from equilibrium should fall as contract expiration approaches. Hence, it is to be expected that as expiration approaches the minimum variance hedge ratio will change, approaching unity at expiration.

From the above discussion of hedging it is clear that in assessing the hedging role of stock index futures it is necessary to determine the extent of risk reduction which these contracts allow. In addition, the value of the minimum variance hedge ratio needs to be determined, and the stability of this ratio and the effectiveness of hedges in relation to time to contract expiration and hedge duration must also be examined.

The final issue to be considered in this section relates to the calculation of h^*. In order to estimate the hedge ratio which minimises risk it is necessary to have perfect foresight about the movements of spot and futures prices over the period of the hedge. Such an implicit assumption has been made by all the studies reviewed in chapter 1. In practice, of course, hedgers do not have perfect foresight. As a result they will have to estimate the optimal hedge ratio in terms of risk minimisation on the basis of expectations about future price movements. Given that it is not possible to determine expectations, a useful proxy might be to use historical information to estimate the mvhr. The question then arises as to what is the most appropriate historical information in terms of reducing risk. This issue is addressed in this chapter in relation to the FTSE-100 contract.

5.3 Data.

In this chapter the hedging performance of the FTSE-100 futures contract is examined using data relating to the period July 1984 to June 1992 and using the methodology set out in the next section. The spot portfolio to be hedged is that underlying the FTSE-100 index. Hence, it is assumed that the portfolio to be hedged moves exactly with movements in the FTSE-100 index. Given the widespread use of index funds by portfolio managers this assumption is reasonable. In line with the discussion in chapter 1, which showed that dividends did not impact significantly on the effectiveness of a hedge, no adjustment is made here to account for dividends. Again, this is not unreasonable, given the long established finding that dividends are highly stable (see, for example, Lintner (1956) and Fama and Babiak (1968)).

Hedge ratios are calculated by regressing the natural log of spot price changes against the natural log of the futures price changes. Logarithmic price changes are most appropriate since logs tend to minimise non-stationarities due to changes in price levels. In all estimations the futures contract nearest to expiration is used. This strategy is used for two reasons. Firstly, the liquidity in the nearby contracts, as evidenced by the information on volume and open interest presented in chapter 2, strongly suggests that nearby contracts are more widely used for undertaking hedging strategies. Secondly, the evidence concerning efficiency presented in chapter 4 suggests that futures prices are unbiased predictors of future spot prices for periods of less than three months from maturity, but are not always so for periods of three or more months from maturity. It is therefore likely that futures contracts which are not the nearby contract will offer a less effective means of hedging the risk associated with an underlying spot position.

The data used for both spot and futures relate to Wednesday closing prices. Thus hedge durations of one week and multiples of one week may be examined using this data. In this chapter we examine hedging effectiveness for hedges of 1, 2 and 4 weeks duration. The FTSE-100 futures contract trades in a cycle of March-June-September-December. There are thus 416 observations for one week hedges (8 years x 4 quarterly expiration dates x 13 weeks per quarter), 192 observations for two week hedges (8 x 4 x 6) and 96 observations for four week hedges (8 x 4 x 3).[2] All prices are obtained from Datastream.

5.4 Methodology.

In examining hedging effectiveness, minimum variance hedge ratios are estimated since, as has been shown, these result in a hedged position with less risk than do other hedging strategies, such as the beta hedge. However, comparisons are drawn with the risk return properties of the beta hedge strategy. The examination of hedging performance and hedging effectiveness is undertaken in four stages.

It has been argued that hedging effectiveness may be affected by the duration of the hedge and by the time between the hedge being undertaken and the maturity of the futures contract. The first stage of the analysis is concerned with the stability of hedge ratios with respect to hedge duration. OLS simple regressions are run for nonoverlapping 1, 2, and 4 week hedges. The hedges are lifted at between zero and twelve weeks prior to expiration. The OLS regression which is estimated is:

$$DS_t = \alpha + \beta DF_t + e_t \qquad (5.6)$$

where DS_t = the one week difference in the spot index for one week hedges, the two week difference in the spot index for two week hedges and the four week difference in the spot index for four week hedges

DF_t = the one week difference in the futures price for one week hedges, the two week difference in the futures price for two week hedges and the four week difference in the futures price for four week hedges

α, β = regression parameters, where β is the minimum variance hedge ratio, h^*

and e_t = a residual term.

All observations are in natural logarithms.

By comparing the estimated minimum variance hedge ratios from equation 5.6 and the R^2's for hedges of different durations, the impact of hedge duration can be examined. In addition, comparisons of the mean and standard deviations of returns for hedged (both mvhr and beta hedge) and unhedged portfolios are examined. Thus hedging effectiveness is examined using both R^2's and the standard deviation of returns.[3]

The issue of the stability of the minimum variance hedge ratios with respect to time to contract expiration constitutes the second stage of the analysis. This issue is examined by means of multiple regression using dummy variables to represent different subsets of the data based on weeks to expiration. Equations are estimated separately for hedge durations of 1, 2, and 4 weeks and are of the form:

$$DS_t = \alpha + \beta_0.DF_t.D_0 + \beta_1.DF_t.D_1 + \beta_2.DF_t.D_2 + ... + \beta_n.DF_t.D_n + e_t \qquad (5.7)$$

where α, β_i = regression parameters where the beta's are minimum variance hedge ratios for hedges with i weeks to expiration

D_i = dummy variables set to one for hedges with i weeks to expiration and zero otherwise.

For hedge durations of 1 week i = 0, 1,..., 11

2 weeks i = 0, 2,..., 10

4 weeks i = 0, 4, 8.

Estimates for hedges up to 12 weeks away from expiration were not used in this analysis due to some missing observations.

Having estimated equation 5.7, comparisons of the estimated β_is are made to examine the impact of time to expiration.

It was noted earlier that if the behaviour of arbitrageurs changes over time, then the minimum variance hedge ratio may also change over time, independent of changes in hedge duration and time to contract expiration. It is therefore of interest to examine the stability of the hedge ratios further. This is done in the third stage of the analysis. Two different approaches are used to analyse this issue. Firstly, rather than estimate hedge ratios for the whole period we estimate optimal hedge ratios on a yearly basis. Thus minimum variance hedge ratios are estimated for each year from July to June for the period 1984 to 1992. Comparisons are then made of the annual hedge ratios and hedging effectiveness in each year. Such analysis is only undertaken for hedge durations of 1 and 2 weeks, due to small sample sizes for hedges of 4 weeks duration. Secondly, minimum variance hedge ratios are estimated using a moving window (or rolling) regression procedure and we then test to see if the generated hedge ratio series follows a random walk. For this analysis equation 5.6 is estimated using the first j observations and then subsequently reestimated for every group of j consecutive observations by adding the next observation and dropping the first observation. Different values of j (the size of the window) are used to see if this influences the results. The rationale underlying this approach is that investors who are seeking to hedge their spot position may choose to adjust their hedge ratios regularly on the basis of the historical hedge ratio for the last j weeks. For one week hedges windows of 4, 8, and 13 weeks are used. The size of the windows for 2 week hedges are 4 (8 weeks) and 6 (12 weeks) and for 4 week hedges the window size is 3 (12 weeks). Tests for random walk will be carried out by estimating the following equation:

$$hr_t = b_0 + b_1 hr_{t-1} + b_2 hr_{t-2} + e_t \qquad (5.8)$$

where hr_t, hr_{t-1}, hr_{t-2} = hedge ratios.

The null hypothesis that the hedge ratios follow a random walk corresponds to $H_0:(b_0,b_1,b_2) = (0,1,0)$. If the null hypothesis is rejected, the stationarity of the hedge ratio series will be examined by testing for unit roots using the Augmented Dickey-Fuller method.

The fourth stage of the analysis of hedging performance involves an examination of hedge ratios and hedging effectiveness when hedging strategies are determined on the basis of historical information. Hedgers could adopt a number of different approaches to determine the hedge ratio to be used in the coming period. In this thesis we examine two different approaches based on the analysis of the stability of hedge ratios discussed above. The first approach involves using the annual hedge ratios estimated when examining hedge ratio stability. The optimal hedge ratio estimated for one time period is used as the actual hedge ratio in the subsequent time period. Thus, for example, the optimal hedge ratio relating to the period July 1984 to June 1985 is used as the actual hedge ratio for the period July 1985 to June 1986. The hedging effectiveness of this strategy is compared to the hedging effectiveness of the optimal (perfect foresight) hedge to determine if the use of historic information severely limits the hedging performance of the FTSE-100 contract.

The second approach involves a more sophisticated strategy based on a dynamic hedging strategy. In this case hedge ratios are estimated using the rolling regression procedure. The hedge ratio is then adjusted every 1 or 2 weeks, depending on the hedge duration, to take account of the newly estimated optimal hedge for the preceding j weeks. Consider, for example, hedges of 1 week duration and a window size of 8 weeks. In this case an optimal hedge ratio is estimated for the first 8 weeks and this ratio is used to hedge the week nine position. At the end of week nine another optimal hedge ratio is estimated on the basis of weeks 2 - 9 and this ratio is used in week ten. This procedure is continued throughout the period under analysis. Different sized windows are used to determine if the use of different amounts of historical information impacts on hedging performance.

5.5 Results.

5.5.1 The Duration Effect.

Equation 5.6 was estimated for hedge durations of one, two and four weeks. The relevant results from the regressions are presented in table 5.1. The table shows the estimated values of h*, the minimum variance hedge ratio, the standard errors relating to each estimate of h* and the R^2s for each of the regressions. In addition to this information, table 5.1 also shows whether h* is significantly less than unity, the beta hedge.

Table 5.1 shows that the minimum variance hedge ratios (h*) increase markedly as hedge duration increases, in line with expectations. However, for hedges of all durations considered the minimum variance hedge ratio is less than unity, the beta hedge ratio. Hence, if the classic 1:1 hedging strategy were adopted, the resultant position would have greater risk than does the position resulting from a hedging strategy which uses the value of the minimum variance hedge ratio. This is confirmed in the lower part of table 5.1 which shows the mean annual return and the standard deviation of returns for the unhedged portfolio, the hedged portfolio based on the mvhr and the hedged portfolio based on the beta hedge ratio, for hedge durations of 1, 2 and 4 weeks. The degree of risk reduction achieved with both the mvhr and the beta hedge is substantial. For example, for hedges of two weeks duration the standard deviation of

Table 5.1: Hedging performance - the duration effect.

	Hedge Duration		
	One week	Two weeks	Four weeks
h^* (mvhr)	.9101	.9330	.9633
Standard Errors	.0097	.0107	.0101
R^2	.9548	.9756	.9898
Number of observations	416	192	96
Is h^* significantly < 1, the beta hedge? (confidence level)	Yes (99.9%)	Yes (99.9%)	Yes (99.9%)
Unhedged Portfolio			
Mean return	11.636	9.746	9.746
S. D. of returns	118.981	91.187	77.141
Mvhr portfolio			
Mean return	6.198	5.286	5.141
S. D. of returns	25.298	14.255	7.804
Decrease in sd from unhedged portfolio	78.7%	84.4%	89.9%
Beta hedge portfolio			
Mean return	5.661	4.965	4.965
S. D. of returns	27.786	15.654	8.333
Decrease in sd from unhedged portfolio	76.6%	82.8%	89.2%

Mean and standard deviation of returns are in percent per annum.

returns is reduced by over 80% using either strategy. However, in all cases the mean return is higher and the standard deviation of returns lower using the mvhr, as compared to the beta hedge ratio. These results are in line with those of Lindahl (1992) and in contrast to those of Figlewski (1984, 1985). Figlewski's results have been called into question due to the small sample sizes in his work.

Table 5.1 also shows that the values of R^2 increase as hedge duration increases, again in line with the findings of Lindahl (1992) and others, suggesting that hedging effectiveness increases with hedge duration. The standard deviations of returns also demonstrate this clearly. From the values of R^2 it can be seen that the variance of the returns for the hedged position represents only 4.52% of the variance of the returns of the unhedged position for one week hedges. For two week hedges this figure falls to 2.44% and for four week hedges it falls further to 1.02%. Clearly, then the residual risk associated with the hedged position when the minimum variance hedge ratio strategy is adopted is very small in percentage terms compared to that of the unhedged position.

If returns are normally distributed then 68% of the observations are estimated to lie within + or - 1 S.D. of the mean return and approximately 95% within + or - 2

S.D.s of the mean. Thus 68% of observations will lie within the range -19.1% to 31.496% for 1 week hedges, -8.969% to 19.541% for 2 week hedges, and -2.663% to 12.945% for 4 week hedges. This compares with the figures for the unhedged portfolio of -107.345% to 130.617% for 1 week, -81.441% to 100.933% for 2 week, and -67.395% to 86.887% for 4 week returns. Hence, while it is not possible to eliminate all risk by hedging, the FTSE-100 stock index futures contract does enable a substantial reduction in risk to be achieved, especially with longer duration hedges. These results for the duration effect are in line with expectations following the discussion of theoretical issues earlier.

5.5.2 The Expiration Effect.

In order to investigate the impact of time to contract expiration on hedge ratios, equation 5.7 was estimated for hedges of one, two and four weeks duration. Table 5.2 presents the results of this estimation. There is clear evidence from the table that hedge ratios do vary with time to contract expiration as was expected. Although a continuous pattern is not evident it does appear that for one week hedges the minimum variance hedge ratios approach the beta hedge as contract expiration approaches. All hedges lifted within 5 weeks of expiration have hedge ratios insignificantly less than the beta hedge at the 95% confidence level.

Table 5.2: Minimum variance hedge ratios - the expiration effect.

Hedge Duration	Weeks to expiration	h* (MVHR)	Standard Errors
1 week	0	.9738	.0851
	1	.9399	.0646
	2	.8813	.0833
	3	.9176	.0690
	4	.8831	.0699
	5	.8881	.0686
	6	.8230	.0638
	7	.8586	.0634
	8	.9756	.0673
	9	.9331	.0394
	10	.8933	.0304
	11	.6885	.0445
R^2	.8882		
Number of observations	416		
2 weeks	0	.8177	.0403
	2	.9520	.0417
	4	.9313	.0404
	6	.9288	.0374
	8	.9919	.0286
	10	.8592	.0222
R^2	.9637		
Number of observations	192		
4 weeks	0	.9749	.0372
	4	.9777	.0321
	8	.9560	.0175
R^2	.9805		
Number of observations	96		

Similarly all hedges lifted six or more weeks from expiration have hedge ratios significantly less than unity at the 95% level, with the exception of the hedges lifted eight and nine weeks before expiration. The hedge ratio for nine weeks is significantly less than the beta hedge at the 90% level. No obvious explanation can be given for the result relating to eight weeks prior to expiration, although it could be due to relatively small sample sizes for each subset of data.

As far as two week hedges are concerned the hedge ratio values show no discernible pattern. Once again the finding for the hedge lifted eight weeks prior to expiration is difficult to explain. Finally, for four week hedges those lifted zero and four weeks prior to expiration have hedge ratios insignificantly different from the beta hedge at all normal confidence levels, while that relating to eight weeks prior to expiration is significantly less than unity, at the 95% confidence level.

While the results for expiration effects do not show patterns as clearly as do Lindahl's findings, some general conclusions can be drawn. Of particular significance is the fact that hedge ratios do clearly vary with the time remaining before contract expiration. In addition, for one and four week hedges, those lifted further from expiration are generally significantly less than the beta hedge, in contrast to those lifted closer to expiration.

5.5.3 Hedge Ratio Stability.

As explained in section 5.4 hedge ratio stability is examined in two ways. Firstly, we estimate equation 5.6 on an annual basis. The results of these estimations are reported in table 5.3 for one and two week hedges. It is evident from the results in this table that minimum variance hedge ratios have varied over time. For example, for both one and two week hedges the mvhr is insignificantly different from unity for 1984/5, 1985/6 and 1988/9, but is significantly less than unity for the other five years. Indeed, the estimated annual minimum variance hedge ratios vary from .8637 to .9906 for one week hedges and from .8915 to 1.0264 for two week hedges. Thus there is clearly evidence that hedge ratios are not stable through time.

Another interesting finding emerges from this analysis, in that there is evidence of changes in hedging effectiveness, year on year. In particular, it appears that hedging effectiveness has increased substantially since the earliest days of trading in this contract. The values of R^2 are markedly higher for the most recent years than they are for the early years of trading. It thus appears that the market for the FTSE-100 stock

Table 5.3: Hedge ratio stability - annual hedge ratios.

Year	h^* (mvhr)	One week hedges Standard Errors	R^2
1984/5	.9906	.0424	.9160
1985/6	.9830	.0382	.9299
1986/7	.8966$^+$	.0329	.9371
1987/8	.8905$^+$	.0227	.9685
1988/9	.9432	.0341	.9386
1989/90	.8637$^+$	.0279	.9503
1990/1	.8890$^+$	.0202	.9748
1991/2	.9448$^+$	.0195	.9791

Year	h^* (mvhr)	Two week hedges Standard Errors	R^2
1984/5	1.0264	.0467	.9565
1985/6	.9618	.0377	.9674
1986/7	.8915$^+$	.0366	.9642
1987/8	.9230$^+$	.0267	.9820
1988/9	.9567	.0309	.9775
1989/90	.8967$^+$	.0353	.9671
1990/1	.9409$^+$	.0203	.9899
1991/2	.9537$^+$	.0246	.9856

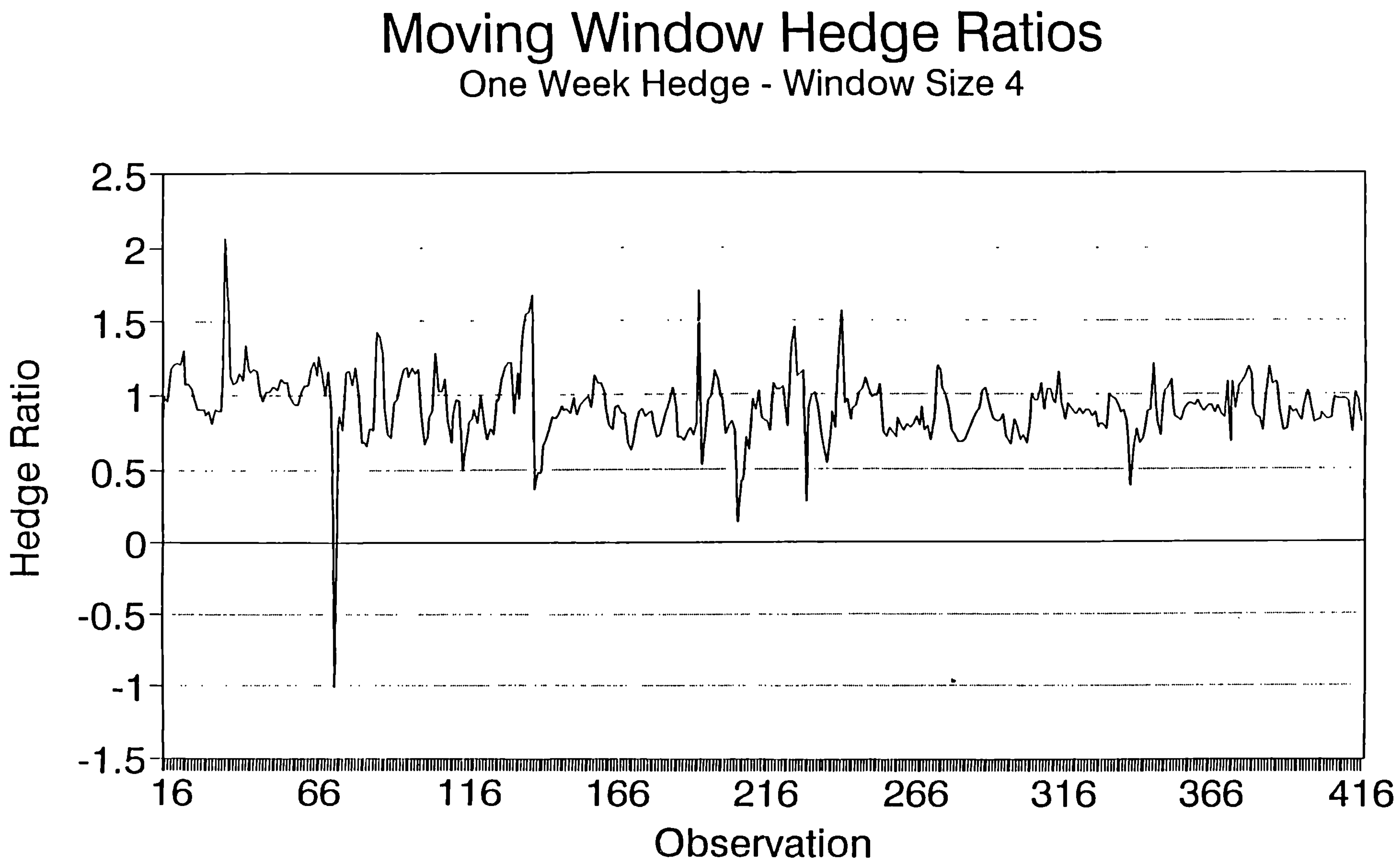
$^+$ Significantly less than 1 at the 5% level.

index futures contract has provided a more effective means by which to hedge the risks associated with stock portfolios in recent years, suggesting a reduction in basis risk.

We know consider hedge ratio estimations using the moving window regression procedure. These estimations were run to examine further the stability of hedge ratios over time. Figures 5.1 - 5.6 show the values of the hedge ratios calculated using this procedure for hedges of 1, 2, and 4 weeks using different size windows. There is clear evidence from these figures that the hedge ratio does vary over time, supporting the previous results and suggesting that a dynamic hedging strategy is worthy of consideration.

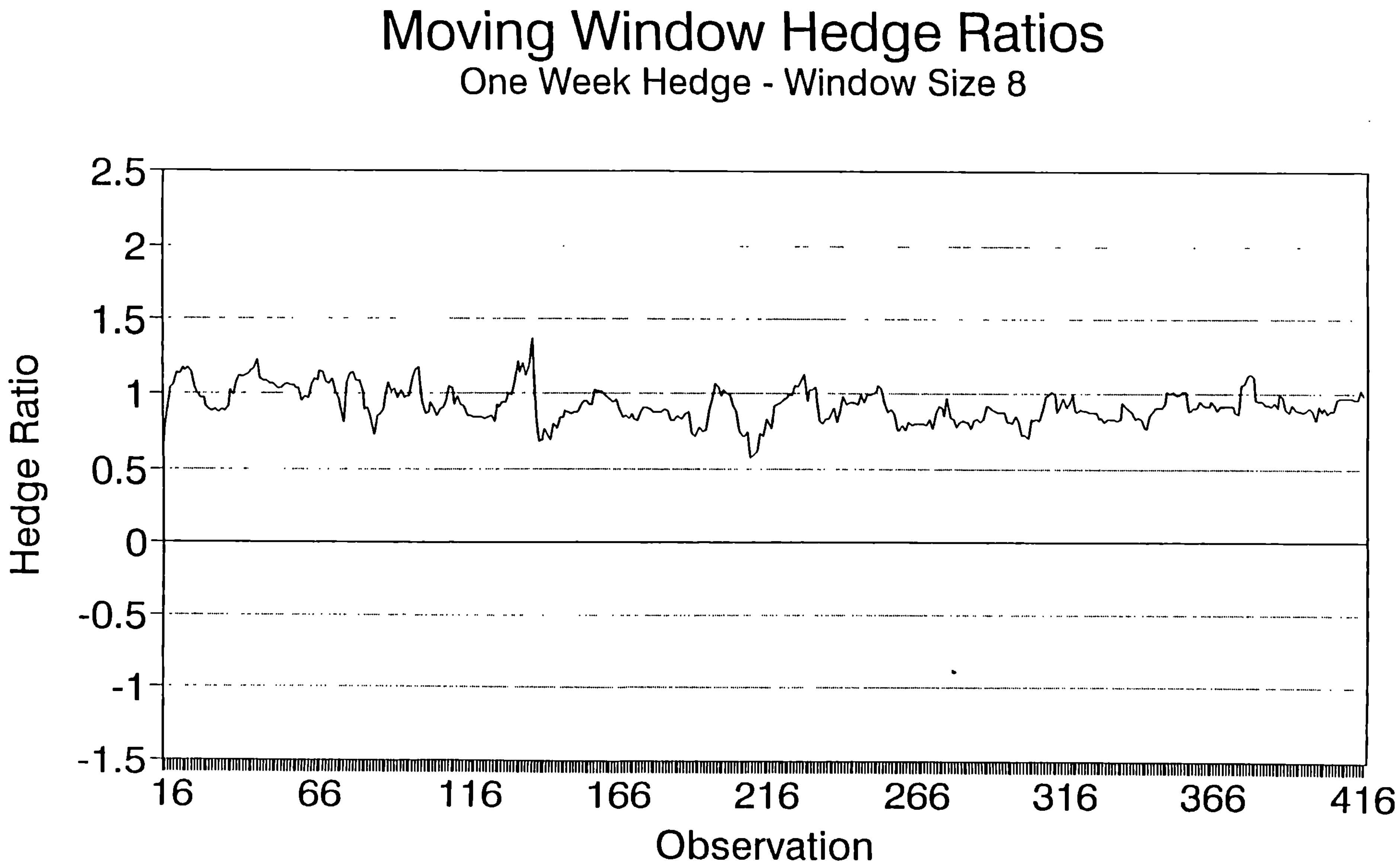
In order to undertake a more formal examination of the question of hedge ratio stability the estimated hedge ratios were examined to determine whether they follow a random walk. This issue is analysed by estimating equation 5.8 and testing the null hypothesis $H_0:(b_0,b_1,b_2) = (0,1,0)$. The results of the tests of this hypothesis to determine whether the estimated hedge ratios follow a random walk are presented in table 5.4.

Figure 5.1



Moving Window Hedge Ratios
One Week Hedge - Window Size 4
Hedge Ratio
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
16
66
116
166
216
266
316
366
416
Observation

Figure 5.2



Moving Window Hedge Ratios
One Week Hedge - Window Size 8
Hedge Ratio
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
16
66
116
166
216
266
316
366
416
Observation

Figure 5.3

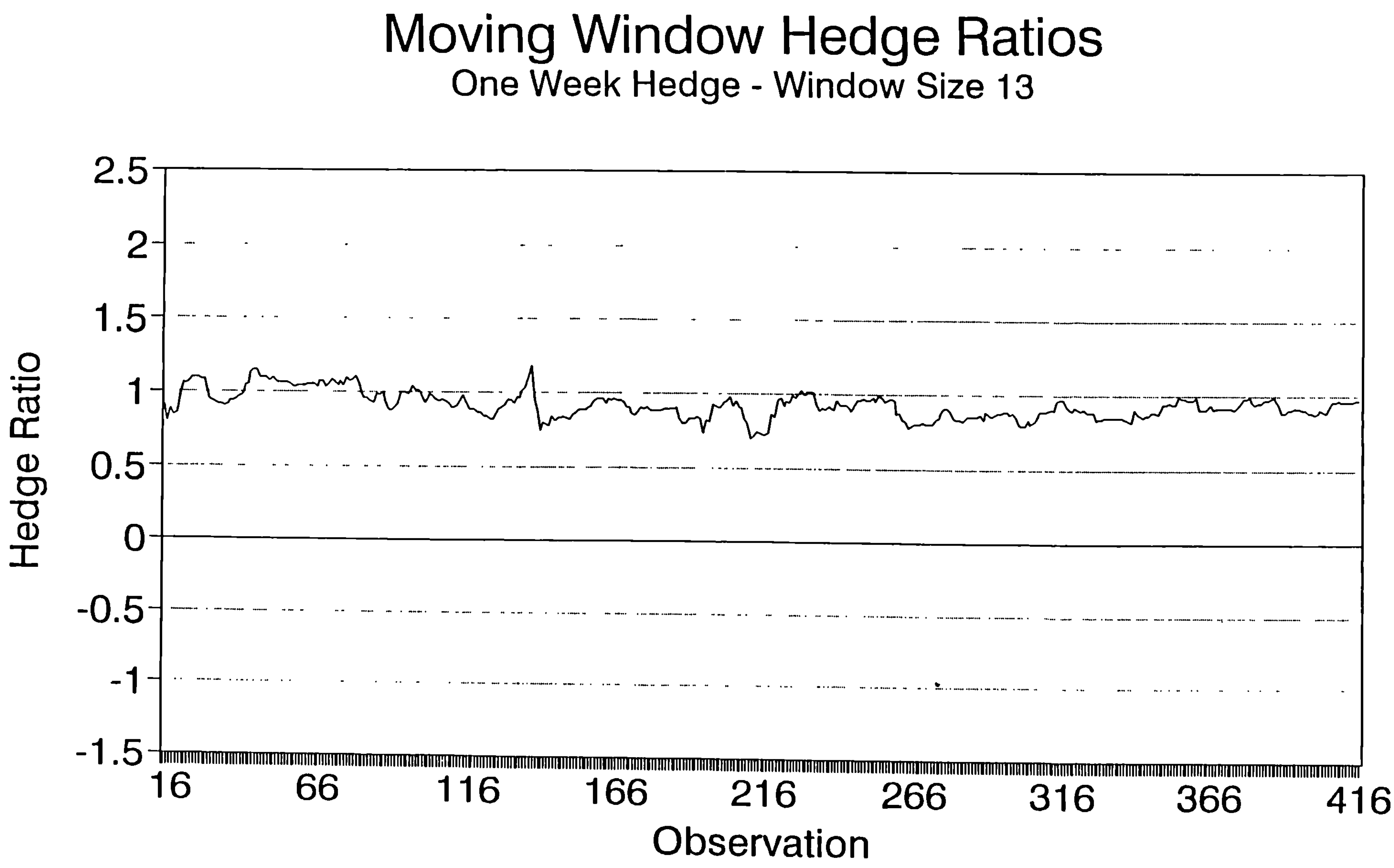
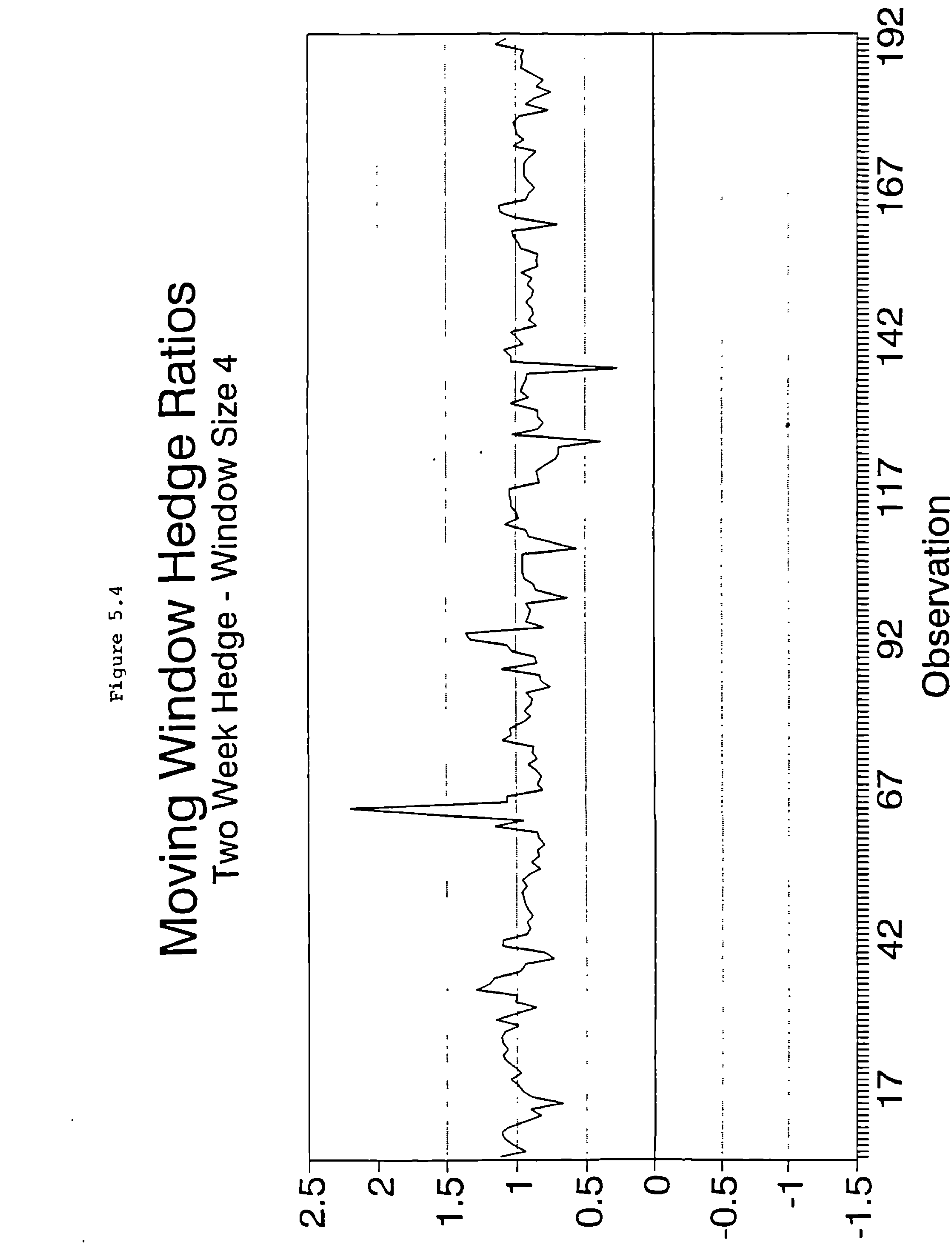

Moving Window Hedge Ratios
One Week Hedge - Window Size 13
Hedge Ratio
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
16
66
116
166
216
266
316
366
416
Observation

Figure 5.4



Moving Window Hedge Ratios
Two Week Hedge - Window Size 4
Hedge Ratio
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
17
42
67
92
117
142
167
192
Observation

Figure 5.5

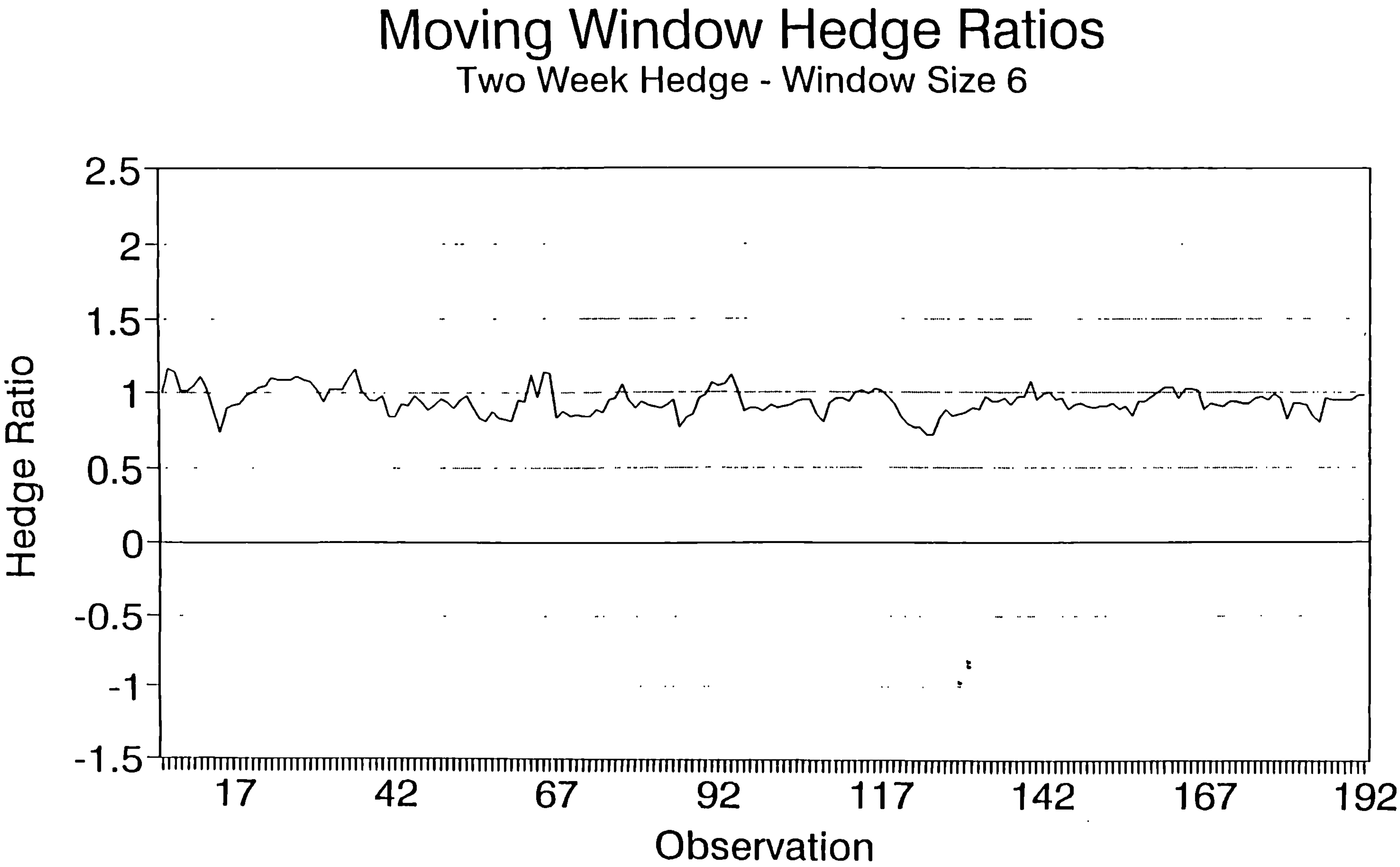
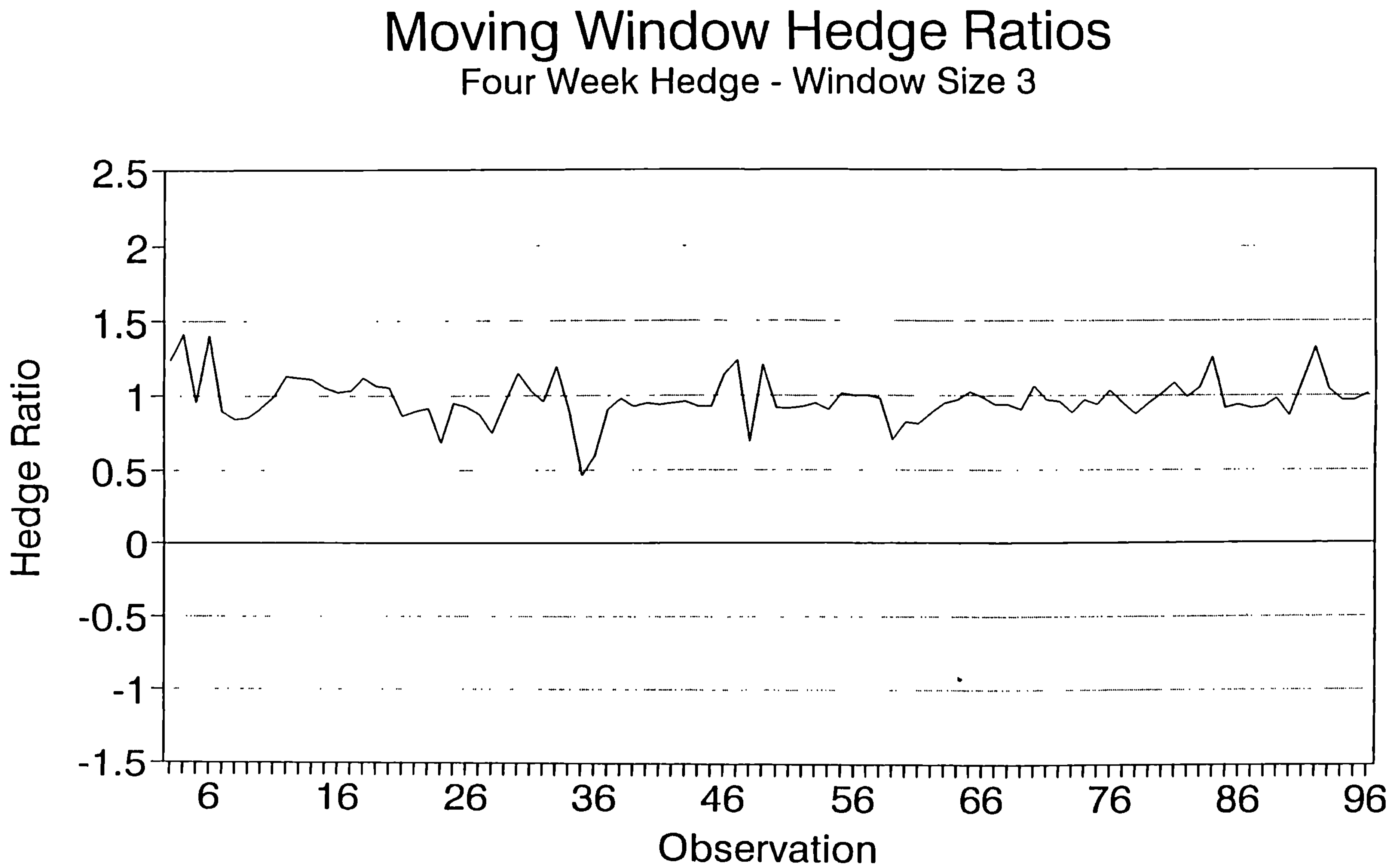

Moving Window Hedge Ratios
Two Week Hedge - Window Size 6
Hedge Ratio
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
17
42
67
92
117
142
167
192
Observation

Figure 5.6



Moving Window Hedge Ratios
Four Week Hedge - Window Size 3
Hedge Ratio
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
6
16
26
36
46
56
66
76
86
96
Observation

Table 5.4: Test of Random Walk of the Hedge Ratio.

$H_0:(b_0,b_1,b_2) = (0,1,0)$

Hedge Duration	Size of Window	b_0	b_1	b_2	χ^2	Is H_0 accepted?
		(t statistics)				
1 week	4	.4722	.4576	.0276	147.33	No
		(9.88)	(9.24)	(0.56)		
	8	.1488	.8940	-.0554	34.71	No
		(5.83	(17.99)	(-1.11)		
	13	.0809	.9609	-.0484	18.28	No
		(4.27)	(19.22)	(-0.97)		
2 weeks	4	.5264	.4197	.0224	74.88	No
		(7.05)	(5.74)	(0.31)		
	6	.2869	.6908	.0037	35.36	No
		(5.43)	(9.53)	(0.05)		
4 weeks	3	.7233	.2136	.0371	63.62	No
		(6.12)	(2.10)	(0.37)		

The critical value for the chi-squared statistic is 9.49.

Table 5.5: Unit root tests for the stationarity of hedge ratios.

Hedge Duration	Size of Window	Number of observations	ADF statistic	Is hr stationary?
1 week	4 (4 weeks)	411	-10.1189	Yes
	8 (8 weeks)	407	- 5.8661	Yes
	13 (13 weeks)	402	- 4.2739	Yes
2 weeks	4 (8 weeks)	187	- 7.1424	Yes
	6 (12 weeks)	185	- 5.4647	Yes
4 weeks	3 (12 weeks)	92	- 6.2144	Yes

The results in table 5.4 show that for all hedge durations and all window sizes for which the tests were carried out the null hypothesis is rejected. Hence, in contrast to the findings of Malliaris and Urrutia (1991) the estimated hedge ratios do not follow a random walk.

Given these findings, the stationarity of the minimum variance hedge ratios was examined using the Dickey-Fuller technique. Table 5.5 presents the results of the ADF tests. The results in table 5.5 clearly demonstrate that for all hedge durations and for all window sizes the hedge ratios are stationary. Thus while figures 5.1 - 5.6 show that the hedge ratios do vary across time they are nonetheless stationary.

5.5.4 Hedging Effectiveness and the Use of Historical Information.

In this sub-section we report and discuss the results of analysis examining the hedging effectiveness of the FTSE-100 stock index futures contract when hedging strategies based on historical information are used. The results of the analysis using annually calculated hedge ratios are presented in tables 5.6a and 5.6b. Table 5.6a relates to one week hedges and 5.6b to two week hedges. The tables shows the annual mean returns and standard deviation of returns for four portfolios: the unhedged portfolio; the minimum variance hedge portfolio (assuming perfect foresight); the hedged portfolio based

Table 5.6a: Hedging effectiveness using historical information - annual minimum variance hedge ratios - one week hedges.

Year	Unhedged	Portfolio Mvhr	Mvhr(-1)	Beta
1984/5				
Mean	17.268	0.299	-	0.123
S.D.	104.140	30.179	-	30.193
1985/6				
Mean	27.593	4.574	4.396	4.176
S.D.	86.315	22.848	22.857	22.893
1986/7				
Mean	33.771	10.594	8.361	7.921
S.D.	101.488	25.452	27.155	27.860
1987/8				
Mean	-19.503	3.644	3.801	6.488
S.D.	205.925	36.541	36.566	44.222
1988/9				
Mean	14.484	5.348	5.857	4.797
S.D.	90.007	22.301	22.825	22.912
1989/90				
Mean	8.766	6.717	6.529	6.394
S.D.	100.807	22.464	24.216	27.298
1990/1				
Mean	4.675	8.530	8.420	9.012
S.D.	113.750	18.075	18.356	22.878
1991/2				
Mean	4.475	6.273	6.167	6.378
S.D.	105.248	15.219	16.417	16.388

Figures are for mean and standard deviation of annual returns in percent.
Mvhr(-1) refers to a portfolio hedged using the mvhr from the previous year.

Table 5.6b: Hedging effectiveness using historical information - annual minimum variance hedge ratios - two week hedges.

		Portfolio		
Year	Unhedged	Mvhr	Mvhr(-1)	Beta
1984/5				
Mean	18.462	-1.362	-	-0.853
S.D.	70.772	14.757	-	14.864
1985/6				
Mean	22.318	3.650	2.396	2.908
S.D.	69.620	12.576	13.391	12.867
1986/7				
Mean	39.611	10.936	8.675	7.446
S.D.	76.310	14.438	15.605	17.082
1987/8				
Mean	-26.582	3.328	2.306	5.822
S.D.	162.721	21.857	22.540	25.662
1988/9				
Mean	16.586	3.677	4.131	3.092
S.D.	71.900	10.775	11.062	11.246
1989/90				
Mean	10.016	4.945	4.606	4.361
S.D.	80.376	14.587	15.517	17.197
1990/1				
Mean	-1.868	9.974	9.417	10.717
S.D.	84.172	8.474	9.346	9.973
1991/2				
Mean	-0.573	5.914	5.827	6.229
S.D.	72.972	8.773	8.826	9.450

Figures are for mean and standard deviation of annual returns in percent.
Mvhr(-1) refers to a portfolio hedged using the mvhr from the previous year.

on the previous year's mvhr (mvhr(-1)); and the beta hedge portfolio. The third portfolio is a hedged portfolio where the hedging strategy is based on historical information.

The results reported in tables 5.6a-b demonstrate that all three hedged portfolios achieve a substantial reduction in risk compared to the unhedged portfolio. It is evident (indeed, almost definitional) that the hedged portfolio based on the historical mvhr does not achieve the same level of risk reduction as does the perfect foresight mvhr portfolio. However, two points are worthy of note. Firstly, the extent of risk reduction with the mvhr(-1) is very substantial and extremely close to that achieved by using the perfect foresight mvhr. Indeed, as a percentage of the standard deviation of returns of the unhedged portfolio, the standard deviation of returns of the mvhr(-1) portfolio is never as much as 2 percentage points higher than that of the mvhr portfolio. Thus while the level of risk reduction is not as great using the mvhr(-1), it is still clearly a very effective hedging strategy.

The second point worthy of note relates to a comparison of the mvhr(-1) portfolio and the beta hedge portfolio. For both one week and two week hedges the degree of risk reduction using a hedging strategy based on the mvhr for the previous year is greater than that achieved using the beta (or classic) hedge in all but one year (1991/2 for one week hedges and 1985/6 for two week hedges). Both the mvhr and the beta hedge strategies emphasise risk reduction. However, this analysis suggests that using the mvhr calculated on the basis of historical information is superior to the classic hedge strategy in terms of risk reduction.

We now turn to the analysis of the hedging effectiveness of historically based hedging strategies using the moving window regression procedure. The results of this analysis are reported in table 5.7. Two sets of standard deviations of returns are reported for different window sizes. The first relates to the perfect foresight minimum variance hedge ratio. This column demonstrates that the larger the window size used to estimate the mvhrs the higher is the standard deviation of returns. This is unambiguously true for one week hedges. For two week hedges the standard deviation of returns does not rise continuously over all window sizes. Nonetheless, the pattern is clearly one of the standard deviation increasing as the window size increases. This is as expected. If the coming period's price movements are known exactly then all risk can be removed by establishing a perfect hedge for each period separately. Thus for a one week hedge the most important information when calculating a particular week's hedge ratio relates to the price movements in that week. The smaller the

Table 5.7: Hedging effectiveness using historical information - rolling regression minimum variance hedge ratios.

Window size	Standard deviation of annual returns mvhr	mvhr(-1)
(a) One week hedges		
8	22.924	27.381
13	23.812	26.170
26	23.973	24.890
39	24.070	24.725
52	24.150	24.745
65	24.263	24.693
78	24.277	24.670
91	24.407	24.784
104	24.478	24.841
S.D. of returns of unhedged portfolio: 125.798		
(b) Two week hedges		
6	12.847	16.287
12	13.551	14.933
18	13.514	14.946
24	13.726	14.754
30	13.712	14.548
36	13.780	14.584
42	13.854	14.490
48	13.900	14.561
S.D. of returns of unhedged portfolio: 97.308		

The total samples of 416 (1 week hedges) and 192 (2 week) are used to generate hedge ratios. The first 104 and 48 are dropped to calculate the s.d.s to allow comparisons on the same basis across the different window sizes. Thus the s.d.s relate to sample sizes of 312 and 144.

window size, the greater is the weight given to the relevant week's price movements and the more effective is the hedge likely to be.

The second column presents the standard deviation of returns based on the mvhr calculated for the previous j weeks. Thus, for example, the mvhr for week 105 is that calculated on the basis of weeks 97-104 for a window size of 8 and weeks 92-104 for a window size of 13. Clearly then, information on the current week (say week 105) is not included when determining the hedge ratio.

The column headed mvhr(-1) shows that the standard deviation of returns does not rise with the window size. Rather, the standard deviation falls as the window size increases over a large range of window sizes. The minimum standard deviation occurs with a window size of 78 for one week hedges and 42 (84 weeks) for two week hedges. This suggests that when calculating mvhrs on the basis of historical information, risk is reduced by using data over longer periods, in contrast to the perfect foresight mvhrs. Again, this is as expected. When historical information is used, no weight is given to the relevant week's price movements (since it is not yet available). However, with smaller window sizes more weight is given to each week included. Given that any one week may be an outlier (i.e. highly untypical), by including data from more weeks, the weight given to outliers is reduced and a more representative hedge ratio is likely to result. However, there is likely to come a point when the use of additional historical data will not be beneficial. If hedge ratios are changing over time, then data from, say, two years previously may have little relevance in determining the current hedging strategy. Thus beyond a certain window size the standard deviation of returns will rise, as shown in table 5.7.

A final point to note from table 5.7 is that while the mvhr strategy based on historical information is not as effective at reducing risk as the perfect foresight mvhr strategy, nonetheless, considerable risk reduction is achieved. For example, the degree of risk reduction (decrease in standard deviation) achieved by the perfect foresight mvhr is 81.78% for one week hedges and 86.8% for two week hedges. The best corresponding figures for the mvhr based on historical information are 80.39% and 85.11% respectively. Clearly, for the optimal window size there is very little difference between the perfect foresight strategy and that based on historical information.

5.6 Summary and conclusions.

In this chapter the hedging performance of the FTSE-100 stock index futures contract has been examined for the period since its introduction in 1984. Hedging is arguably the major justification for the existence of futures contracts. Given this situation it is surprising that the hedging performance of the FTSE-100 stock index futures contract has not previously been addressed.

It has been shown in this chapter that using the FTSE-100 contract to hedge stock portfolios which mirror the FTSE-100 index is a very effective means of reducing the risk associated with a spot stock position. Even with a (perfect foresight) hedging strategy based on hedge durations of only one week the variance of the hedged position represents less than 5% of the variance of the unhedged position. For longer duration hedges the hedging effectiveness is increased.

Of particular concern in this chapter has been the question of whether minimum variance hedge ratios are constant or vary through time. In this regard the study examines two important factors in determining hedge ratios: namely the impact of a hedge duration effect and the question of whether hedge ratios vary with time to expiration of the contract. In addition, the issue of whether hedge ratios follow a random walk is considered.

As far as hedge duration is concerned, there is evidence that hedge ratios rise towards the beta hedge with increases in the time the hedge is held. The minimum variance hedge ratio is greater for a four week hedge than for a two week hedge, which in turn is greater than the hedge ratio for a one week hedge. Similarly, as mentioned above, hedging effectiveness, as measured by the value of R^2, increases with hedge duration.

The evidence concerning an expiration effect is less clear cut, although it does appear that hedge ratios approach unity as the contract expiration approaches, at least for one and four week hedges. However, there are some results in this analysis which are difficult to explain and may be due to relatively small sample sizes for each subset of data analysed.

The question of whether hedge ratios follow a random walk is addressed by generating series of hedge ratios using the moving window regression procedure and the series are then examined. Different sizes of window are used, as are different hedge durations. All the results reject the hypothesis that hedge ratios follow a random walk, in contrast to the finding of Malliaris and Urrutia (1991) for the S&P 500 futures contract in the USA. In addition, unit root tests suggest that the series of hedge ratios are stationary.

The implication of these results, together with the clear evidence from figures 5.1 - 5.6 that hedge ratios vary over time, is that in order to minimise the variance of returns from a hedged portfolio a dynamic hedging strategy should be adopted. However, in advocating a dynamic hedging strategy it is necessary to take account of the additional costs which will arise from pursuing such a course of action. Hence, the investor must weigh up the benefits of reducing risk by frequent changing of hedge ratios, against the increased transactions costs associated with adopting such a dynamic strategy.

Finally, perfect foresight mvhr strategies and beta hedge strategies have been compared with hedging strategies based on historical information. This is an important comparison given the failure of all previous studies to address the point that hedgers simply do not have perfect foresight. While hedge strategies based on historical information result in less risk reduction than does the perfect foresight mvhr strategy, they do greatly reduce risk and appear to be superior to the beta or classic hedging strategy.

The evidence presented in this chapter strongly suggests that the FTSE-100 futures contract is an effective means by which to hedge risk, even if a static hedging strategy is adopted. A portfolio as broadly diversified as the FTSE-100 stock index will have virtually no unsystematic risk. It has been shown here that when such a portfolio is combined with selling the futures contract on the basis of the minimum variance hedge ratio almost all systematic risk can be removed. Thus the introduction of the futures contract on the FTSE-100 stock index has clearly given portfolio managers a valuable instrument by which to avoid risk at times when they wish to do this without liquidating their spot position. In addition, while the results presented in this chapter relate to the hedging of an established spot position, the fact that the contract is such an effective means by which to manage risks suggests that it will also be effective for those investors requiring anticipatory hedging, as discussed in chapter 1.

Footnotes.

1. An alternative hedge strategy is that proposed by Rutledge (1972). Rutledge considered the hedging problem (the choice of h) in terms of maximising utility, where the mean and standard deviation of returns are arguments in the utility function. Essentially, the choice of h is a constrained optimisation problem, where the hedger seeks to maximise expected returns subject to constraints on the level of risk incurred. Given that investigation of such a strategy involves (arbitrary) assumptions concerning the hedger's choice of constraint, and that the Rutledge model has strong similarities with the minimum variance hedge ratio, this model is not considered here.

2. Given that the contracts trade in 13 week cycles the hedges of 2 and 4 weeks duration involve one week in each quarter where the position is not hedged.

3. Given that R^2 is equal to 1-V(H)/V(U), the two means of examining hedging effectiveness have very strong links.

Chapter 6: Conclusion.

6.1 Summary.

In the introduction to this thesis it was suggested that rigorous scientific research is required before policies are formulated, investment strategies executed and judgements made concerning the role and functioning of futures markets. It is the author's belief that the research carried out in this thesis helps to achieve this aim and provides an original contribution towards the understanding of the role and functioning of the FTSE-100 stock index futures market and its impact on the underlying spot market.

The aim of this thesis was not only to fill an obvious gap in the finance literature, but also to improve, where possible, on previous research. Thus, in addition to providing insights for the first time for the FTSE-100 futures market, the methodologies applied have been developed and refined here, enabling more reliable inferences to be drawn. In order to achieve the objectives set at the beginning, this thesis has examined four issues which are of central concern to futures market participants and policymakers: the risk return relationship within an asset pricing model framework; the impact of futures trading on spot price volatility and its link to information; the short-term and long-term efficiency of futures markets; and finally the properties of hedge ratios and the effectiveness of the FTSE-100 stock index futures contract in providing a hedging vehicle for holders of stock portfolios.

After a review of the literature in chapter 1, chapter 2 examines the risk return relationship within a CAPM framework using both the Black, Jensen and Scholes and Fama and MacBeth methodologies. The FTSE-100 futures contract was found to be a risky asset in systematic risk terms, with beta values ranging between 1.01 and 1.14. While futures returns are adequately explained by the CAPM before the 1987 crash, the same is not true post-crash. Abnormal returns were evident in the latter period suggesting market inefficiency. Such a conclusion was given support by the finding of a day of the week effect. Weekly returns to Mondays and Fridays were found to be serially correlated, whereas those to Wednesdays were not. As far as the time to maturity of the contract is concerned, contracts further from maturity appear to be associated with lower systematic risk and higher excess returns. Given the evidence of thin trading in futures of more than three months prior to maturity, this is not surprising. While the findings are interesting in their own right, they also generate additional areas worthy of further research, which are taken up in subsequent chapters.

Chapter 3 investigates the impact of the introduction of futures trading on the FTSE-100 stock index contract on the market for the underlying asset. Previous research has characterised the issue in terms of stabilisation or destabilisation of the spot market. As shown in this thesis, such characterisation fails to recognise the important connecting link between information and volatility. As such, by criticising the onset of futures trading for destabilising the spot market, it may be that the messenger is being blamed for carrying a message more effectively. It is therefore essential, as shown here, that when examining this issue a methodology is used which enables such connecting links to be established and analysed before any policy implications are drawn. By using GARCH such links can be examined and problems of time dependence encountered by previous studies can also be overcome. The results presented here for the impact of the existence of futures trading suggest that spot price volatility has been affected. Before the introduction of futures the impact of previous news persisted for longer periods than post-futures. Thus information is impounded into spot prices more rapidly post-futures suggesting that futures have expanded the routes by which information is conveyed to market participants. Hence, while price volatility may have increased post-futures, this is due to an improvement in the quality and speed of information flowing to the spot market. The prima facie evidence supporting the popular view of futures destabilising the spot market is thus counterproductive and even dangerous. By undertaking rigorous research using appropriate techniques it has been shown that increased short-term volatility is associated with an improved flow of information.

The efficiency of the market for the FTSE-100 stock index futures contracts was examined in chapter 4. While the efficiency of futures markets has been subject to considerable investigation, the results have been inconclusive. This is due in some part to inappropriate methodologies being used in some cases. However, differences remain and it is therefore important to investigate efficiency for relatively new markets such as the FTSE-100 futures market. In addition, the methodologies used to test for efficiency need to be extended. In chapter 4 the recent developments in cointegration analysis have been exploited to test for market efficiency. Unlike previous studies, the use of the Johansen procedure allowing tests of parameter restrictions has been combined with the use of ECMs. This has allowed examination of both the short-term and the long-term efficiency of the market. In addition, variance bounds tests have been developed and used to further test for efficiency. The market is found to provide unbiased predictors of future spot prices in both the short and long-term for 1, 2 and 4 months prior to maturity. For 5 months prior to maturity there is evidence of long-term unbiasedness, but short-term deviations from this relationship. For 3 and 6 months prior to maturity futures prices do not provide unbiased predictors of future spot prices and thus efficiency is rejected. The evidence from the variance bounds tests confirmed the findings of the cointegration and ECM analysis. Given the disagreements evident in previous research, such confirmation is welcome.

Finally, in chapter 5 hedging strategies and effectiveness were examined. Given that hedging is the primary function of futures markets, it is surprising that this issue has not previously been addressed for this contract. In addition to examining the duration and expiration effects, the research investigated the stability of hedge ratios and, by examining the use of historical information in devising hedging strategies, provided a more thorough analysis than have previous studies. First and foremost, there is clear evidence that the FTSE-100 stock index futures contracts provide a highly effective means of reducing the risk associated with holding a stock portfolio. As far as hedge duration is concerned, both hedging effectiveness and hedge ratios increase as the duration of the hedge increases. Hedge ratios appear to approach unity as expiration nears, although the evidence in this regard is not as clear as that for the duration effect. Tests suggest that hedge ratios do not follow a random walk and unit root tests show the hedge ratios to be stationary. The results strongly suggest that a dynamic hedging strategy is appropriate. Finally, while hedging strategies based on historical information are less effective than the perfect foresight hedging strategies, nonetheless they are highly effective at reducing risk and more effective than beta hedges. Thus the FTSE-100 futures contract allows investors to greatly reduce the risk which they face without having to liquidate their spot position.

6.2 Relevance of Research Results.

The results of the research undertaken in this thesis should be of interest to investors. The evidence presented here clearly demonstrates that the FTSE-100 stock index futures contract provides a highly effective means of reducing the risk associated with holding portfolios of underlying securities. It has also been shown that dynamic hedging strategies may be appropriate for investors. In addition, the risk return relationship discussed in chapter 2 demonstrates that investing in the FTSE-100 futures contract provides an alternative to investing in the underlying portfolio. The level of systematic risk is similar to that of the underlying portfolio. This is important given that futures have been shown to provide an alternative means by which to participate in market index movements cheaply and to change market position rapidly. The findings regarding efficiency in chapter 4 imply that portfolio managers and investors in general wishing to formulate future investment strategies have an important source of information in current futures prices as to what future spot prices will be. The finding of inefficiency for 3 and 6 months prior to maturity has implications for the timing, initiating and rolling over of hedges. The evidence of chapter 3 should provide reassurance to investors in the underlying spot market that the onset of futures trading has not had a destabilising impact. While spot price volatility has increased, the evidence suggests that this is due to an increase in the flow of information to this market.

The research carried out here should also be of interest to policymakers and regulators alike. The results suggest that the market for the FTSE-100 stock index futures contract is efficient and provides an effective means through which investors in the stock market can adjust their exposure to risk to reflect their own personal preferences. Thus this market provides policymakers with a benchmark for designing and developing new futures instruments. It should also be of comfort to regulators that the public disquiet over the role of futures markets is misguided. The evidence presented here suggests that the call for further regulation of futures markets is unwarranted.

6.3 Implications for further research.

A natural extension of this thesis would involve undertaking similar investigations for other futures markets using the methodologies adopted here. This would enhance our understanding of the role and functioning of futures markets in general and provide investors and policy makers with important information.

It would be interesting to further develop the work carried out in this thesis. Firstly, the work on the risk return relationship could be extended to incorporate time varing risk premia. Secondly, information transference and the associated impact on spot market volatility could be examined using higher frequency data. In addition, recent developments in the GARCH methodology, including the EGARCH, could be used to investigate the transmission of information between markets. The issue of market efficiency could be examined further by expanding the information set to include the impact of information from other markets, such as the money and foreign exchange markets. Finally, the effectiveness of the FTSE-100 futures contract in hedging the risk associated with diversified portfolios which do not necessarily mirror the index could be analysed.

It should also be recognised that while this thesis has examined what the author perceives to be the most important issues in relation to futures markets, there are related research questions of importance which have not been addressed here. For example, this thesis has not examined the existence or otherwise of arbitrage opportunities or the pricing relationship between the current spot and the current futures markets.

BIBLIOGRAPHY

Aggarwal, R. (1988) 'Stock Index Futures and Cash Market Volatility' *Review of Futures Markets*, vol. 7, 290-299

Akgiray, V. (1989) 'Conditional Heteroscedasticity in Time Series of Stock Returns: Evidence and Forecasts', *Journal of Business*, vol. 62, 55-80

Allen, D.E. (1983) *Finance: A Theoretical Introduction*, Martin Robertson & Co Ltd., Oxford

Antoniou, A. (1985) *The Economics of Futures Markets*, Mimeograph, School of Economics, Newcastle upon Tyne Polytechnic

Antoniou, A. and Foster, A.J. (1992a) 'Short-Term and Long-Term Efficiency in Commodity Spot and Futures Markets', *CERF Discussion Paper*, Brunel University

Antoniou, A. and Foster, A.J. (1992b) 'The Effect of Futures Trading on Spot Price Volatility: Evidence for Brent Crude Oil using GARCH', *Journal of Business, Finance and Accounting*, vol. 19, 473-484

Arditti, F.D. and John, K. (1980) 'Spanning the State Space with Options', *Journal of Financial and Quantitative Analysis*, vol. 15, 1-9

Arrow, K.J. (1964) 'The Role of Securities in the Optimal Allocation of Risk-bearing' *Review of Economic Studies*, vol. 31, 91-96

Baldauf, B. and Santoni, G.J. (1991) 'Stock Price Volatility: Some Evidence from an ARCH Model' *Journal of Futures Markets*, vol. 11, 191-200

Ball, R. and Kothari, S.P. (1989) 'Nonstationary Expected Returns: Implications for Tests of Market Efficiency and Serial correlation in Returns', *Journal of Financial Economics*, vol. 25, 51-74

Banz, R.W. and Miller, M.H. (1978) 'Prices for State-Contingent Claims: Some Estimates and Applications', *Journal of Business*, vol. 51, 653-672

Barnhart, S.W. and Szakmary A.C. (1991) 'Testing the Unbiased Rate Hypothesis: Evidence on Unit Roots, Cointegration, and Stochastic Coefficients' *Journal of Financial and Quantitative Analysis*, vol. 26, 245-267

Baxter, J., Conine, T. and Tamarkin, M. (1985) 'On the Commodity Market Risk Premium: Additional Evidence', *Journal of Futures Markets*, vol. 5, 121-125

Becketti, S. and Roberts, D.J. (1990) 'Will Increased Regulation of Stock Index Futures Reduce Stock Market Volatility?' *Federal Reserve Bank of Kansas City Economic Review*, November/December, 33-46

Bhattacharya, A.K., Ramjee, A. and Ramjee, B. (1986) 'The Causal Relationship Between Futures Price Volatility and the Cash Price Volatility of GNMA Securities' *Journal of Futures Markets*, vol. 6, 29-39

Bilson, J. (1981) 'The Speculative Efficiency Hypothesis', *Journal of Business*, vol. 54, 435-452

Black, F. (1972) 'Capital Market Equilibrium with Restricted Borrowing', *Journal of Business*, vol. 45, 444-455

Black, F. (1976) 'The Pricing of Commodity Contracts', *Journal of Financial Economics*, vol. 3, 167-179

Black, F., Jensen, M.C. and Scholes, M. (1972) 'The Capital Asset Pricing Model: Some Empirical Tests', in Jensen, ed., *Studies in the Theory of Capital Markets*, Praeger, New York, 79-124

Blank, S.C., Carter, C.A. and Schmiesing, B.H. (1991) *Futures and Options Markets*, Prentice-Hall, London

Board, J. and Sutcliffe, C. (1991) 'Information, Volatility, Volume and Maturity: An Investigation of Stock Index Futures' *University of Southampton Discussion Paper*, No. 91-5

Bollerslev, T. (1986) 'Generalised Autoregressive Conditional Heteroskedasticity' *Journal of Econometrics*, vol. 33, 307-327

Bollerslev, T. (1987) 'A Conditional Heteroskedastic Time Series Model For Speculative Prices and Rates of Return' *The Review of Economics and Statistics*, August, 542-547

Bollerslev, T., Chou, R.Y. and Kroner, K.F. (1992) 'ARCH Modeling in Finance: A Review of the Theory and Empirical Evidence', *Journal of Econometrics*, vol. 52, 5-59

Brealey, R.A. and Myers, S.C. (1991) *Principles of Corporate Finance*, 4th ed., McGraw-Hill, London

Breeden, D. (1980) 'Consumption Risk in Futures Markets', *Journal of Finance*, vol. 35, 503-520

Breeden, D.T. and Litzenberger, R.H. (1978) 'Prices of State-contingent Claims Implicit in Options Prices', *Journal of Business*, vol. 51, 621-651

Brennan, M.J. (1979) 'The Pricing of Contingent Claims in Discrete Time Models', *Journal of Finance*, vol. 34, 53-68

Brorsen, B.W. (1991) 'Futures Trading, Transactions Costs, and Stock Market Volatility' *Journal of Futures Markets*, vol. 11, 153-163

Butler, K.C. and Malaikah, S.J. (1992) 'Efficiency and Inefficiency in Thinly Traded Stock Markets: Kuwait and Saudi Arabia', *Journal of Banking and Finance*, vol. 16, 197-210

Campbell, T.S. (1988) *Money and Capital Markets*, Scott, Foresman and Company, Glenview, Illinois

Canarella, G. and Pollard, S.K. (1986) 'The Efficiency of the London Metal Exchange', *Journal of Banking and Finance*, vol. 10, 575-593

Carlton, D.W. (1984) 'Futures Markets: Their Purpose, Their History, Their Growth, Their Successes and Failures', *Journal of Futures Markets*, vol. 4, 237-271

Carroll, B.L. (1989) *Financial Futures Trading*, Butterworth & Co (Publishers) Ltd., London

Carter, C.A., Rausser, G.C. and Schmitz, A. (1983) 'Efficient Asset Portfolios and the Theory of Normal Backwardation, *Journal of Political Economy*, vol. 91, 319-331

Castelino, M.G. (1992) 'Hedge Effectiveness: Basis Risk and Minimum-Variance Hedging,' *Journal of Futures Markets*, vol. 12, 187-201

Chan, K.C. (1988) 'On the Contrarian Investment Strategy', *Journal of Business*, vol. 61, 147-163

Chang, E.C., Chen, C. and Chen, S. (1990) 'Risk and Return in Copper, Platinum, and Silver Futures', *Journal of Futures Markets*, vol. 10, 29-39

Charemza, W.W. and Deadman, D.F. (1992) *New Directions in Econometric Practice*, Edward Elgar, Aldershot

Chiang, A.C. (1974) *Fundamental Methods of Mathematical Economics*, 2nd edition, McGraw-Hill, Kogakusha Ltd, Tokyo

Chowdhury, A.R. (1991) 'Futures Market Efficiency: Evidence from Cointegration Tests', *Journal of Futures Markets*, vol. 11, 577-589

Cicchetti, P., Dale, C., and Vignola, A. (1981) 'Usefulness of Treasury Bill Futures as Hedging Instruments,' *Journal of Futures Markets*, vol. 1, 379-387

Cootner, P. (1960) 'Returns to Speculators: Telser vs. Keynes, *Journal of Political Economy*, vol. 68, 396-414

Copeland, T.E. and Weston, J.P. (1988) *Financial Theory and Corporate Policy*, 3rd edition, Addison-Wesley Publishing Company, Reading, Massachusetts

Corgel, J. B. and Gay, G.D. (1984) 'The Impact of GNMA Futures Trading On Cash Market Volatility' *AREUEA Journal*, vol. 12, 176-190

Cornell, B. (1985) 'The Weekly Pattern in Stock Returns: Cash versus Futures: A Note', *Journal of Finance*, vol. 40, 583-588

Cox, C.C. (1976) 'Futures Trading and Market Information' *Journal of Political Economy*, vol. 84, 1215-1237

Cox, J.C. and Ross, S.A. (1976) 'The Valuation of Options for Alternative Stochastic Processes', *Journal of Financial Economics*, vol. 3, 145-166

Cox, J.C. and Rubinstein, M. (1985) *Options Markets*, Prentice-Hall Inc, Englewood Cliffs, New Jersey

Cuthbertson, K., Hall, S. and Taylor, M. (1992) *Applied Econometric Techniques,* Philip Allen, Oxford

De Bondt, W.F.M. and Thaler, R. (1985) 'Does the Stock Market Overreact', *Journal of Finance*, vol. 40, 793-808

De Bondt, W.F.M. and Thaler, R. (1987) 'Further Evidence On Investor Overreaction and Stock Market Seasonality', *Journal of Finance*, vol. 42, 557-581

Debreu, G. (1959) *Theory of Value*, John Wiley, New York

Dixon, R. and Holmes, P. (1992) *Financial Markets: The Guide for Business*, Chapman and Hall, London

Dubofsky, D.A. (1992) *Options and Financial Futures: Valuation and Uses*, McGraw-Hill, London

Duffie, D. (1989) *Futures Markets*, Prentice-Hall, London

Dusak, K. (1973) 'Futures Trading and Investor Returns: An Investigation of Commodity Market Risk Premiums', *Journal of Political Economy*, vol. 81, 1387-1406

Dyl, E. and Maberly, E. (1986a) 'The Daily Distribution of Changes in the Price of Stock Index Futures', *Journal of Futures Markets*, vol. 6, 513-521

Dyl, E. and Maberly, E. (1986b) 'The Weekly Pattern in Stock Index Futures: A Further Note', *Journal of Finance*, vol. 41, 1149-1152

Ederington, L.H. (1979) 'The Hedging Performance of the New Futures Markets,' *Journal of Finance*, vol. 34, 157-170

Edwards, F.R. (1988a) 'Does Futures Trading Increase Stock Market Volatility?' *Financial Analysts Journal*, vol. 44, 63-69

Edwards, F.R. (1988b) 'Futures Trading and Cash Market Volatility: Stock Index and Interest Rate Futures' *Journal of Futures Markets*, vol. 8, 421-439

Edwards, F.R. and Ma, C.W. (1992) *Futures and Options*, McGraw-Hill, New York.

Elam, E. and Dixon, D. B. (1988) 'Examining the Validity of a Test of Futures Market Efficiency', *Journal of Futures Markets*, vol. 8, 365-372

Elam, E.W. and Vaught, D. (1988) 'Risk and Return in Cattle and Hog Futures', *Journal of Futures Markets*, vol. 8, 79-87

Elton, E.J. and Gruber, M.J. (1991) *Modern Portfolio Theory and Investment Analysis*, 4th edition, John Wiley and Sons Inc., New York

Engle, R.F. (1982) 'Autoregressive Conditional Heteroscedasticity With Estimates of the Variance of United Kingdom Inflation' *Econometrica*, vol. 50, 987-1008

Engle, R.F. and Bollerslev, T. (1986) 'Modelling the Persistence of Conditional Variances' *Econometric* Reviews, vol. 5, 1-50

Engle, R.F. and Granger, C.W.J. (1987) 'Co-integration and Error Correction: Representation, Estimation and Testing', *Econometrica*, vol. 55, 251-276

Engle, R.F., Lilien, D.M. and Robins, R.P. (1987) 'Estimating Time Varying Risk Premia in the Term Structure: The ARCH-M Model', *Econometrica*, vol. 55, 391-407

Engle, R.F. and Rothschild, M. (1992) 'Editors' Introduction: Statistical Models for Financial Volatility' *Journal of Econometrics* (special issue on ARCH models in finance), vol. 52, 1-4

Eun, C. and Resnick, B. (1984) 'Estimating the Correlation Structure of International Share Prices', *Journal of Finance*, vol. 39, 1311-1324

Evans, D.M. (1849) *The Commercial Crisis 1847-1848*, second edition, David & Charles (Publishers) Ltd.

Fabozzi, F.J., (ed.) (1987) *Advances in Futures and Options Research*, JAI Press, London

Fabozzi, F.J. and Kipnis, G.M. (editors) (1984) *Stock Index Futures*, Dow Jones, Irwin, Illinois, USA

Fama, E.F. (1965) 'The Behavior of Stock Market Prices' *Journal of Business*, vol. 38, 34-105

Fama, E.F. (1970) 'Efficient Capital Markets: A Review of Theory and Empirical Work', *Journal of Finance*, vol. 25, 383-417

Fama, E.F. (1991) 'Efficient Capital Markets: II', *Journal of Finance*, vol. 46, 1575-1617

Fama, E.F. and Babiak, H. (1968) 'Dividend Policy: An Empirical Analysis', *Journal of the American Statistical Association*, vol. 63, 1132-1161

Fama, E.F. and MacBeth, J. (1973) 'Risk, Return, and Equilibrium: Empirical Tests', *Journal of Political Economy*, vol. 81, 607-636

Figlewski, S. (1981) 'Futures Trading and Volatility in the GNMA Market' *Journal of Finance*, vol. 36, 445-456

Figlewski, S. (1984) 'Hedging Performance and Basis Risk in Stock Index Futures,' *Journal of Finance*, vol. 39, 657-669

Figlewski, S. (1985) 'Hedging with Stock Index Futures: Theory and Application in a New Market,' *Journal of Futures Markets*, vol. 5, 183-199

Frenkel, J.A. (1977) 'The Forward Exchange Rate, Expectations and the Demand for Money: The German Hyperinflation', *American Economic Review*, vol. 67, 653-670

Frenkel, J.A. (1979) 'Further Evidence on Expectations and the Demand for Money During the German Hyperinflation', *Journal of Monetary Economics*, vol. 5, 81-96

Friedman, M. (1953) *Essays in Positive Economics*, University of Chicago Press

Friedman, M. and Savage, L.J. (1948) 'The Utility Analysis of Choices Involving Risk', *Journal of Political Economy*, vol. 56, 279-304

Froewiss, K.C. (1978) 'GNMA Futures: Stabilizing or Destabilizing?' *Federal Reserve Bank of San Francisco Economic Review*, Spring, 20-29

Geisst, C.R. (1982) *A Guide to the Financial Markets*, Macmillan

Geweke, J.F. and Feige, E.L. (1979) 'Some Joint Tests of the Efficiency of Markets for Foreign Exchange', *Review of Economics and Statistics*, vol. 61, 334-341

Gilles, C. and LeRoy, S.F. (1991) 'Econometric Aspects of the Variance-Bounds Tests: A Survey', *Review of Financial Studies*, vol. 4, 753-791

Goss, B.A. (1972) *The Theory of Futures Trading*, Routledge and Kegan Paul, London

Goss, B.A. (1981) 'The Forward Pricing Function of the London Metal Exchange' *Applied Economics*, vol.13 , 133-150

Goss, B.A. (1986a) 'The Forward Pricing Function of the London Metal Exchange' in Goss, ed., *Futures Markets: Their Establishment and Performance*, Croom Helm, London, 157-173

Goss, B.A. (ed.) (1986b) *Futures Markets: Their Establishment and Performance*, Croom Helm, London

Goss, B.A. and Yamey, B.S. (eds) (1978a) *The Economics of Futures Trading*, 2nd ed., The Macmillan Press Ltd, London

Goss, B.A. and Yamey, B.S. (1978b) 'Introduction: The Economics of Futures Trading', in Goss and Yamey, eds., *The Economics of Futures Trading*, 2nd. ed., The MacMillan Press Ltd, London, 1-59

Graham, D. and Jennings, R. (1987) 'Systematic Risk, Dividend Yield and the Hedging Performance of Stock Index Futures,' *Journal of Futures Markets*, vol. 7, 1-13

Granger, C.W.J. (1986) 'Developments in the Study of Cointegrated Economic Variables' *Oxford Bulletin of Economics and Statistics*, vol. 48, 213-228

Granger, C.W.J. and Newbold, P. (1974) 'Spurious Regressions in Econometrics' *Journal of Econometrics*, vol. 2, 111-120

Gravelle, H. and Rees, R. (1981) *Microeconomics*, Longman, London

Gray, R.W. (1961) 'The Search for a Risk Premium', *Journal of Political Economy*, vol. 69, 250-260

Hakkio, C.S. and Rush, M. (1989) 'Market Efficiency and Cointegration: An Application to the Sterling and Deutschmark Exchange Markets' *Journal of International Money and Finance*, vol. 8, 75-88

Hall, S.G. (1991) 'The Effect of Varying Length VAR Models on the Maximum Likelihood Estimates of Cointegrating Vectors', *Scottish Journal of Political Economy*, vol. 38, 317-323

Hansen, L.P. and Hodrick, R.J. (1980) 'Forward Exchange Rates as Optimal Predictors of Future Spot Rates: An Econometric Analysis', *Journal of Political Economy*, vol. 88, 829-853

Harrington, D.R. (1987) *Modern Portfolio Theory, The Capital Asset Pricing Model and Arbitrage Pricing Theory: A User's Guide*, 2nd ed., Prentice-Hall, London

Harris, L. (1989) 'S&P 500 Cash Stock Price Volatilities' *Journal of Finance*, vol. 44, 1155-1175

Harrison, J.M. and Kreps, D.M. (1979) 'Martingales and Arbitrage in Multiperiod Securities Markets', *Journal of Economic Theory*, vol. 20, 381-408

Haugen, R.A. (1993) *Modern Investment Theory*, 3rd ed., Prentice-Hall, London

Hawawini, G, (1983) 'Why Beta Shifts as the Return Interval Changes', *Financial Analysts Journal*, vol. 39, 73-77

Heifner, R.L. (1972) 'Optimal Hedging Levels and Hedging Effectiveness in Cattle Feeding,' *Agriculture Economics Research*, vol. 24, 25-36

Henderson, J.M. and Quandt, R.E. (1980) *Microeconomic Theory: A Mathematical Approach*, 3rd ed., McGraw-Hill, London

Heywood, J. (1984) *Using the Futures, Forwards and Options Markets*, A. & C. Black (Publishers) Ltd., London

Hicks, J.R. (1946) *Value and Capital*, 2nd ed., Oxford University Press, Oxford

Hill, J. and Schneeweis, T. (1981) 'A Note on the Hedging Effectiveness of Foreign Currency Futures,' *Journal of Futures Markets*, vol. 1, 659-664

Hill, J. and Schneeweis, T. (1982) 'The Hedging Effectiveness of Foreign Currency Futures,' *Journal of Financial Research*, vol. 3, 95-104

Hirshleifer, J. (1958) 'On the Theory of Optimal Investment Decision', *Journal of Political Economy*, 56, 329-52

Huang, R. (1984) 'Some Alternative Tests of Forward Exchange Rates as Predictors of Future Spot Rates' *Journal of International Money and Finance*, vol. 3, 153-168

Johansen, S. (1988) 'Statistical Analysis of Cointegration Vectors', *Journal of Economic Dynamics and Control*, vol. 12, 231-254

Johansen, S. and Juselius, K. (1990) 'Maximum Likelihood Estimation and Inference on Cointegration - With Applications to the Demand for Money', *Oxford Bulletin of Economics and Statistics*, vol. 52, 169-210

Johnson, L. (1960) 'The Theory of Hedging and Speculation in Commodity Futures,' *Review of Economic Studies*, vol. 27, 139-151

John, K. (1984) 'Market Resolution and Valuation in Incomplete Markets', *Journal of Financial and Quantitative Analysis*, vol. 19, 29-44

Jorion, P. (1985) 'International Portfolio Diversification with Estimation Risk', *Journal of Business*, vol. 58, 259-278

Junkus, J.C. & Lee, C.F.(1985) 'Use of Three Stock Index Futures in Hedging Decisions' *Journal of Futures Markets*, vol. 5, 201-222

Kaldor, N. (1960) *Essays on Economic Stability and Growth*, Duckworth & Co.

Keane, S.M. (1983) *Stock Market Efficiency. Theory, Evidence and Implications*, Philip Allan Publishers Ltd., Oxford

Keynes, J.M. (1930) *Treatise on Money*, Macmillan, London

Kleidon, A.W. (1986) 'Variance Bounds Tests and Stock Price Valuation Models', *Journal of Political Economy*, vol. 94, 953-1001

Knight, F.H. (1921) *Risk, Uncertainty and Profit*, Houghton Mifflin, Boston and New York

Kolb, R.W. (1988) *Understanding Futures Markets*, second edition, Scott, Foresman and Company, USA

Koppenhaver, G.D. (1983) 'The Forward Pricing Efficiency of the Live Cattle Futures Market', *Journal of Futures Markets*, vol. 3, 307-319

Koutsoyiannis, A. *Theory of Econometrics*, 2nd ed., MacMillan, London

Lai, K. S. and Lai, M. (1991) 'A Cointegration Test for Market Efficiency', *The Journal of Futures Markets*, vol. 11, 567-575

LeRoy, S.F. and Porter, R.D. (1981) 'The Present-Value Relation: Tests Based on Implied Variance Bounds', *Econometrica*, vol. 49, 555-574

Leuthold, R.M., Junkus, J.C. and Cordier, J.E. (1989) *The Theory and Practice of Futures Markets*, Lexington Bokks, Lexington

Levhari, D. and Levy, H. (1977) 'The Capital Asset Pricing Model and the Investment Horizon', *Review of Economics and Statistics*, vol. 59, 92-104

Levy, H. and Sarnat, M. (1970) 'International Diversification of Investment Portfolios', *American Economic Review*, vol. 60, 668-675

Levy, H. and Sarnat, M. (1990) *Capital Investment and Financial Decisions*, 4th ed., Prentice-Hall, London

Lindahl, M. (1989) 'Measuring Hedging Effectiveness with R^2: A Note', *Journal of Futures Markets*, vol. 9, 469-475

Lindahl, M. (1991) 'Risk-Return Hedging Effectiveness Measures for Stock Index Futures,' *Journal of Futures Markets*, vol. 11, 399-409

Lindahl, M. (1992) 'Minimum Variance Hedge Ratios for Stock Index Futures: Duration and Expiration Effects,' *Journal of Futures Markets*, vol. 12, 33-53

Lintner, J. (1956) 'Distribution of Incomes of Corporations among Dividends, Retained Earnings and Taxes', *American Economic Review*, vol. 66, 97-113

Lintner, J. (1965) 'The Valuation of Risk Assets and the Selection of Risky Investments in Stock Portfolio and Capital Budgets', *Review of Economics and Statistics*, vol. 47, 13-37

London Stock Exchange (1991) *FT-SE Share Indices: Five Year History*, The International Stock Exchange of the United Kingdom and the Republic of Ireland, London

MacDonald, R. and Taylor, M.P. (1989) 'Rational Expectations, Risk and Efficiency in the London Metal Exchange: An Empirical Analysis', *Applied Economics*, vol. 21, 143-153

MacMinn, R.D. (1987) 'Forward Markets, Stock Markets and the Theory of the Firm', *Journal of Finance*, vol. XLII, No. 5, 1167-1185

Malliaris, A.G. and Urrutia, J. (1991) 'Tests of Random Walk of Hedge Ratios and Measures of Hedging Effectiveness for Stock Indexes and Foreign Currencies,' *Journal of Futures Markets*, vol. 11, 55-68

Mandelbrot, B. (1963) 'The Variation of Certain Speculative Prices' *Journal of Business*, vol. 36, 394-419

Mankiw, N.G., Romer, D. and Shapiro, M.D. (1985) 'An Unbiased Reexamination of Stock Market Volatility', *Journal of Finance*, vol. 40, 677-687

Mankiw, N.G., Romer, D. and Shapiro, M.D. (1991) 'Stock Market Forecastability and Volatility: A Statistical Appraisal', *Review of Economic Studies*, vol. 58, 455-477

Marcus, A.J. (1984) 'Efficient Asset Portfolios and the Theory of Normal Backwardation: A Comment', *Journal of Political Economy*, vol. 94, 162-164

Markowitz, H. (1952) 'Portfolio Selection', *Journal of Finance*, vol. VII, no. 1, 77-91

Marshall, A. (1923) *Industry and Trade*, 4th ed., MacMillan and Co.Ltd, London

Marshall, J.F. (1989) *Futures and Options Contracting: Theory and Practice*, South-Western Publishing, Cincinnati

Mill, J.S. (1871) *Principles of Political Economy*, vol. II, 7th edition, Longmans, Green, Reader & Dyer

Miller, S.M. and Russek, F.S. (1990) 'Cointegration and Error Correction Models: The Temporal Causality between Government Taxes and Spending', *Southern Economic Journal*, vol. 57, 221-229

Moriarty, E.J. and Tosini, P.A. (1985) 'Futures Trading and the Price Volatility of GNMA Certificates - Further Evidence' *Journal of Futures Markets*, vol. 5, 633-641

Mossin, J. (1966) 'Equilibrium in a Capital Asset Market', *Econometrica*, vol. 34, 768-783

Peters, E. (1986) 'Hedged Equity Portfolios: Components of Risk and Return,' *Advances in Futures and Options Research*, JAI Press, vol. 1 part B, 75-91

Phillips-Patrick, F.J. and Schneeweis, T. (1988) 'The Weekend Effect for Stock Indexes and Stock Index Futures: Dividend and Interest-Rate Effects', *Journal of Futures Markets*, vol. 8, 115-121

Report of the Presidential Task Force on Market Mechanisms, (1988).

Ritchken, P. (1987) *Options: Theory, Strategy and Applications*, Scott, Foresman and Company, Glenview

Roll, R. (1977) 'A Critique of the Asset Pricing Theory's Tests; Part 1: On Past and Potential Testability of the Theory', *Journal of Financial Economics*, vol. 4, 129-176

Ross, S.A. (1976a) 'Options and Efficiency', *Quarterly Journal of Economics*, vol. 90, 75-89

Ross, S.A. (1976b) 'Return, Risk and Arbitrage', in Friend and Bicksler, eds., *Risk and Return in Finance*, Ballinger, Cambridge

Ross, S.A. (1978) 'A Simple approach to the Valuation of Risky Streams', *Journal of Business*, vol. 3, 453-476

Ross, S.A. (1989) 'Information and Volatility: The No-Arbitrage Martingale Approach to Timing and Resolution Irrelevancy' *Journal of Finance*, vol. 44, 1-17

Ross, S.A. and Westerfield, R.W. (1988) *Corporate Finance*, Times Mirror/Mosby College Publishing, St Louis

Rutledge, D.J.S. (1972) 'Hedgers' Demand for Futures Contracts: A Theoretical Framework with Applications to the United States Soybean Complex', *Food Research Institute Studies*, vol. 11, 237-256

Rutterford, J. (1983) *Introduction to Stock Exchange Investment*, MacMillan, London

Schwarz, E.W., Hill, J.M. and Schneeweis, T. (1986) *Financial Futures: Fundamentals, Strategies, and Applications*, Irwin, Homewood, Illinois

Sharpe, W.F. (1964) 'Capital Asset Prices: A Theory of Market Equilibrium Under Conditions of Risk', *Journal of Finance*, vol. 19, 425-442

Sharpe, W.F. (1981) *Investments*, third edition, Prentice-Hall Inc. Englewood Cliffs

Shiller, R.J. (1979) 'The Volatility of Long-Term Interest Rates and Expectations Models of the Term Structure', *Journal of Political Economy*, vol. 87, 1190-1209

Shiller, R.J. (1981a) 'Do Stock Prices Move Too Much to be Justified by Subsequent Changes in Dividends?', *American Economic Review*, vol. 71, 421-436

Shiller, R.J. (1981b) 'The Use of Volatility Measures in Assessing Market Efficiency', *Journal of Finance*, vol. 36, 291-304

Simpson, W.G. and Ireland, T.C. (1982) 'The Effect of Futures Trading on the Price Volatility of GNMA Securities' *Journal of Futures Markets*, vol. 2, 357-366

Solnik, B. (1988) *International Investments*, Addison-Wesley Publishing Co., Reading, Massachusetts

So, J.C. (1987) 'Commodity Futures, Risk Premium and Unstable Systematic Risk', *Journal of Futures Markets*, vol. 7, no. 3, 311-326

Stein, J.L. (1961) 'The Simultaneous Determination of Spot and Futures Prices' *American Economic Review*, vol. 51, 1012-1025

Stock, J.H. (1987) 'Asymptotic Properties of Least Squares Estimators of Cointegrating Vectors', *Econometrica*, vol. 55, 1035-1056

Stoll, H.R. (1979) 'Commodity Futures and Spot Price Determination and Hedging in Capital Market Equilibrium,' *Journal of Financial and Quantitative Analysis*, vol. 14, 873-894

Stoll, H.R. and Whaley, R.E (1988) 'Volatility and futures: Message versus messenger' *Journal of Portfolio Management*, Winter, 20-22

Telser, L. (1958) 'Futures Trading and the Storage of Cotton and Wheat', *Journal of Political Economy*, vol. 66, 233-255

Telser, L. (1960) 'Returns to Speculators: Telser vs. Keynes: Reply', *Journal of Political Economy*, vol. 67, 404-415

Tucker, A.L. (1991) *Financial Futures, Options and Swaps*, West Publishing Co., St. Paul, USA

U.S. Securities and Exchange Commission (1988) *The October 1987 Market Break*, U.S. S.E.C.

Wadhwani, S.B. (1988) 'On the Inefficiency of Financial Markets', *LSE Quarterly*, vol. 2, no. 1, 1-25

Williams, J. (1986) *The Economic Function of Futures Markets*, Cambridge University Press, Cambridge

Wong, K.A., Hui, T.K. and Chan, C.Y. (1992) 'Day-of-the-week Effects: Evidence from Developing Stock Markets', *Applied Financial Economics*, vol. 2, 49-56

Working, H. (1953) 'Futures Trading and Hedging', *American Economic Review*, vol. 63, 314-343

Yadav, P. K. and Pope, P. F. (1990) 'Stock Index Futures Arbitrage: International Evidence', *Journal of Futures Markets,* vol. 10, 573-603