ARBITRAGE IN THE FTSE 100 INDEX FUTURES

by

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ABSTRACT

This thesis presents five empirical papers investigating the issue of arbitrage trading of the FTSE 100 stock index futures. The first paper explores the effects of non-synchronous trading on the spot index and develops a new technique as well as improving current methodologies for removing them. Studies in U.S. have shown that if the problem of non-synchronous trading is severe, the reported spot index is not reliable affecting the correct pricing of futures contracts. The second paper investigates the elasticity of supply of arbitrage in the futures market and the ability of the spot and the futures markets to respond to new information. It shows that arbitrage trading is initiated when spot prices largely drift apart from the futures prices. In addition, the futures prices tend to uncover new information before the spot prices, although this relationship is not stable over time. The analysis incorporates all possible channels of information to the markets, which previous research fails to consider. The third paper analyses the behaviour of the deviation of the actual futures price from its theoretical value. Although this deviation is seen to have decreased its size over the years, it is still significant and persistent. Furthermore, it cannot be explained by the tax-timing option on pricing the futures or the effects of non-synchronous trading. The fourth paper examines the presence, size and frequency of the profitability of the observed arbitrage opportunities by applying different transactions costs bounds to account for different classes of traders. After applying trading simulations arbitrage profitability is found to be frequent and significant, despite the fact that its size has decreased over the years. Finally, the thesis concludes with the fifth empirical paper which investigates the impact of futures trading on the spot and futures market volatility. It finds that arbitrage increases spot and futures price volatility but a volatile market brings the two markets closer. On the whole, the thesis shows that although profitable arbitrage opportunities are not present in the long-run, they are not quickly removed in the short-run, allowing the spot and futures prices to drift apart.

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INTRODUCTION

The presence of futures markets is directly related to the execution of two very important functions; the transfer of risk through hedging and the discovery of new information about future outcomes which facilitates and improves the discovery of prices. Despite the fact that both roles of the futures markets are significant for the enhancement of market conditions, hedging is seen as the most vital aspect of these functions. As a result, futures markets are expected to serve as a tool for reducing risk associated with unfavourable changes in the future. Futures bring risk management opportunities to asset markets.

The successful performance of futures markets and the fulfilment of their functions can only be guaranteed if the prices of the futures markets and their underlying markets remain close and do not have the possibility to drift apart without limit. At any point where futures prices and the price of the underlying asset do diverge by more than a given limit, arbitrage trading becomes essential by acting to enforce the *law of one price*. An arbitrageur exploits the spread between prices in the futures market and its underlying market by buying in one market at one price and simultaneously selling in the other market at a higher price. The purchase in the 'cheap' market will drive prices up for that market, while the sale in the 'expensive' market will drive prices down until the efficient pricing relationship between the markets is restored. Consequently, arbitrage trading is the imperative link between the futures market and its underlying spot market. As a result, the presence of arbitrage is directly related to the closeness of the two markets' prices, which has also important implications for futures markets serving their proper functions, namely hedging and price discovery.

Although a simplified view of arbitrage trading suggests that it is a risk-free process of easily acquired profits without the need of capital investment, arbitrage trading is somewhat more involved. The main reason is because there is a wide range of transactions costs to be faced by an arbitrage trader, which can quickly transform an initially perceived arbitrage opportunity to one where costs could outweigh expected profit. However, if price discrepancies persist for long without triggering profitable arbitrage opportunities, then the spot and futures markets will drift apart over the long term with potentially devastating consequences for the functions of the futures market and for hedging in particular.

Given the vital role of arbitrage in maintaining a price discipline between spot and futures markets which ensures the performance of hedge trades and the discovery of new information, this thesis focuses its attention on arbitrage in the U.K. stock index futures market. This thesis is motivated by a desire to further the investigation of arbitrage activity in U.K. stock index futures. There are a number of reasons for identifying this field of study as being worthy of further analysis. First, the majority of the existing studies concentrate only on the U.S. market, while this thesis attempts to find whether the results reached for the U.S. market can also be seen in a large, sophisticated and well developed financial market such as the U.K. Furthermore, the thesis extends the methodologies used in the existing literature so enhancing the techniques used to assess arbitrage. Second, when investigating the pricing relationship between the index futures market and its underlying stock index, the thesis accounts for transaction costs so as to consider the occurrence of profitable arbitrage opportunities rather than 'numerical' arbitrage opportunities which do not consider such costs. The inclusion of such costs is omitted by a large number of studies. A common approach has been to estimate deviations of observed futures prices from theoretical prices assuming that such mispricing can be fully exploited through arbitrage trading. The presence of transactions costs, however, can transform an apparent arbitrage opportunity to a non-profitable one and so prevent arbitrage trading from taking place. Thus, the thesis distinguishes between profitable and non-profitable arbitrage opportunities in its investigation of the pricing of index futures contracts.

Overall, this thesis brings together a diverse set of considerations which, though largely present in the existing literature, have not been investigated together before. These factors consist of the correct pricing of the stock index futures and its implications for measuring arbitrage opportunities, the transmission of information between the spot and the futures markets and the investigation of volatile prices in spot and futures markets which may result from arbitrage trading. These factors are analysed using a number of techniques new to the field of study. An extensively updated data set is used for all analysis.

The overall findings, in brief, show that the problem of non-synchronous trading in the U.K. in not as severe as in the U.S. Furthermore, profitable arbitrage opportunities still exist, although their frequency and size appear to have decreased over the years as the futures market has matured. In addition, the early unwinding option, which is rarely considered in the existing literature can generate higher profits than the hold-until-expiration rule. Moreover, although the futures market appears to respond mainly first to the arrival of information before the spot market, this relation can vary over time. Finally, arbitrage appears to cause increased volatility in both spot and futures markets, but could be the result of improved response to new information through arbitrage. Similarly, volatile markets appear to decrease arbitrage, thus bringing the spot and futures markets closer.

The thesis is presented as follows. Chapter one provides information about the FTSE 100 stock index market and its futures market to describe the subject of subsequent empirical analysis. The chapter refers to the development of the futures market and its supporting role to the underlying spot market. A review of the existing literature relating to the issues of this thesis is also presented. Overall, the first chapter builds the foundations upon which the empirical investigation is evolved.

Chapter two presents, explains and analyses the possible impact of non-synchronous trading in the spot market on an investigation of pricing relationships between spot and futures markets. Research in the U.S. in particular shows reported spot indexes to be unreliable for such analysis since their calculation does not consider that not all constituent shares will have necessarily traded. This problem is generally referred to as non-synchronous trading. Some studies label this factor as 'stale pricing', although it can be considered to be a form of non-synchronous trading. In order to account for this problem we adopt different methodologies but concentrate mainly on the use of the Kalman filter which has recently been used in dealing with this issue. In addition, the chapter further contributes to the existing literature by presenting a new approach of accounting for non-synchronous trading. This approach involves the derivation of an implied index from options contracts, which corresponds to the reported spot index without the problem of non-synchronous trading.

Chapter three investigates the supply of arbitrage as the link between the spot and the futures markets and the ability of the futures market to discover information and predict future price movements. This is initially achieved with the application of cointegration theory in order to establish the relationship between spot and futures markets. The relationship is then modelled using the error-correction models implied by a cointegrating relationship. Existing literature on the subject of price discovery between spot and futures index markets appears not to have considered all the possible sources through which information is transmitted between markets. The thesis addresses this issue by adopting a recently developed model which identifies and accounts for all channels of information flow between spot and futures markets. To date this model has only been applied to energy futures markets. The model combines the Garbade and Silber model with the Granger causality models to fully analyse the supply of arbitrage and the price discovery relationships between the spot and the futures markets in the U.K. In addition, we show that by relying only on point estimations of arbitrage and price discovery, the existing literature has not accounted for potentially important time-varying relationships between spot and futures markets. The chapter addresses this by employing the Rolling regression method to identify and present the time-varying element of arbitrage.

Chapter four focuses on the estimation and examination of mispricing in the FTSE 100 stock index futures contract. This is achieved by applying the adjusted for non-synchronicity spot index and the implied index series as derived previously using the cost-of-carry model. In addition, the reported spot index is used to analyse the severity of non-synchronous trading in the U.K. When applying the cost-of-carry model previous research has relied on the use of dividend yields or actual dividend inflows. If the use of either case affects the empirical results, then the conclusions of such studies could be misleading. We therefore investigate both approaches to ascertain whether the results can be significantly different due to the choice of dividend data. Finally, the performance of the mispricing series is extensively analysed and in particular, its relation to the time remaining until expiration for a futures contract and its persistence over time are investigated.

Chapter five builds upon the analysis performed in chapter four by focusing not only on apparent arbitrage opportunities suggested by the presence of mispricing, but also on the estimation of potential to undertake profitable arbitrage in such cases. This is achieved with the application of transactions costs bounds to specify whether mispricing can generate profits through arbitrage trading. Investigation involves an analysis of path dependence in mispricing, the frequency and size of violations of the non-arbitrage pricing boundaries and the calculation of arbitrage profitability. In addition the chapter challenges the study by Miller *et al.*, which suggests that the observed price movements are not arbitrage-induced but a statistical illusion due to the presence of non-synchronous trading.

Chapter six completes the empirical investigation undertaken by this thesis. The chapter concentrates on concerns about a possible causal relationship between arbitrage and increased volatility in markets. The chapter first identifies whether increased mispricing can generate increased volatility in both spot and futures markets.

Second, the notion of whether higher market volatility can lead to an increase in mispricing is explored. The method followed incorporates past levels of volatility (spot/futures markets), volatility transmitted from the other market (spot/futures), as well as trading volume of the spot market. Similar work has not previously been applied to the FTSE 100. The majority of existing studies tends only to analyse prices in order to identify a relation between market volatility and arbitrage and ignore the element of trading volume. In addition, when analysing volatility in relation to arbitrage, there is a tendency in the existing literature not to account for the profitability of the arbitrage opportunities. These shortcomings are addressed with the empirical investigation of this chapter. Finally and most important, the study benefits from the use of GARCH models for the derivation of spot and futures volatility instead of the traditional constructed measures used in previous research.

Chapter seven provides a summary of the empirical findings and provides conclusions to the thesis. It considers the implications of these results and points to possible issues worthy of further investigation.

CHAPTER 1

THE STOCK INDEX FUTURES MARKET

1.1 THE FUTURES MARKET

For the last twenty years there has been a remarkable explosion in the number and variety of financial instruments some of which disappeared after a while, while others were developed fairly quickly, increasing substantially their trading volume. The innovations in the financial instruments and institutions were mainly caused due to the Government restrictions and taxes that are imposed on the already existing instruments. For example, the Eurodollar market was invented due to the existence of a restriction known as Regulation Q, while the Eurobond market was invented in order to overcome an imposed tax. In addition, in the 1970s a lot of changes in the financial environment involving increased volatility of interest rates and exchange rates also led to the introduction of financial instruments which would protect against such volatility. A successful financial innovation should be able to reduce transaction costs and expand the market in such a way that further innovations will be stimulated. One of the most significant among the financial innovations is the futures contracts.

It is claimed that trading in futures contracts started its existence in the seventeenth century in countries like

Japan and Holland, however they only started to resemble today's futures trading in the nineteenth century. The first futures trading involved only agricultural products (such as corn and soybeans) as a result of the seasonal nature of their supply. However, nowadays, financial futures contracts (such as bonds, stocks and foreign currencies) are more important and were found to represent over 60% of the annual volume of futures contracts traded by the end of the 1980s.[1] The change in the nature of the futures has led to the birth of new types of market participants such as banks, pension funds, insurance companies , investment companies and university endowment funds. These financial institutions manage their risks and their portfolios of assets through the futures markets.

WHAT IS A FUTURES CONTRACT

A futures contract is an agreement to buy (long position) or sell (short position) a fixed standard quantity of a specific financial instrument or quality of commodity at a price fixed today for delivery on a fixed future date and place. Sometimes alternatives are specified for the delivery arrangements. In such cases the party who has agreed to sell has the right to choose between these alternatives.

The contract's fixed price is called the delivery price and the contract's maturity date is called the delivery date. Because the terms of the settlement between the parties to

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[1] 'Financial markets: An introduction', R. Dixon and P. Holmes, 1992, p 121.

the contract depend on the price of the underlying commodity or financial instrument at the time of settlement, futures contracts are often called *derivative instruments*. With only a few standardised contracts traded, the trading volume in available contracts is higher leading to greater liquidity, smaller price fluctuations and lower transaction costs in the futures market.

The futures contracts must be bought or sold on designated contract markets which is an centralised, organised and regulated exchange such as the CBOT (Chicago Board Of Trade) or LIFFE (London International Financial Futures and Options Exchange). At any point in time the contracts trade for the closest delivery month and a number of subsequent delivery months. The exchange specifies when trading in a particular month's contract will begin. Furthermore, the exchange is also responsible for specifying the last day on which trading can take place for a given contract. This is usually a few days before the last day on which delivery can be made.

THE USERS OF FUTURES MARKETS

A great number of investors use the stock index futures as the most economical substitute for buying and selling a diversified portfolio of stocks. The prices of the futures contracts are closely related to the values of diversified portfolios rather than to the prices of individual stocks. As a result, investors can decide to buy or sell futures rather than buy or sell many different stocks. The reason why trading in futures is more economical than buying or selling many different stocks is because the transactions costs involved in the futures trading (such as brokers' fees and margin requirements) are much lower. Therefore, trading stock index futures contracts becomes less expensive than trading the equivalent basket of stocks.

HEDGERS

The prime aim of the introduction of futures markets is to allow for companies and individuals to protect themselves against future unfavourable changes in prices (for financial futures in particular changes in interest and exchange rates). As a result the futures market serves as the way of reducing or even eliminating risk. This is achieved through hedging. An example of a case that requires hedging could be when someone is obliged to hold a large inventory of a commodity that cannot be sold until a later date. A futures contract would be used to hedge against any future price fluctuations (fix the price) by having the hedger going short the commodity futures (*short hedging*). If the price of the asset goes down the investor does not perform well on the sale of the asset, but makes a gain on the short futures position. If the price of the asset goes up, the investor gains from the sale of the asset, but makes a loss on the futures position.

It is quite possible that the prices will fluctuate in such a way that the investor would have been better off if he/she had not undertaken the hedging strategy. However, the purpose of hedging is no other than to reduce the risk being faced or will be faced by making the outcome more certain. It does not necessarily improve the outcome. There is a number of reasons why hedging using futures contracts may not work perfectly in practice and not eliminate risk.

1. There is a possibility that the asset underlying in the futures contract will not be exactly the same as the asset that the investor wishes to hedge.
2. The hedger might not be able to know for certain the precise date when the asset will be bought or sold.
3. It is also possible that the futures contract expires later than the date that the hedging strategy must be terminated.

SPECULATORS

The risk reduced by hedging is transferred to the counterparty to the trade, who may be another hedger with opposite requirements or a speculator. Speculators expose themselves to risk by buying or selling in futures market in order to profit from the future price fluctuations (buy an asset when the price is low and sell it when it is high) and thus, provide liquidity to the market. They are classified according to their methods. Scalpers seek to trade profitably based on price movements in the next few minutes (they try to profit by a few ticks per trade on a large number of transactions). Day traders close out their futures positions on the same day that the positions were initiated, so as to avoid large price movements when the market is closed. Position traders, keep a futures position for long periods of time (weeks or even months) so that price moves in a favourable way to their position.

ARBITRAGEURS

Arbitrageurs are investors who exploit price discrepancies between markets by entering into transactions in two or more markets. When the opportunity emerges, an arbitrageur tries to take advantage of it by buying in one market at a particular price and simultaneously selling in the other market at a higher price. However, these price discrepancies can only be temporary since they can easily be eliminated by the arbitrage process itself. This is done, because the purchase in one market will drive prices up for that market, while the sale in the other will drive prices down. Consequently, arbitrage is very important for keeping futures and underlying spot prices in line.

In recent years, arbitrage reflects a wide range of activities. For example, tax arbitrage is a strategy by which gains or losses are shifted from one tax jurisdiction to another in order to profit from differences in tax rates. In a similar manner currency arbitrage is a form of trading which involves buying a currency in one market and selling it in another so as to profit from exchange rate inconsistencies in different money centers. An arbitrage strategy could also involve transacting simultaneously in a futures and a forward contract of similar characteristics but different rates and profit from this discrepancy. A final reference to different types of arbitrage involves the spread arbitrage. Arbitrage trading can also take place by taking advantage of price discrepancies between futures contracts with different expirations (calendar spread). The arbitrageur in this case profits from identifying whether the size of the difference between the prices of the two contracts will increase or decrease.

MARGIN REQUIREMENTS

Having two investors trading with each other on a futures contract creates several risks. Such risks involve the possibility that one of the investors may not fulfil his/her obligations and withdraw from the deal either due to lack of financial resources or simply because the investor has changed his/her mind. *Margins* or *good faith deposits*, are the security deposits intended to guarantee that people with positions in futures will in fact be able to fulfil their obligations. The margins depend on many factors including the price volatility of the contract. Some brokers allow an investor to earn interest on the balance in his/her margin account. Therefore, the balance in the account does not represent an opportunity cost because it earns a competitive interest rate which could be earned elsewhere. Margins are lower for hedgers than for speculators since the hedgers' position in the underlying commodity, guarantees the resources to fulfil the promise in the futures contract.

MARKED TO MARKET PROCESS

No payment is made when the futures contract is written so that the futures contract has zero market value at its initiation. But as the contract matures, the investor will be expected to provide or receive daily instalment payments regarding the product that is traded. The total of the daily instalments and the payment taking place at the maturity of the contract will equal the futures price arranged when the contract was initiated. The instalments that are paid every day throughout the life of a futures contract are dictated by the daily change in the futures price. When there is a rise in the futures price it is the investor who is short in the futures contract who will pay the investor who is long an amount equal to the rise. The opposite takes place in a price fall. This process is called marked-to-market on futures exchanges.

1.2 The Stock Index And Index Futures Contracts

A stock index reflects the changes in the value of a hypothetical portfolio of stocks. The weight of the stock in the portfolio can equal the proportion of the portfolio invested in the stock. The stocks in the portfolio can have equal weights or weights that change according to an individual stock's market capitalisation. For an arithmetic index that uses market value weights for its constituent stocks (as is the case for the FTSE 100), a percentage increase in the value of a stock index over a period of time is equal to the percentage increase in the total value of the stocks of the portfolio at that time. A stock index is not usually adjusted for cash dividends. That can be further explained by saying that any cash dividends received on the portfolio are ignored when percentage changes in most indices are being calculated.

The LSE (London Stock Exchange) is, in terms of market capitalisation, the third largest stock exchange in the world and the largest in Europe. It lists the shares of over 2,000 companies with a capitalisation in excess of £650 billion and a daily turnover exceeding £2 billion[1].

The stock index futures contracts are cash settled than physically delivered. Cash settlement is the process at expiry of a contract, whereby a cash difference reflecting a price change passes hands, rather than any physical delivery of the underlying instrument. In fact, prior to

[1]This information was kindly provided by the LSE.

expiry, most open positions in any contract will have been closed out by the creation of an offsetting position or rolled forward to a further dated delivery month. Closing out a position involves going into the market and enter an opposite trade to the original one.

Since the majority of the studies related to this thesis are American and analyse either the S&P 500 or the MMI futures contracts, it is apparent the need of describing these contracts in addition to the U.K. FTSE 100 futures. Furthermore, this will allow us to expose their similarities and differences which should then be considered when comparing the results of those studies with ours.

♦ April 1982 , the CME (Chicago Mercantile Exchange) developed a futures contract based on the S&P (Standard & Poor's) 500 Composite Index. It is based on a portfolio of 500 different stocks: 400 industrials, 40 utilities, 40 financial institutions and 20 transportation companies. The weights of the stocks in the portfolio at any given time reflect the stock's total market capitalisation. The latter can be estimated after multiplying the stock price by the number of shares outstanding. The S&P 500 index accounts for 80% of the market capitalisation of all the stocks listed on the NYSE (New York Stock Exchange).

♦ July 1984 , the CBOT developed a futures contract based on the MMI (Major Market Index). This index is based on a portfolio of 20 big heavily traded stocks listed on the NYSE. The stocks are weighted according to their prices. However, adjustments are made to reflect the effects of stock dividends. The MMI is very closely correlated to the widely known Dow Jones Index, which is also based on relatively few stocks.

♦ The FTSE (Financial Times Stock Exchange) 100 Index Futures was first traded in the U.K. in May 1984. It represents an exposure to the equity market of £25 times the current level of the index (e.g. with a FTSE 100 Index of 3000.0, the futures contract gives £75,000 of exposure). The underlying index, FTSE 100, is constructed from 100 of the largest U.K. companies and is a capitalisation weighted index. This means that a change of 5% in the highest capitalised stock would have a greater effect on the index than a 5% move in a lower capitalised constituent.

1.3 THE LITERATURE REVIEW

This section focuses only on the review of the existing literature, which is related to the issues whose empirical investigation is presented and analysed in the chapters to follow. Since there is a large number of studies about the futures market and specifically, the stock index futures market, we are providing a selection of the literature consisting of the important studies relevant to this thesis and avoid diverting from its main issues.

1.3.1 ELASTICITY OF SUPPLY OF ARBITRAGE

As mentioned before, one of the main roles of the futures market is to transfer price risk, which is achieved through the act of hedging. In order for the futures market to fulfil its role, both the spot and the futures prices have to remain closely related. This is where arbitrage trading becomes essential, because it preserves the link between the two markets and restores it whenever spot and futures prices drift apart. The arbitrageur exploits the spread between prices in the spot and futures markets by buying in one market at one price and simultaneously selling in the other market at a higher price. However, this price spread is only temporary because it can be eliminated by the arbitrage process itself. The purchase in one market will drive prices up for that market, while the sale in the other market will drive prices down. Therefore, the arbitrage trading is an important link between the spot and the futures markets because it manages to keep the spot and futures prices close.

The closeness of the relationship between the two markets, which also reflects the presence of arbitrage in the market was investigated by a number of articles based on the estimation of the elasticity of supply of arbitrage. Garbade and Silber (1983) were the first to approach the issue of arbitrage from this angle and their research is presented in more detail in chapter three. Garbade and Silber examined the characteristics of daily price movements in U.S. spot markets and futures markets for storable commodities, such as wheat, corn, oats, orange juice, copper, gold and silver.

They estimate a measure reflecting the elasticity of supply of arbitrage, which is based on a model of arbitrage between spot and futures markets and provides a ratio of the level of supply of arbitrage. The higher the value of the measure, the less willing arbitrageurs will be to enter the market when they detect price discrepancies between spot and futures prices. As a consequence the less closely those prices will be related, and the less quickly the pricing relations will be restored. More specifically if the calculated ratio acquires a value close to zero, then little of the mispricing[1] in period t-1 will persist to

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[1]The term mispricing refers to the deviation of the theoretical futures price from the observed futures price. The mispricing series gives the maximum level of transaction costs that would not allow the occurrence of profitable arbitrage

period t. On the other hand, a value close to one indicates that much of the mispricing in period t-1 will still be present in period t. Such a finding would suggest the persistence of the presence of arbitrage opportunities which may not be profitable enough to attract the interest of arbitrageurs.

After analysing U.S. commodity futures, Garbade and Silber found high elasticity of supply of arbitrage for wheat, corn, oats, orange juice and copper and low for gold and silver. These results suggest exposure risk to hedgers in grain futures unlike the precious metals. This is because high elasticity means persistence in arbitrage opportunities allowing the prices of the spot and the futures to drift away for long. Garbade and Silber explain this difference across the commodities with reasons such as that the transaction and storage costs in precious metals are relatively cheap compared to those in grains.

Schwarz and Laatsch (1991) analysed the relationship between the spot and the futures market concerning the closeness of the two markets through the supply of arbitrage. Unlike Garbade and Silber who investigated commodities, Schwarz and Laatsch applied the Garbade and Silber model on the MMI using intraday, daily and weekly data, for the period September 2, 1985 to March 31, 1988. They report results suggesting relatively small supply of arbitrage, which implies large persistence of mispricing

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opportunities. The issue of mispricing is the subject of chapter four.

even on a daily basis. They also found that the spot and futures market integration is such that the mispricing is not always eliminated within an one-day time interval. The results reported reflect early periods of futures trading as well as later periods. These results show on a basic level that the relationship between the spot and the futures markets is not stable over time highlighting the time-variance element.

Oellermann *et al.* (1989) also investigated the relationship between spot and futures markets by applying the Garbade and Silber model. The data used represented feeder cattle in the U.S. and involved daily prices for the period 1979 to 1986. The data is divided into two 4-year sub-periods so as to take into consideration the structural changes that occurred in the market. In line with the findings of Garbade and Silber they find most of the differential between futures and spot prices on day t-1 to persist to day t. Such findings imply that large differences in price should take place before arbitrage is initiated so as to bring the prices of the two markets close. They also suggest that high costs of delivery may result in the price differentials between the two markets. Additionally, by using two sub-periods the study by Oellermann *et al.* points at the fact that the price relationship between the two markets does not remain stable. For this specific study the lack of stability is attributed to structural changes in the market.

Finally, Schroeder and Goodwin (1991) also calculated the daily speed of convergence between spot and futures prices for the U.S. Their results are based on the annual analysis of the live hog market covering the period between 1975 and 1989. In line with Garbade and Silber they also find that from day to day the spot and futures prices do not converge rapidly. In addition to this, they too find the estimated measure of the supply of arbitrage to vary from year to year, although on average it stayed low.

The studies reviewed in this section concentrate on the workings of the same study, namely by Garbade and Silber. However, the original work by Garbade and Silber is actually incomplete in two ways. At first, it does not account for all possible sources of information. More specifically, the model utilised considers the price series of both the spot and the futures markets. These prices move so as to reflect the new information arriving in the markets. The possible sources of information can be seen to be hedgers and speculators, who act upon price changes and arbitrageurs, who act upon differences between spot and futures prices. As a result, both the spot and the futures prices move based on information coming the three sources mentioned. However, the model by Garbade and Silber incorporates only the arbitrageurs and ignores the presence and importance of the hedgers and speculators. This is explained in further detail in the relevant chapter of this thesis. Nevertheless, it highlights the fact that results based on the incomplete model by Garbade and Silber may be inaccurate and misleading.

Second, although most of the studies manage to show the lack of stability in the relationship between the spot and the futures markets, their investigations are on a relatively elementary level. This is because they attempt to show the instability by dividing the data into sub-periods and still ending up comparing point estimates across those samples. Unlike these studies, this thesis encounters the issue of time-variance more effectively by modelling the supply of arbitrage within a time-varying framework.

Finally, all these studies which base their analysis on the use of the Garbade and Silber model do not incorporate the issue of the profitability of arbitrage opportunities. In other words, by finding, for example, that there is low supply of arbitrage leading to the persistence of mispricing it does not necessarily mean that the futures market is not efficient. This is because the model does not account for transactions costs, which if considered would find at least part of the observed mispricing to be non-profitable to trade upon. This gap in the studies already mentioned is considered in this thesis by also accounting for transactions costs and investigating the presence of profitable arbitrage opportunities as well as the supply of arbitrage in general.

1.3.2 PRICE DOMINANCE RELATIONSHIP

The aim of this section is to provide a review of studies into the price dominance relationship between the spot and the futures stock index markets. This review intentionally focuses on the most important studies relating to this particular field of research and as such is not meant to be exhaustive.

As mentioned before, apart from transferring risk through hedging, futures markets are expected to fulfil a second equally important role, to provide price discovery. By investigating whether the futures market discovers information more rapidly than the spot market, in other words dominates the spot prices, we actually analyse the degree of close relationship between the two markets. Both the futures prices and the spot prices represent the same asset and thus, are expected to have a similar reaction to the arrival of information. The closeness of the two markets can be identified by analysing whether one market responds to information any faster than the other. If the link between the two markets breaks down then the usefulness of the futures market for price discovery will be compromised.

The lower cost and greater liquidity of trading futures makes the futures market the natural entry-port for new information (such as dividend changes, earning announcements, merger proposal etc.). The news, once discovered or revealed in price changes for futures through the trading of hedgers and speculators, is expected to flow from there to the spot market by the arbitrage process. The majority of the existing research on the issue of price dominance have used either the Granger causality tests or the Garbade and Silber model (1983). Both methodologies are presented in detail in chapter three. The Granger causality tests investigate the leads and lags in responses to information by suggesting that if one market leads the other, then the former dominates the latter. On the other hand, the Garbade and Silber approach not only finds which market exhibits dominance features but also provides the level of dominance effectively showing both the direction and the strength of it. Garbade and Silber produce a measure of the level of dominance which if it takes values between zero and 0.5 the spot market dominates the futures market. On the other hand, if it takes values between 0.5 and one then the futures market dominates the spot market.

Although the existing research suggests that the futures market leads the spot market, some also provide evidence of feedback from the spot to the futures market. This is not surprising since the futures market reacts to general economic information (such as inflation changes), while the spot market reacts to both general economic information and company-specific information. Under such circumstances, the spot prices could be expected to lead the futures prices. A number of studies have adopted the Granger tests for lead/lag relationships between the spot and the futures index markets. Kawaller *et al.* (1987) used minute-by-minute data for the S&P 500 index and index futures for the period between 1984 and 1985. Their results suggest that although there is evidence of a feedback from the spot to the futures market, the latter tends to lead the former by about 20 to 45 minutes. However, these findings by Kawaller *et al*. cannot be treated as perfectly reliable because they do not account for the effects of non-synchronous trading. This is an issue discussed later in section 1.3.5, which shows that the observed spot index lags its true value due to non-synchronicity. Therefore, the futures price dominance over the spot as documented could be partly attributed to the delay of the spot adjusting to information due to the presence of non-synchronous trading.

Kawaller *et al*. (1993), looked at minute-by-minute data for the S&P 500 reflecting the last three months in the year 1986. They believed that the lead-lag relationship between the spot and the futures markets does not remain the same over time. This is the result of a situation where mispricing may or may not be present. In the first case arbitrageurs will become active to benefit for price deviations across the markets but in the second case only hedgers and speculators will be active. After employing the technique of SUR by using four equations the prices of the spot and the futures markets were found to be contemporaneous with a small suggestion that the futures dominates the spot market. After incorporating three different volatility measures it was found that increases in the volatility brings the spot and futures markets closer together.

Harris (1989a) accounts for the effects of non-synchronicity as explained in section 1.3.5. After doing so, he investigates the price dominance relationship between the S&P 500 index and the index futures for the days surrounding the October 1987 market crash. More specifically, he uses five-minute observations for the period October 12, 1987 to October 23, 1987. Harris's results suggest a strong price dominance of the futures market over the spot market.

Kutner and Sweeney (1991) examined minute-by-minute data for the S&P 500 and for the period August 1987 to December 1987. The analysis employs Granger causality tests to find that the futures prices discover new information twenty minutes earlier than the spot prices.

Ghosh (1993a) used an error correction model to analyse fifteen-minute returns of the S&P 500 spot and futures indices. The study looks at the period of the year 1988 and finds the futures prices to lead the spot prices by fifteen minutes.

Stoll and Whaley (1990) also considered non-synchronicity, in their investigation for price dominance for the S&P 500 index and the MMI. Their data involves five-minute observations for the period April 21, 1982 to March 31, 1987. In line with previous studies they too find the futures market to dominate the prices of the spot market with weak evidence of feedback from the spot to the futures. However, the model applied by Stoll and Whaley to remove the effects of non-synchronicity, referred to in section 1.3.5, follows an ARMA(p,q) process and requires for p and q to be infinite. In practice, deciding about the order of p and q is subjective and estimating over or under-parameterised versions can induce misleading conclusions.

Cheung and Ng (1990), used fifteen-minute returns of the S&P 500 for the period June 1983 to June 1987. The analysis employs a moving average process to account for the fact that prices in the index may not reflect current information. The results exhibited a contemporaneous relation between spot and futures returns but they also showed the futures returns leading the spot returns by at least fifteen minutes.

Chan (1992) investigates the price dominance relationship for the MMI and the S&P 500 index for two sub-periods; August 1984 to June 1985 and January 1987 to September 1987. The reason for looking at two different sub-periods is that Chan wants to see whether the results are different with the improvement of trading. He overcomes the problem of non-synchronous trading by using transactions and price data and recalculates the index over a five-minute time interval. Once again Chan finds the futures market to lead the spot market with weak evidence of feedback. An important finding of his study is that the price relationship is not stable over time. He also investigates the relationship between the price dominance and the nature of news, the intensity of trading and the market-wide price movements as opposed to those by individual shares. The results suggest that there is no effect on the price dominance relationship due to the nature of news or trading intensities. However, responses to market-wide movements were found to increase the futures dominance. The main importance of Chan's study as opposed to the studies already reviewed in this section is that it highlights the fact that the price dominance relationship can vary through time.

The study by Abhyankar (1995a) investigates the lead/lag relationship between hourly returns in the FTSE 100 stock index futures and the underlying spot index for the period 1986 to 1990. Following Stoll and Whaley (1990) and Chan (1992), Abhyankar employs a regressions model which incorporates hourly futures and spot returns and the results indicate that the futures market seems to lead the spot market. This finding is explained by Abhyankar as the outcome of the presence of lower transaction and entry costs in the stock index futures market which allows traders with market-wide information to prefer the use of the futures markets. Therefore, information is being absorbed by the futures prices earlier than the spot market as index arbitrageurs step in quickly to bring the two markets closely together.

Wahab and Lashgari (1993) applied an error-correction model on daily data of the FTSE 100 index for the period January 1988 to May 1992. Similar to Abhyankar (1995b), their study suggests the changeable nature in the price dominance relationship between the spot and the futures markets with both the spot and the futures markets becoming dominant at different times. Their analysis also investigated the S&P 500 spot and futures indices for the same period employing daily data and using an error-correction model. The results for the S&P 500 also indicate that the price dominance relationship between the spot and the futures markets is bi-directional.

In their study (1993) Theobald and Yallup investigated the period May 1984 to March 1991 of the FTSE 100 index by looking at daily spot and futures returns series. The results showed that the futures market leads the spot market by one day.

Tang, Mak and Choi (1992) considered daily closing prices for the Hang Seng and find the futures market to lead the spot market.

The study by Lim (1992) investigates the pricing relationship between the Nikkei Stock Average Futures and its underlying asset. The Nikkei stock index consists of 225 stocks and its futures contract trades in yen at a price of 500 times the index. The analysis incorporates intraday trading data for four contracts: June 88, September 88, June 89 and September 89 and looks at five trading days randomly selected. After analysing the correlation relationship between the futures price changes and the spot price changes, Lim does not find the futures prices to lead the spot prices and attributes this observation to the relatively small size and transactions volume at the futures market.

The study by Tse (1995) also analyses the lead/lag relationship between the spot index and futures price of the Nikkei Stock Average. Using daily data and for the period 1988 to 1993 the study applies error correction techniques based on the Engle and Granger (1987) cointegration methodology. The results find that the spot index is predictable according to previous information of the futures index and thus the futures market tends to discover price information before its underlying market.

Iihara, Kato and Tokunaga (1996) analysed five-minute log returns of the Nikkei Average Index and the Nikkei Average Futures traded in Osaka. The period covers March 1989 until February 1991. The futures market seems to lead the spot market by up to 20 minutes while the spot market leads the futures market by up to 5 minutes.

The study by Chan, Chan and Karolyi (1991) tests for the presence of a lead/lag relationship between the index futures and the underlying spot market. The analysis investigates the intraday relationship between price changes and price change volatility in the S&P 500 stock index and stock index futures markets from August 1984 to December 1989. They even control for the asynchronous trading in the stock index by computing the index values in each five-minute interval directly from the most recent transactions prices for each of the component stocks. results suggest that there is a strong persistence in both markets volatility and both the spot and the futures prices serve important price discovery roles. They show that the arrival of new information in either market can predict not only the future prices of their own market but also that of the other market.

Puttonen (1993b) analyses the daily behaviour of the FOX spot and the futures indices between May 1988 and December 1990. After applying an error-correction model, the futures market is found to lead the spot by two days, while the opposite was not experienced. The study is also extended to test the effects of trading volume and short sales restrictions on the results. It is seen that different trading volumes diminish but not eliminate the futures dominance, while the short selling restrictions increase it. The latter result is explained by the fact that short selling in Finland is very difficult to take place.

The study by Ng (1987) tests for Granger causality between returns for spot and futures using a variety of stock indices, currencies and agricultural commodities. The analysis uses intraday data to investigate the price behaviour of the S&P 500 index futures prices and its ability to predict the S&P 500 index level. Her results show that overall the futures prices lead the spot prices in discovering new information.

Märtikainen, Perttunen and Puttonen (1995a) employ Granger causality to analyse the daily closing prices of the FOX spot and futures indices and twenty two stocks of the FOX index. The period covers May 1988 to May 1990. The returns in the spot and futures indices are found to lead the returns of the individual stocks by three days. Due to the fact that trading in the FOX index is thin, prices may not reflect new information causing the dominance relationship found. In order to investigate this possibility, the twenty two stocks are grouped into four equally weighted portfolios based on the number of days that no trading took place for the stock. After reapplying the Granger causality tests the portfolios appeared to give similar results suggesting that thin trading does not affect the price dominance relationship.

The study by Herbst, McCormack and West (1987) analyses the lead/lag behaviour between the spot and the futures markets for two indices, the Value Line Index and the S&P 500 Index. The analysis incorporates both intraday and daily data for four futures contracts, September 82, December 82, March 83 and June 83. On both occasions the results suggest that the index futures prices tend to lead those of their spot indices for both the Value Line and the S&P 500.

Ostermark and Hernesniemi (1995), examined the opening, closing, high and low data of the FOX spot and futures indices for the period May 1988 to August 1991. The findings indicate that the futures market tends to lead the spot market in discovering new information.

Shyy, Vijayraghavan and Scott-Quinn (1996), analysed one-minute price series of the CAC 40 spot and futures indices for August 1994. The futures market was found to lead the spot market by three to five minutes. Suggestions that this finding could be due to stale pricing in the index, the analyses furthers its examination by applying midquotes of the indices. The results were different with the spot market leading the futures by three minutes.

Laatsch and Schwarz (1988), analysed minute-by-minute data of the MMI for the period July 1984 to September 1986. The analysis looks at the near and next near futures contract and employs a model of simultaneous equations. The results support the notion that the futures market lead the spot market by one minute.

Swinnerton, Curcio and Bennett (1988), focused on the MMI and used transactions data for the year 1986. Their study shows that the futures changes reflecting new information can lead the spot changes by five minutes.

Zeckhauser and Niederhoffer (1983a), looked at the relation between the basis and changes in the spot prices for the S&P 500 and the VLI indices. Assuming new information is discovered by the futures market before the spot market then the basis should be expected to change before any changes occur in the spot prices. By looking at the next one and three days the results show that increases or decreases in the futures prices are followed by increases or decreases in the spot prices by one to three days.

The study by Finnerty and Park (1987) considers the *causal* relation between stock index and index futures markets. The analysis uses intraday spot and futures prices of the MMI for the period between August 23, 1984 to August 15, 1986. For every time the spot index price moves the nearest preceding change in the futures price was taken.

The regression of the former against the latter showed that *causality* runs from the futures to the spot markets.

Finally, Koontz *et al.* (1990) investigates the price dominance patterns for the U.S. live cattle markets. The data used is weekly and the sample period between January 1973 and December 1984 is divided into three four-years periods so as to capture the changing nature of the relationship. The main finding of their study suggests that based on the structural change of the live cattle market, the pricing relationship of the spot and the futures markets has also changed over time leading to time-varying dominance relationship. In addition, they observe a decline in dependence of the spot market on the futures market for price discovery, while when the spot market is not active the futures market carries the price discovery function. The study by Koontz *et al.* is vital in that it strongly suggests the changeable nature in the price dominance relationship between the spot and the futures markets.

Our main focus is on studies which recognise the time-varying element in the price dominance relationship between the spot and the futures market. Among those is the study by Chan (1992) and Koontz *et al.* (1990) already reviewed and those which approach the issue of dominance by adopting the Garbade and Silber (1983) model. Some of these studies have already been reviewed in the previous section because they also use the Garbade and Silber model to calculate the elasticity of supply of arbitrage.

The Garbade and Silber (1983) study, already reviewed in section 1.3.2, calculated the price dominance ratio for U.S. commodities and found that the futures markets in wheat, corn and orange juice plays an important role in the price discovery process with approximately 75% of the pricing occurring in the futures markets. On the other hand, the pricing of oats and copper is the same between the spot and the futures markets. Garbade and Silber explain their findings by noting that the corn and wheat futures are large and very liquid contracts, while the oat futures market is subject of lower trading and liquidity. Finally, the gold futures market dominates the spot, while the pricing of silver is more evenly divided between the two markets.

Schwarz and Laatsch (1991) already reviewed in section 1.3.2, calculated the price dominance ratio for the MMI based on the Garbade and Silber model. This study is one among those that try to show the time-varying element in the relationship between the spot and the futures markets by looking at different sub-periods. Overall, their results show that the spot market dominated the futures market during the early years of futures trading with an increase in the futures dominance in later years. This difference across time is not surprising given the fact that at the beginning of the futures market, trading was less because the market was new to investors. The importance of this study is that it points at the fact that dominance can vary over time and even reverse, while it is also related to the size of the futures market. Furthermore, they found that the price dominance relationship is also sensitive to a certain type of information.

Oellermann *et al.* (1989), already reviewed in section 1.3.2 is another study which used the Garbade and Silber model for the calculation of the price dominance ratio. The data price series of U.S feeder cattle was divided into sub-sections to capture the time-varying element. This is confirmed by the results where the futures market appears to strongly dominate the spot market in the first sub-period examined, while this relationship becomes weak in the second sub-period. They even further prove their findings by extending their analysis and incorporating the Granger causality tests, which also produce similar results to those of the Garbade and Silber model. The Oellermann *et al.* study is one more study that points at the lack of stability in the relationship between the spot and the futures markets. As mentioned before, they attribute this lack of stability to changes in the structure of the market.

The study by Schroeder and Goodwin (1991) already reviewed in the previous section apply the Garbade and Silber model on U.S. commodities to identify the price dominance relationship between spot and futures markets. Their results are reported on a year-to-year basis and find the dominance relationship to vary from year to year. Overall, the futures prices are seen to dominate the spot prices. However, some years of the sample show spot dominance over the futures. These findings show not only that the level of the dominance relationship can vary over time but also the direction is not stable over time. Schroeder and Goodwin attribute this variation to significant variations of the prices in the market implying that the type of price movements can affect price dominance relationships.

The majority of the studies reviewed in this section do not recognise the time-varying element in the dominance relationship, while those that do try to capture it by employing sub-sections of the sample. However, as explained in the previous section, this approach is not ideal as it still compares point estimates. This thesis however, successfully carries out this topic with the empirical investigation of price dominance within a time-varying framework. Furthermore, the two different methodologies mentioned modelling price dominance approach the same subject from two different angles. The Granger causality tests focus on trading upon past price changes in the market (hedgers/speculators), while the Garbade and Silber model concentrates on the arbitrage link between the markets (arbitrageurs).

Antoniou and Foster (1994) and Foster (1996), actually combined the two methodologies so as to account for all possible sources of information, both hedger/speculators and arbitrageurs, which affect the price discovery role of the futures market. This study investigates the time-varying ability of the spot and the futures markets to impound information based on the use of the generalised model of price discovery. The latter is a synthesis of the Garbade and Silber and the Granger methodologies. The analysis focuses on crude oil spot and futures markets in the U.K. and U.S. during the 1990-1991 Gulf conflict. Foster finds that although the futures markets for crude oil tend to perform their price discovery function, there are times that the spot market incorporates information first. The thesis, adopts the generalised model of price discovery for the FTSE 100 stock index and index futures as a significant contribution to the existing research for the same index.

1.3.3 Mispricing And Arbitrage Opportunities

Mispricing is a very important issue in the futures market because the systematic existence of mispriced futures contracts could lead to the occurrence of arbitrage opportunities, raising questions about the ability of the futures market to correctly price its contracts. We have already referred to the significance of correctly pricing the futures contracts, which has a direct effect on the role that the futures market plays in the processes of hedging and price discovery. In the case that the futures market does function effectively with respect to pricing, then the assumption that prices are correct cannot be guaranteed and any decisions based on them about hedging are likely to be inaccurate.

There is a wide range of studies in the existing literature examining mispricing in the futures market, with the U.S. market attracting more analysis than any other country[1]. Studies generally find the actual futures price to deviate from its theoretical one based on the cost-of-carry model[2]. However, there is no clear consensus as to whether futures contracts are undervalued or overvalued. In his book, Sutcliffe (1997) reviewed a large number of studies on this

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[1]There is a large number of key studies of which the largest number is for the U.S. market, fewer are for Japan, even less are for the U.K. and the rest are for a number of different countries. (Sutcliffe C. (1993), Chapman and Hall).

[2]The cost-of-carry model is presented in detail in chapter four.

subject and found that the majority detect overpriced futures. Some of the studies focus only on the estimation of mispricing and the analysis of its behaviour, while other studies go even further by applying transactions costs bounds and studying profitable arbitrage opportunities.

Modest and Sundaresan (1983) were among the first to analyse the issue of mispricing in the futures contracts. They focus on the June 1982 (April 21 to June 16, 1982) and the December 1982 (April 21 to September 15, 1982) S&P 500 stock index futures contracts. They show that the difference between the observed futures price and the theoretical one, based on the cost-of-carry formula, will fluctuate within an upper and lower bound. These bounds represent the level of the transactions costs. If the mispricing does not exceed those bounds then there is no profitable arbitrage to be exploited. Their study found that there is small frequency of exploitable arbitrage opportunities for the two contracts investigated, concluding that mispricing only rarely violates the transactions costs bounds.

One of the studies which shows the futures contracts to be on average overvalued is the study by MacKinlay and Ramaswamy (1988). Their study investigates the mispricing relationship for the S&P 500 index futures contract for the period between April 1982 and June 1987. The data used is intraday prices of 15-minute apart for every futures contract. Their study tries to find whether the mispricing that exceeds the transactions costs bounds persists. If it does then the arbitrage trading involved will appear not to be enough in order to remove the profitable mispricing. Therefore, the market would be found to be inefficient with all the consequences about hedging. The transaction costs bounds applied were 0.4%, 0.6% and 0.8%. However, they only report results for the 0.6% bound implying that similar findings were acquired with the other two options. They are first interested in the possible relationship that mispricing could have with the time remaining until the maturity of a contract. In case time-to-maturity affects the level of mispricing then it is not only the transactions costs that should be considered but also other factors leading to changeable non-arbitrage boundaries.

After regressing absolute levels of mispricing against time-to-maturity, MacKinlay and Ramaswamy find a positive relationship between them suggesting that there is higher mispricing and more arbitrage opportunities the further away a futures contract is from its maturity. This result is a first indication of path dependence in the mispricing series. In other words that mispricing tends to follow specific patterns. In their study, MacKinlay and Ramaswamy state that an implication of the hypothesis that mispricing is path dependent is that, if the mispricing has crossed one of the arbitrage bounds, it is less likely to cross the opposite bound. This is claimed to be the result of the fact that arbitrageurs will close out their initial positions when mispricing is outside one bound before it reaches the other bound. They therefore, investigate this matter by examining the upper-bound and lower-bound mispricing violations, subsequent violations and crossings for each contract of their sample period. MacKinlay and Ramaswamy state that even if during a contract's life the mispricing is substantially positive (negative) it is often the case that at some time before expiration mispricing is negative (positive). As a consequence, the arbitrage traders can often have the opportunity to profitably unwind their positions before maturity, which makes the predictions about expiration day based on the identification of mispricing outside the arbitrage bound difficult. Their findings show that mispricing for the S&P 500 futures contract is path dependent which suggests that the arbitrage traders choose to unwind their positions before maturity.

Bhatt and Cakici (1990) also find the futures contract for the S&P 500 index to be on average overvalued for the period April 21, 1982 to June 19, 1987. Their analysis uses daily data and looks at both the nearest and the next nearest to maturity contract on both a year-to-year and contract-to-contract basis. After regressing the absolute value of mispricing, calculated in the same way as MacKinlay and Ramaswamy do, against time-to-maturity and dividend yield they find a positive and significant relationship between them for both the near and the longer maturity contracts. Finally, although mispricing is small, it is even smaller for the later years of the sample than the early years analysed. This is explained as the result of the maturity in the futures market which lead to better informed traders and more efficient futures prices.

Yadav and Pope (1990) also try to replicate the model of MacKinlay and Ramaswamy but for the U.K. so as to discover whether findings in the U.S. apply in the U.K. too where transactions costs are higher. In order to do so they use daily data for the FTSE 100 index and index futures contract for the period July 1, 1984 to June 30, 1988. When deciding about the transactions costs bounds, Yadav and Pope recognise that different traders are liable to different transactions costs and use four bounds: 0.5%, 1.0%, 1.5% and 2.0%. They find significant mispricing, which is auto-correlated of order one mainly before the October 1986 Big Bang[1]. This implies less persistence of mispricing after the market deregulation, which they find to be consistent with the growth and higher performance of the arbitrage activity. They calculate arbitrage profits based on four trading rules: 1) hold position until expiration, 2)unwind the position before expiration, 3)roll the position forward into the next futures contract and 4)choose whichever of the previous three strategies produces higher profits. The analysis also allows for a delay between observing the mispricing exceeding the transactions costs bounds (ex post) and actually trading on it (ex ante). The results show that early unwinding or rolling forward are subject to discounted transactions costs and thus can produce additional profits to those based on hold-to-expiration, even if mispricing falls within the original transactions cost bounds. However, ex ante opportunities were found to generate smaller arbitrage profits relative to ex post opportunities. The reason for

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[1]On October 27, 1986 the U.K. stock market was substantially deregulated.

this is that what the trader observes ex post as a riskless profit opportunity is not necessarily a real ex ante exploitable profit opportunity because there is no guarantee that the prices at the next available transaction will continue to be favourable for the trader. Finally, similarly to MacKinlay and Ramaswamy they regress the absolute level of mispricing against time to maturity and consistent with previous research they detect a positive relationship between them.

The study by Chung (1991) analyses the MMI for the period July 24, 1984 to August 31, 1986. He believes that the analysis should consider the delay that occurs between observing a favourable arbitrage opportunity and actually trading on it, which was ignored by the previous studies. As Chung notes, what appears as an ex post riskless profitable opportunity is not necessarily a real ex ante exploitable profitable opportunity because there is no guarantee that the prices at the next available transaction will still be attractive. Therefore, the size and frequency of the boundaries violations is not important, while the size and frequency of profitable arbitrage opportunities should be the goal of the investigations. In addition, Chung notes that previous studies fail to consider the significance in the effects of non-synchronous trading by relying on the reported spot index. As a result Chung uses minute-by-minute price data and tests only ex ante arbitrage trading schemes allowing for execution lags of 20 seconds, 2 minutes and 5 minutes. He also applies three transactions costs bounds of 0.5%, 0.75% and 1.0%. His conclusions state that although there are profitable arbitrage opportunities, previous research has overestimated the size and frequency of them. Moreover, these profitable opportunities appear to have declined as the futures market has matured, which again is attributed to better informed traders.

A number of studies considered the issue of attributing mispricing to the differential tax treatment of spot and futures and the existence of a tax-timing option in a spot position but not in a futures position. Cornell and French (1983a, 1983b) analyse the mispricing of the S&P 500 index and the NYSE index futures and argue that the actual futures prices diverge from their predicted ones because we ignore the different way the stock and futures returns are taxed. Futures traders must pay taxes on all gains in the year they arise, while stockholders pay taxes only on realised gains or losses. As a result, the stockholders have the advantage of the timing option. In the case where there is a decrease in the value of the stock, the stock can be sold and part of the loss can be transferred to the trader's tax liability. On the other hand, if the value of the stock appreciates, the tax payment can be delayed by not realising gains. In contrast to the stockholder's tax timing option, the futures trader lacks this option. The reason why is that capital gains or losses have to be realised either at the end of the year or at the maturity of the contract depending on which comes first. Cornell and French show that by accounting for the tax-timing option the predicted futures price is less.

On the other hand, Cornell (1985) who investigates the daily behaviour of five S&P 500 futures contracts spanning the period May 5, 1982 to September 1, 1983, finds that the tax-timing option does not have a significant impact on the pricing of futures contracts. He also regresses absolute levels of mispricing against time-to-maturity to find a positive relationship between them suggesting that there is higher mispricing and more arbitrage opportunities the further away a futures contract is from its maturity.

Moreover, Yadav and Pope (1990) argue that the tax timing option is more important in the U.S. because the tax law dictates that the tax liability on open futures contracts should be assessed by realising them at the end of the tax year. In the U.K., though, the tax liability arises daily as the futures position is marked-to-market. Yadav and Pope also find the tax-timing option to be of no importance in the pricing of the futures contracts.

1.3.4 Arbitrage And Market Volatility

There have been several accusations against the futures market claiming that the arbitrage trading initiated by the futures market increases market volatility. This section discusses some of the key studies in this area. The discussion is intended to highlight a number of the most important and relevant studies rather than to provide an exhaustive review.

Aggarwal (1988), found post-futures period to be more volatile than the pre-futures period. However, he also found that volatility has increased in all markets even in markets were there are no futures contracts traded, leading to the assumption that stock index futures trading may not be the primary cause.

Several studies on the impact of stock index futures markets have showed that stock index futures trading actually decreases stock price volatility because of the flow of more efficient information (Danthine (1978)). Edwards (1988a, 1988b) examined the volatility of the stock market before and after the introduction of the index futures trading. The results show that the introduction of futures trading did not increase stock price volatility but in fact reduced the volatility. The only volatility that was observed was a short-run volatility, such as that occurring on futures contract expiration days (*triple witching days*[1]), which is being eliminated in the long run.

Several studies also point out that index arbitrage keeps spot and futures prices close, imposing the law of one price and one market (Grossman (1988b), Hill and Jones (1988)). In addition to this, index arbitrageurs are said to add liquidity to the stock market, which should lower stock price volatility (Grossman (1988b), Fremault (1991)). Holden (1991) argues that index arbitrage does not cause excess volatility. Arbitrage is only the *transmission mechanism* not the *source* of excess volatility created by either noise trading or panic trading. Brorsen (1991) argues that increasing market frictions (by increasing transaction costs, increasing margins, limiting arbitrage with short sale restrictions,[2] or banning trading in futures), short-run price volatility will be reduced but long-run volatility will not be affected.

Becketti and Roberts (1990) distinguish between normal volatility and jump volatility. Normal volatility is described as the ordinary ups and downs in stock prices,

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[1]The day every three months when four contracts reach maturity; stock index futures, stock index options on index futures and options on individual stocks.

[2]Short selling involves the sale of securities that are not owned and the purchase of them at a later date. There are restrictions that do not allow the full use of the proceeds from selling sort shares. Short sale restriction does not apply in the futures market.

while jump volatility is described as the sporadic and unexpected changes in prices. Studies show that the frequency of jumps began increasing before futures began trading through arbitrage and they were found to perform less frequent since the introduction of the stock index futures contracts. Edwards (1987) also concludes that there is no evidence that arbitrage trading can destabilise the stock market. Merrick (1987) states that although there is evidence of arbitrage-related volume on the NYSE, there is little evidence that arbitrage and stock price volatility are related.

Kawaller, Koch and Koch (1990), analysed transactions data of the S&P 500 index for the last quarters of the years 1984 to 1986. After estimating the minute-by-minute variance of the spot and the futures price changes, the findings indicated that the former was less than the latter by five times.

Grunbichler and Callahan (1994), used different lengths of intraday data for the DAX spot index and futures covering the period November 1990 to September 1991. These were five, fifteen and thirty-minute returns which showed that the variance in the futures returns was exceeding the variance in the spot returns. However, this difference was found to be smaller as time period became bigger.

Mak, Tang and Choi (1993), looked at the daily closing prices on the Hang Seng index during the October 1987 crash. Specifically, the data covers seventeen months before the crash and sixteen months after the crash. After measuring the variance in the spot and the futures returns, the futures market appeared to be more volatile both before and after the crash. The excess volatility was seen to be higher after the crash.

Strickland and Xinzhong (1993), analysed hourly data of the FTSE 100 spot and futures indices for the period January 1988 to December 1989. The variance of the futures price changes was found to be larger by 45% than the variance of the spot price changes.

Yadav and Pope (1990), examined the period between 1984 to 1988 by looking at daily returns series for the FTSE 100 spot and futures indices. After estimating the variances of close to close returns and open to open returns, it was found that the futures returns exhibited higher volatility.

Bortz (1984), examined the S&P 500 index by looking at daily data series covering the first six months of the S&P 500 futures life. The results suggested that the futures prices were more volatile than the spot prices.

Miller, Muthuswamy and Whaley (1994), used intraday data for the S&P 500 covering the period April 1982 to March 1991. After estimating the changes in both the spot and the futures prices for fifteen, thirty and sixty-minute intervals for every futures contract of that period, they found the futures prices to be more volatile than the spot prices.

Harris, Sofianos and Shapiro (1994), used intraday data for the S&P 500 for two years, 1989 and 1990. The variance in the futures returns for one and five-minute intervals was significantly larger than the variance in the spot returns.

Cheung and Ng (1990), also used intraday data for the S&P 500 spot and futures indices. The period analysed was June 1983 to June 1987 with each futures contract investigated individually. The fifteen-minute returns examined proved the futures variance to be higher than the spot variance by approximately 53% on average.

Chu and Bubnys (1990), examined daily data for the S&P 500 and the NYSE spot and futures indices for the period 1982 to 1988. After comparing the volatility of the logged spot and futures price changes, the latter were higher than the former for both indices.

Morse (1988), investigated three different indices, the S&P 500, the NYSE and the MMI. The period covered is between 1986 to 1988. All indices were found to exhibit higher variance in the futures returns than that of the spot returns.

Park (1993), investigated the MMI using intraday data for the period 1984 to 1986. After estimating the variance of both spot and futures returns series, unlike previous studies the former were found to be higher than the latter. However, when using a different way of measuring volatility such as the period of time needed so that the price changes to that of a preset interval, the findings were reversed.

This study clearly suggests that analysis of market volatility can be sensitive to the way volatility is computed.

Brenner, Subrahmanyam and Uno (1989b), investigated the daily price changes of the Nikkei Stock Average traded on SIMEX, covering the period September 1986 to June 1988. The results showed that the variance of the futures price changes was larger than the variance of the spot price changes.

The study by Brenner, Subrahmanyam and Uno (1990b) incorporated daily closing series for the Nikkei Stock Average traded on both the SIMEX and the OSE. The period analysed was January 1989 to September 1989. Unlike the results of their previous study (1989b), the results of this study showed the spot volatility to be higher than the futures volatility.

The study by Lim and Muthuswamy (1993) looked at five-minute returns series of the Nikkei Stock Average traded on SIMEX covering twenty five days between 1981 and 1991. The variance of the spot returns series was found to be larger than that of the futures returns series.

The study by Iihara, Kato and Tokunaga (1996), incorporated five-minute return series for the Nikkei Stock Average index traded in Osaka and for the period March 1989 to February 1991. The data series were grouped into three subsections and the results showed that for two out of the three groups the variance of the spot log returns was higher than the variance of the futures log returns.

Martikainen and Puttonen (1994b), used daily data for the FOX index in Finland covering the period May 1988 to March 1990. The variance of the futures returns series was found to be higher than that of the spot returns series by 60%. In a similar study, Martikainen, Perttunen and Puttonen (1995a) also found the futures to be more volatile than the spot but the ratio was estimated to be 80%.

Gould (1988) states that excess volatility is due to the technological aspect of the futures market as well as the high leverage[1] observed. The information is more efficiently provided in the futures market due to the technological improvements while the report of stock market prices, particularly in the case when volume is large, can suffer from significant lags. Therefore actions may take place first in the futures market leading to greater price changes in shorter periods of time. However, Gould concludes that volatility, caused mainly from the futures market through arbitrage trading, due to higher leverage and better information technology, is a phenomenon the market should come to expect and adjust to.

Bessembinder and Seguin (1992) analyse daily prices of the S&P 500 index, NYSE composite trading volume and S&P 500 futures price and volume for the period January 1978 to September 1989. Their approach involves regression of the

[1]Someone can take a larger position with less capital in futures than in stocks.

daily S&P 500 volatility on the NYSE composite volume, the S&P 500 futures volume and the daily prices. The evidence provided suggests that volatility declines with futures trading activity, which is attributed to the attraction of additional traders due to low cost of futures trading. However, they find no supporting evidence that futures trading leads to price destabilization.

Maberly, Allen and Gilbert (1989) test for a difference in volatility between the post-S&P futures period and the pre-S&P futures period using daily data to find that volatility has increased significantly since the introduction of the S&P futures contract. They explain this phenomenon as the result of a significant increase in the rate of information flow.

Choi and Subrahmanyam (1994) use intraday data to investigate the *destabilisation* hypothesis stating that the introduction of the MMI futures induced increased volatility on the underlying stocks. The period analysed is the year 1984. Trading in MMI futures commenced on July 23, 1984. Their findings show no significant change in intraday volatility of the underlying stock market around the introduction of the MMI futures, therefore the hypothesis that the index futures market destabilises the underlying spot market through arbitrage trading is not supported.

Chan, Chan and Karolyi (1991) investigate the intraday relationship between price changes and price change volatility in the S&P 500 stock index and stock index futures markets from August 1984 to December 1989. They extend the studies of lead-lad relations between stock and futures price changes by allowing the volatility of price changes as well as price changes themselves to interact across the spot and futures markets. As a result, they analyse the volatility spillovers across the two markets and find strong dependence in both directions in the volatility of price changes between the spot and futures markets. The arrival of new information in the spot market is transmitted to the volatility of the futures market and information originating in the futures market is transmitted to the volatility of the spot market.

MacKinlay and Ramaswamy (1988) examined the intraday behaviour of the S&P 500 index futures contract and its underlying index for the period between April 1982 and June 1987. The data used is intraday prices of 15-minute apart for every futures contract. They measure the variability of the futures price changes and the spot price changes and find the former to exceed the latter. This result remains the same even after controlling for the effects of non-synchronous trading in the spot market.

Board and Sutcliffe (1995) use hourly data of the FTSE 100 index for the period May 3, 1984 to June 30, 1991 and transactions data for the near contract for FTSE 100 index futures for the same period. The study compares the volatility of the spot and the futures markets by considering the effects of applying different measures of volatility to the analysis and different time intervals used in computing volatility. The findings show that futures volatility tend to be higher than that of the spot market and this relationship is affected by the input and output frequencies used to calculate volatility.

Damodaran (1990) used daily data covering five years before S&P 500 futures were introduced and five years after their introduction. He looked at the returns series of 699 firms quoted on the NYSE but never on the S&P 500 for the time period analysed as well as the returns series of 378 firms quoted on the S&P 500 for the same period. After comparing returns across the indices, the results showed that after the S&P 500 was introduced, the volatility of the returns on the S&P 500 was increased in relation to the other stocks.

Koch and Koch (1993), investigated eight days in 1987 and 1988 for two indices, the S&P 500 and the MMI. The volatility of each index for those days was compared to the volatility of shares that were no part of either index for the same days. The volatility was measured as the logarithm of the ratio of daily highest price over daily lowest price. The results showed that in all cases of shares the volatility estimated was not different.

Kamara, Miller and Siegel (1992), used daily closing returns on the S&P 500 index for the years between 1976 to 1988. They analysed the variance of the daily returns as well as monthly returns for both before and after the introduction of the futures market. The evidence showed that after futures were introduced to the market the variance of the monthly returns did not change while the variance of the daily returns increased. This variability in the results over different time scales was a sufficient proof for them that the introduction of the futures market is not responsible for the change of the volatility in prices.

Baldauf and Santoni (1991), investigated daily closing prices for the S&P 500 index covering the period between 1975 to 1989. As a first approach they estimated the daily percentage changes in the index and compared its value before and after the futures market was introduced. The results showed that prices were more volatile after the futures were set up. The research continues by employing and ARCH model to account for the positive serial correlation in the value of the percentage price changes. The results of this case showed no increase in the volatility of prices after the futures were introduced.

Lee and Ohk (1992a), investigated volatility in the indices of a number of countries, Australia (All Ordinaries), Hong Kong (Hang Seng), Japan (TOPIX), UK(FT Ordinary) and USA(NYSE). They looked at 100, 250 and 500 before the futures were introduced as well as after their introduction. The results of comparing the variance of returns before and after the introduction of the futures market, showed no change for Australia and a decline for Hong Kong. For the remaining cases, depending on the number of days volatility was found higher after the birth of the futures.

Lee and Ohk (1992b), looked at four years before and three years after futures were introduced for four indices, UK (FTSE 100), USA (NYSE), Japan (TOPIX) and Hong Kong (Hang Seng). After comparing daily and monthly-estimated volatility for the spot prices before and after the introduction of the futures, the UK case demonstrated a decline in volatility, while Japan exhibited an increase in the volatility. Their research also incorporates a number of macro-economic factors which could affect spot volatility. These results showed no change in the volatility patterns after the introduction of futures.

Antoniou, Holmes and Priestley (1995), used daily data for three years before and three years after the introduction of futures for a number of indices, FTSE 100 (UK), DAX (Germany), S&P 500 (USA), Nikkei Stock Average (in Osaka, Japan), Ibex 35 (Spain) and SMI (Switzerland). Their research related volatility to asymmetric response to good and bad news. The results showed that spot volatility was not affected by the introduction of the futures market in the UK, USA, Japan and Spain, while it was reduced in Germany and Switzerland. They also found that in all cases and before the introduction of futures, bad news tend to affect spot volatility more than good news. These results remained the same for the years after the introduction of the futures only for Japan, Spain and Switzerland.

The studies mentioned so far appear to fail to address the issue of volatility in direct relation to the change in the arbitrage spread and the trading volume of the spot index. The study by Chan and Chung (1993) on the other hand, extends the investigation of volatility by applying a model which incorporates past levels of volatility (spot/futures markets), volatility transmitted from the other market (spot/futures) as well as trading volume of the spot market. Their study analyses the MMI and its futures contracts on an intraday basis for the period August 1, 1984 to June 28, 1985. Their findings showed that arbitrage affects both market volatility and spot trading volume. They also showed that a volatile market causes a decrease in the mispricing, which they attribute to an increase in the supply of arbitrage services or faster price adjustments.

Based on the work by Chan and Chung we investigate the issue of market volatility and index arbitrage including trading volume for the U.K. index FTSE 100 market. Never before has the issue had a similar approach in the U.K. Yadav and Pope (1990) were only interested in comparing the daily level of volatility between the FTSE 100 spot and futures markets to find that the futures market exhibits higher volatility. Their results directed them to the conclusion that the arbitrage link between the spot and the futures markets was not maintained. Similarly, MacKinlay and Ramaswamy (1988) used intraday transaction data for the S&P 500 stock index and the S&P 500 futures for the period April 1982 to June 1987. They state that if arbitrageurs maintained the link between the spot and the futures markets then the variability of the two markets should be equal. However, their analysis shows that the variability of the futures price changes exceeds the variability of the price changes in the S&P 500 index.

Antoniou and Holmes (1995b), on the other hand, compared the daily volatility of the spot market before and after the introduction of the FTSE 100 futures market in relation to the flow of information. They found that although there is an increase in the spot volatility after the introduction of the futures market, this is due to higher speed in adjusting to new information. Therefore, the futures market has improved the informational efficiency of the stock market. However, the studies fail to address the issue of volatility in direct relation to the change in the arbitrage spread and the trading volume of the spot index. In addition, when analysing volatility in relation to arbitrage, there is a tendency in the existing literature not to account for the profitability of the arbitrage opportunities. Finally, the analysis benefits from the use of GARCH models to describe the volatility of spot and futures markets instead of the traditional constructed measures of volatility.

1.3.5 Non-Synchronous Trading

As a result of the importance of the service that the futures market is expected to provide, the correct pricing of a futures contract becomes vital. The way a futures contract is priced involves the consideration of the observed value of the underlying index.

In the U.S. the stock index prices are averages of the last transaction prices of component stocks. On the other hand, in the U.K. the FTSE 100 index is constructed by taking a weighted average of the mid-quotes of the prices of the securities that comprise the index, - at which market makers are forced to trade. It is very important whether all previous information is incorporated in the current price quotes. The index lags behind the true value of the underlying FTSE 100 stocks when any of the constituent stocks have not recently traded, since underlying stock values may change between trades. As a result of reacting to information with a lag, serial correlation will be present in the index returns, which may not be genuine but the outcome of the way the index is constructed. This phenomenon is best described by Abhyankar (1995a) as follows;

> "...if a constituent stock is not traded at the instant when the index is calculated, observed index values are then based on the last transaction price recorded for that stock....the index reflects *stale* prices. Unlike the S&P 500 Index which is based on the last recorded

> transaction price, the FTSE 100 Index is calculated using the mid-point of the *inside* spread quoted by designated competitive market-makers on the London Stock Exchange. It could be argued that since the FTSE 100 Index is based on prices which are tradeable for the quantities indicated, the problem of *stale* prices in the index may be reduced. Current evidence (a recent study by the London Stock Exchange, Quality of Markets Review, Spring 1992), however, suggests that a majority of actual trades on the London Stock Exchange take place within the spread. Hence, it is likely that the index autocorrelation problem exists in the FTSE 100 Index because the mid-point of the spread may not always reflect a *tradeable* price."
> (Abhyankar 1995a, p461)

The main focus of this thesis is the analysis of the presence of mispricing and arbitrage opportunities between the FTSE futures market and its underlying spot market. As a consequence, by not considering the issue of non-synchronous trading when it is present it could result in misleading conclusions. MacKinley and Ramaswamy (1988), who examine intraday transaction data for the S&P 500 stock index futures prices and the intraday quotes for the underlying index for the period April 1982 to June 1987, discuss how non-synchronous trading can lead to the perception of arbitrage opportunities. In order to document the effect of non-synchronous trading in their data they calculate auto-correlation coefficients for 15, 30, 60 and 120 minute intervals. They find the presence of non-synchronous trading by observing that as the time interval becomes larger, the size of the first order auto-correlation coefficient is reduced. They also find that auto-correlation in the index is not induced only by non-synchronicity. It could also be that the prices of the index can be foreseen which can make the market inefficient on an intraday basis if the forecast price changes can be exploited profitably given transaction costs.

Other studies that have considered the effects of non-synchronous trading on portfolio returns are those by Scholes and Williams (1977), Dimson (1979), Cohen *et al.* (1979), Cohen *et al.* (1983), Atchison *et al.* (1987), Shanken (1987) and Lo and MacKinlay (1990a). On the whole, these studies concluded that non-synchronous trading on its own cannot fully explain the observed auto-correlation in the index returns.

Similarly, Miller *et al.* (1994) suggest that the observed mispricing of the futures contract is because stocks in the index portfolio do not trade frequently and arbitrage opportunities may only be statistical illusions. The increasing interest in the problem of non-synchronous trading and its effects has encouraged the growth in the number of techniques available for removing those effects from the data. We focus on these techniques that are currently available based on the studies of Harris (1989a), Stoll and Whaley (1990), Miller *et al.* (1994) and Antoniou and Garrett (1993).

STOLL AND WHALEY (1990)

Stoll and Whaley (1990) model the relation between the price movements of the index futures contracts and the underlying index considering both the CME's S&P 500 index and the CBOT's MMI futures contracts. They analyse 5-minute movements applying data reflecting the period April 21, 1982 to March 31, 1987. They find that the non-synchronous trading appears to have effects on the data and in particular the S&P 500 index. The model they derive aims at the removal of the effects of both non-synchronous trading and bid-ask. The transaction prices that are used in computing the index price returns fluctuate randomly between bid and ask levels. Such a random price movement between bid and ask prices in successive transactions can contaminate the true price returns. In the case of a stock index portfolio because the index level is an average of prices across stocks at a given point in time, the movements between the bid and ask for some stocks could be offset by opposite movements from the ask to bid for other stocks.

The model Stoll and Whaley develop shows that when the effects of non-synchronicity and the bid/ask effects are present, the observed returns on the index to follow an ARMA(p,q) process where the order of p and q is infinite The error term consists of three components; the true return innovation in the portfolio, the weighted average error from the individual stock bid/ask spreads and the random error from the non-synchronous trading case. The true portfolio returns are then acquired by the residual from the model. This model requires for p and q to be infinite, but that is only in theory. In practice, however, the order of the ARMA model will only have to be very high so as to remove the bid-ask and non-synchronous trading effects. Deciding about the order of p and q is more or less subjective and an incorrect selection can be very critical. In addition to this, estimating over-parameterised versions of the model can contaminate the results and induce misleading conclusions.

Furthermore, the Stoll and Whaley model adjusts index returns for both non-synchronous trading and bid-ask effects. However, in the U.K. the FTSE 100 index does not suffer from bid-ask effects since it is constructed from mid-prices. On the other hand, the way the model is constructed, it makes it difficult to distinguish between the non-synchronous adjustment and the bid-ask spread adjustment. That is because the residuals component which is used to produce the adjusted price returns is made up of the three components mentioned above. As a result, the use of this model becomes problematic when analysing the FTSE 100 index.

HARRIS (1989a)

We continue by reviewing the next study which provides a technique for removing the effects of non-synchronous trading from the data. This is the study of Harris (1989a). In this study Harris analyses the relationship between the S&P 500 index and futures index over a ten-day period around the October 1987 stock crash event. He uses observations 5-minutes apart for the period October 12, 1987 to October 23, 1987. The model developed takes into consideration the non-synchronous trading effects and is applied on a very detailed data set that incorporates the complete transaction history of all the stocks comprising the index.

Harris approaches the estimation of the non-synchronous trading adjustment by formulating it as a problem of extracting a factor common to all securities in the index. If the common factor can be estimated, then a new index adjusted for non-synchronous trading can be generated. The results suggest that the effects of non-synchronous trading are present in the data series. However, by removing these effects there is still auto-correlation in the index, which implies that this auto-correlation must be genuine and changes in prices depend on previous ones. Therefore, since only part of the serial correlation is removed, non-synchronous trading can be responsible for some of the observed serial correlation and cannot explain its entire presence. More specifically, Harris finds the S&P 500 index to be very auto-correlated (0.697 for the entire sample) while the adjusted for non-synchronicity index is less correlated. However, the auto-correlation in the adjusted series is still large (0.527 for the entire sample).

Looking at the non-synchronous trading problem as simply the problem of extracting a factor common to all securities in an index, is an interesting approach. However, the technique suggested by Harris has enormous data requirements for its implementation such as access to trade by trade data on each individual stock in the index, and information on the number of shares traded and the number of shares outstanding. As a consequence of the large amounts of very specific data required, the Harris (1989a) model is difficult to implement.

MILLER, MUTHUSWAMY AND WHALEY (1994)

The next study to review is by Miller *et al.* (1994). This study investigates the intraday behaviour of the S&P 500 stock index basis changes during the period April 21, 1982 to March 31, 1991 and the VLI (Value Line Index) basis changes during the period September 1, 1982 to March 11, 1988. The study proposes that the observed performance of the basis, which is usually explained as induced by arbitrage activity, can be the result of the fact that many stocks in the index portfolio trade infrequently. In order to investigate this possibility, the authors develop a model that removes the non-synchronous trading effects.

Miller, Muthuswamy and Whaley (1994) show that an MA(1) process should be sufficient to remove the non-synchronous trading effects. However, in the case when securities may not trade every period an MA(q) process is needed to remove these effects, where q reflects the number of periods for which a security has not traded. However, unless there is specific information available about the trading of the securities, q will have to be very large. Using a higher order moving average process will make the model more complicated and more difficult to estimate. Based on these considerations, Miller, Muthuswamy and Whaley argue that the modified AR(1) model that they develop and use is a better, simpler and more natural way to capture the effects of the non-synchronous trading. After applying their model Miller *et al*. find that the effects of non-synchronous trading are present and severe in the data series.

ANTONIOU AND GARRETT (1993)

We finally review the study by Antoniou and Garrett (1993) who analyse the pricing relationship between the FTSE 100 index and the FTSE 100 stock index futures contract on the 19th and 20th October 1987, the period of the stock market crash. They apply minute-by-minute transaction prices for the December 1987 FTSE 100 stock index futures contract. The purpose was to investigate the extent to which the FTSE 100 futures contract contributed to the crash. The paper recognises the non-synchronous trading problem of index price data and uses the Kalman Filter model to remove these effects. It is known from Harris (1989a) that the observed value of the spot index consists of the true value of the index plus an adjustment for non-synchronous trading. This model is similar to Harris's notion but differs from it by the way both the unobserved and observed components are estimated.

As a result, Antoniou and Garrett produce a model which can be viewed as an unobserved components model in which the observed series consists of a signal reflecting the unobserved, true value of the index and noise reflecting the non-synchronous trading adjustment. As a consequence, the task of removing the effects caused by non-synchronous trading is a problem of signal extraction where the signal to be extracted is the true value of the spot index. Furthermore, by extracting this signal, they also acquire a measure of the non-synchronous trading adjustment. After applying the model Antoniou and Garrett find that non-synchronous trading and its effects explain little of the observed behaviour of the markets.

There are certain advantages of removing the non-synchronous trading effects with the use of the Kalman filter in contrast to the techniques developed by Stoll and Whaley (1990) and Harris (1989a). These advantages at first involve the absence of the need to make assumptions about the stochastic process that observed returns follow when there is a case of non-synchronous trading. Second, a problem generated by the use of all these models, apart from the Kalman filter, is the fact that they produce adjusted returns and not adjusted price series. That becomes a severe problem in analysing the relationship between a stock index and a stock index futures market that this thesis is trying to do. The investigation of the existence of profitable arbitrage opportunities in the index futures market is based, among other, on the use of the cost-of-carry model (as demonstrated in later chapters). It is apparent that models like the cost-of-carry formula require adjusted prices than adjusted returns. Finally, the approach suggested by Harris (1989a) requires a wide range of detailed data, which make it difficult and expensive to apply.

1.4 CONCLUSIONS

The reviews presented in this chapter clearly show that the US market has attracted more analysis than any other country in the investigation of the pricing relationship between the index futures market and its underlying stock market in terms of mispricing and arbitrage relationships. Some of them conclude their analysis with the investigation of mispricing without extending to the research of profitable arbitrage opportunities. It is also apparent that empirical work for the U.K. market is very limited; Yadav and Pope (1990, 1991), who do not appear to make any adjustments so as to account for the effects of the non-synchronous trading; Antoniou and Garrett (1993) who despite adjusting for non-synchronicity only cover the two days surrounding the October 1987 market crash and do not aim at the detection and analysis of arbitrage; and Antoniou and Holmes (1995b) who simply compare market volatility pre- and post-futures without examining the direct relation with arbitrage nor involving the trading volume element. Finally, the model of the elasticity of supply of arbitrage and the price dominance relationship, not only has been applied exclusively in the U.S. market but is also incomplete by not considering all the possible available sources of information in the markets, not being investigated withing a time-varying framework and not distinguishing between profitable and non-profitable arbitrage opportunities.

All these gaps in the existing literature are considered, investigated and corrected in this thesis. The chapters that follow, not only apply a large and updated series of approximately ten-year data for the U.K. market, but also estimates profitable arbitrage opportunities (taking into account transactions costs), after considering the issue of non-synchronous trading. This is achieved in two ways; first, with the application of an already existing model and second, by approaching the issue of a reliable spot index price series with a totally new and far better technique. Unlike previous methods this novel technique is able to overcome the problem of non-synchronous trading without the necessary use of adjusting methods. The use of adjusting methods may not produce accurate results because they could be liable to misspecification errors not detected so far. In addition, the novel method used in this thesis manages to overcome the a-synchronicity which exists in the closing time of the futures market and the underlying spot market. This is achieved by involving the options market in order to derive an implied index to replace the reported spot index. Since the options market closes at the same time as the futures market, the implied index will reflect prices of the same time as the futures prices. Furthermore, the elasticity of supply of arbitrage and the price dominance relationships are investigated after accounting for all possible sources of information in the markets and within a time-varying framework. Finally, the analysis of the relation between arbitrage and market volatility incorporates the use of trading volume as a significant element.

CHAPTER 2

THE EFFECTS OF NON-SYNCHRONOUS TRADING ON THE FTSE 100 STOCK INDEX

2.1 INTRODUCTION

In the last few years, due to the availability of higher frequency price data of stock indices and stock index futures, there has been an increasing interest in the role of non-synchronous trading and the way it affects individual securities and index prices and returns. Significant auto-correlation has been observed in security and index prices and returns, which can give rise to short term predictability implying market inefficiency, depending upon transaction costs. However, these observations may actually be the result of non-synchronous trading. It is due to these concerns that the non-synchronous trading issue has generated a renewed interest.

When analysing the existence of arbitrage[1] opportunities between spot and futures markets, failing to account for the non-synchronous trading effects while they are present, can generate misleading results. Index arbitrage opportunities in particular, can be identified by comparing the theoretical futures price (F') with the actual futures price (F). The theoretical futures price is computed based

[1] The issue of arbitrage is extensively analysed in later chapters.

on the cost-of-carry model and requires the use of the observed value of the underlying stock index as one of the variables. If the stock index futures contract is priced correctly, then the difference between F and F′ is equal to zero. Assuming no transaction costs, any deviation in this difference away from zero will imply the existence of an arbitrage opportunity. However, in the presence of non-synchronous trading the observed value of the underlying index used in the cost-of-carry model could be severely contaminated giving rise to illusionary arbitrage opportunities.

It is apparent that there is a need for constructing better measures of the underlying values of the FTSE 100 stocks. A number of techniques has been developed in order to remove the non-synchronous trading effects from prices and returns. The chapter focuses on the major and more recent techniques so that the observed FTSE 100 stock index can be adjusted for non-synchronous trading.

In addition, a main contribution of this chapter is the use of a novel approach for constructing the FTSE 100 index price series required in the cost-of-carry model. This is achieved with the use of FTSE 100 option contracts which generate the Implied Index series which should produce reliable and accurate results since it overcomes the problem of non-synchronous trading without having to rely on any methods for adjusting the data.

The rest of the chapter is organised as follows; Section two presents and evaluates the methods proposed in the literature to remove the non-synchronous trading effects. It also explains the derivation of the Implied Index series. Section three provides a description of the data used. The empirical findings are given in section four, while section five provides a summary and conclusions.

2.2 METHODOLOGY

2.2.1 MILLER, MUTHUSWAMY AND WHALEY (1994)

Miller, Muthuswamy and Whaley (1994) point out two cases of non-synchronous trading. The first is when a security trades at least once every trading period but not always at the close of each period, while there is also the case when a security does not trade every consecutive period. Both cases are closely related and can be easily identified based on the length of the trading period over which prices or returns are calculated. If the calculations are made on a time basis that is longer than one trading interval such as a day, week or even month, then all the securities comprising the index should have traded at least once. However, it is unlikely that all of them transacted exactly at the close of the day (daily), or the last day of the week (or month). On the other hand, if prices or returns are computed over short trading periods such as ten or fifteen minutes, then it is highly unlikely that all the stocks would have had the opportunity to trade at least once every period. On the whole, the smaller the trading period the more severe the non-synchronous trading effects become. In the presence of non-synchronous trading the observed price of the index is not necessarily a reflection of its true price because it has stale prices. In addition to this if stocks react to new information with a time lag then, auto-correlation will be evident in the behaviour of the index prices wrongly inducing short term predictability of them. The study by Miller, Muthuswamy and Whaley (1994) investigates the behaviour of the S&P 500 stock index basis changes during the period 1982 through 1991. The study proposes that the observed performance of the basis, which is usually explained as induced by arbitrage activity, can be the result of the fact that many stocks in the index portfolio trade infrequently. In order to investigate this possibility, the authors develop a model that removes the non-synchronous trading effects.

At first all securities are assumed to trade with perfect synchronicity (each security trades exactly at the close of every time period), thus, the individual security prices are expected to follow a zero mean random walk. Under such a perfectly continuous market the true change in the security price is white noise and the observed change in the security price could be described as an MA process as follows:

$$s_{i,t} = s^{*}_{i,t} \tag{2.1}$$

where:

$s_{i,t}$: the observed price change in an individual security

$s^{*}_{i,t}$: the true price change in an individual security

The relation expressed in equation (2.1) can be adjusted for the case of a portfolio of securities where the observed price change of the portfolio is given by the following:

$$s_{p,t} = \sum_{i=1}^{n} w_i s_{i,t}^{*} = s_{p,t}^{*} \tag{2.2}$$

where:

w_i : the proportion of the portfolio that is invested in the I-th security and $\sum_{i=1}^{n} w_i = 1$

n : the number of securities the portfolio consists of.

In the presence of non-synchronous trading effects not all securities trade at the close of each time period. In Miller et al model it is assumed that a fraction ϕ of the observed price change of the I-th security reflects old information that arrived at t-1 period. The remainder of the observed price change, $(1-\phi)$, reflects information that arrives at time t. The observed security price change is then given by:

$$s_{i,t} = (1-\phi)s_{i,t}^{*} + \phi s_{i,t-1}^{*} \tag{2.3}$$

The value of ϕ lies between 0 and 1, ($0 < \phi < 1$) and the more close it gets to zero the more continuous the trading is. When ϕ becomes equal to zero then the observed change in the index level fully reflects the contemporaneous true change in the price. On the other hand, as ϕ takes values close to one, the effects of non-synchronous trading become more and more severe. When ϕ acquires the value of one that will mean that the last trade of a security in the index actually happened in a previous trading period and the observed change in the index level lags its true change.

In the case of a portfolio of securities, the observed price change in the portfolio is derived as follows:

$$s_{p,t} = \sum_{i=1}^{n} w_i s_{i,t} \tag{2.4}$$

Based on equation (2.3), equation (2.4) can be rewritten as follows:

$$s_{p,t} = \sum_{i=1}^{n} w_i [(1-\phi) s^*_{i,t} + \phi s^*_{i,t-1}] \tag{2.5}$$

$$s_{p,t} = (1-\phi) \sum_{i=1}^{n} w_i s^*_{i,t} + \phi \sum_{i=1}^{n} w_i s^*_{i,t-1} \tag{2.6}$$

$$s_{p,t} = (1-\phi) s^*_{p,t} + \phi s^*_{p,t-1} \tag{2.7}$$

Miller, Muthuswamy and Whaley (1994) show that the modified MA(1) process[1] described in equation (2.7) is sufficient to remove the non-synchronous trading effects. However, in the case when securities may not trade every period an

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[1]It is a modified MA(1) process because the component representing the portfolio price change has not the standard coefficient of one.

MA(q) process is needed to remove these effects[1], where q reflects the number of periods for which a security has not traded. Unless there is specific information available about the trading of the securities, q will have to be very large. Using a higher order moving average process will make the model more complicated and more difficult to estimate.

Based on these considerations, Miller, Muthuswamy and Whaley argue that the modified AR(1) model that they develop and use is a better, simpler and more natural way to capture the effects of the non-synchronous trading. In this case, the observed price change of the portfolio will, once again depend on the contemporaneous true price change weighted by $1-\phi$. The difference lies in the fact that instead of the remaining weight being on the lag one true price change, it is distributed across an infinite number of lagged true price changes, where the weights decline geometrically with the order of the lag to reflect the greater importance attached to recent news compared with older news. Based on these assumptions, the observed price change of the portfolio is given by the following:

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[1]The study by Muthuswamy (1990) also supports that an MA(q) process is a good approximation of the observed change in the index level when a security trades every q periods. This is also reinforced by Cohen, Maier, Schwartz and Whitcomb (1979) who assume that the observed returns follow an MA(q) process. However, both in the Cohen *et al.* (1979) study and in the Stoll and Whaley (1990) study the MA process incorporates a bid-ask component.

$$s_{p,t} = (1-\phi)s^*_{p,t}$$

$$+ [(1-\phi)\phi s^*_{p,t-1} + (1-\phi)\phi^2 s^*_{p,t-2} + (1-\phi)\phi^3 s^*_{p,t-3} + \dots] \quad (2.8)$$

The weights that are adjusted to the lead portfolio price changes sum to the non-synchronous trading parameter ϕ. Equation (2.8) can be rewritten as follows:

$$s_{p,t} = (1-\phi)s^*_{p,t} + \phi s_{p,t-1} \quad (2.9)$$

When referring to a stock index like FTSE 100 equation (2.9) becomes:

$$s_t = (1-\phi)s^*_t + \phi s_{t-1} \quad (2.10)$$

where:

s_t^* : the un-observed true change in the index level

The change in the index level, which is denoted in small letters, is given by the following where all values are observed values:

$$s_t \equiv S_t - S_{t-1} \quad (2.11)$$

The modified AR(1) process[1] shown in equation (2.10) is likely to provide a good approximation of the true price changes and easy to estimate. This model is also similar

[1]As with the modified MA(1) process, the AR(1) process is referred to as modified because the residual representing the index price change has not the standard coefficient equal to unity.

to Lo and MacKinlay's (1990a) AR(1) model of non-synchronous trading where $(1-\phi)$ is the probability of trade during a period.

As the model shows, the true change in the index level can be viewed as the residual from a regression of the observed change in the index level on the lagged observed change. The following equation is an empirically testable reexpression of equation (2.10) as provided by Miller et al.

$$s_t = \alpha + \phi s_{t-1} + \epsilon_t \tag{2.12}$$

We then use the residuals from the regression in order to produce estimates of the innovations in the index level which is given as follows:

$$s_t^* = \frac{\hat{\epsilon}_t}{(1-\hat{\phi})} \tag{2.13}$$

where:

s^*_t : the change in the index level adjusted for non-synchronous trading

$\hat{\epsilon}_t$: the estimated residuals from a regression of observed changes on observed changes lagged one period

$\hat{\phi}$: the estimated coefficient on lagged observed changes in the index level

The estimated innovations of the index reflect the contemporaneous true changes in the index level.

Therefore, the model generates changes in the index level that are adjusted for non-synchronous trading.

2.2.2 ANTONIOU AND GARRETT (1993)

The study by Antoniou and Garrett (1993) analysed the pricing relationship between the FTSE 100 index and the FTSE 100 stock index futures contract on the 19th and 20th October 1987, the period of the stock market crash. The purpose was to investigate the extent to which the FTSE 100 futures contract contributed to the crash. The paper recognises the non-synchronous trading problem of index price data and uses the Kalman Filter model to remove these effects.

THE CONCEPT OF STATE SPACE

The state space models were developed originally by control engineers (Kalman 1960) but are receiving increasing attention in the economic literature. Lets assume there is a system that consists of the following three components: the input signals, the state variables and the output variables. State models of systems identify the dynamics and interaction of these variables. The output variables of the system are determined by the input variables and the initial conditions reflected to the state variables. As a result, the analysis of state systems requires the knowledge of the input signals for the period t_0-t_∞ along with the knowledge of the initial states at time t_0 in order to acquire the output signals for the same period t_0-t_∞.

The state of a dynamic system is the minimum set of state variables that are required to fully describe the outputs of the system based on its inputs. The state variables reflect the cumulative effect of all past inputs to the

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index plus an adjustment for non-synchronous trading. Let S_t be the time series of observed index price, which is assumed to consist of the un-observed true value of the index S_t^*, and the non-synchronous trading adjustment assumed to be a zero mean, serially uncorrelated process, u_t[1]. This is expressed in the following equation:

Measurement equation $$S_t = S_t^* + u_t \qquad (2.14)$$

Following Antoniou and Garrett (1993) who based their study on Harris (1989a), the model described in equation (2.14) can be viewed as an unobserved components model in which the observed series consists of a signal reflecting the unobserved, true value of the index and noise reflecting the non-synchronous trading adjustment. As a consequence, the task of removing the effects caused by non-synchronous trading is a problem of signal extraction where the signal to be extracted is the true value of the spot index. Furthermore, by extracting this signal, we can also acquire a measure of the non-synchronous trading adjustment. We assume that information arrives in the market in a random fashion and represent this behaviour as a random walk.

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[1]In the same way as with the model of Lo and MacKinlay (1990a), the non-synchronous adjustment is serially uncorrelated. The reason why is due to the independence in the probability of non-synchronous trading in different periods. However, dependence is also probable leading to auto-correlation, but Lo and MacKinlay (1990) state that it is empirically unlikely to have as much persistence in non-synchronous trading as required to produce weekly auto-correlation of thirty percent.

Antoniou and Garrett (1993) apply the Kalman filter technique in order to extract the component S_t^*[1]. The Kalman filter uses only past information and as a consequence, can be applied in real time. Equation (2.14) is the measurement equation and from it they specify the transition equations which describe the evolution of the un-observed component, S_t^* as follows:

Transition $S_t^* = S_{t-1}^* + \beta_{t-1} + \epsilon_t$ (2.15a)

equations $\beta_t = \beta_{t-1} + \zeta_t$ (2.15b)

The Kalman filter estimation method is an updating method which bases the regression estimates for each time period on last period's estimates plus the data for the current time period. The Kalman filter will provide sequentially updated estimates of S_t^* based on information about the spot index component as the latter becomes available. In order to achieve this we must have some prior notion as to how S_t^* varies over time. In this case, the specification of equations (2.15a) and (2.15b) implicitly assume that information arrives randomly and prices move as a random walk with a stochastic trend β_t. Specifying S_t^* as a random walk assumes that the market is efficient and any predictability is the result of non-synchronous trading. Furthermore, Antoniou and Garrett (1993) attribute the

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[1]For a detailed analysis of the workings of the Kalman Filter in estimating the measurement and transition equations refer to Harvey 1981 Chapter 4, Harvey 1989, Chapter 3, Harvey 1987 and Antoniou and Garrett (1993).

stochastic specification of the trend to the arguments in Ross (1989), which show theoretically that prices, and therefore rate of change of prices, will move in response to new information in a market with no arbitrage opportunities. Given that we have already assumed that information arrives in a stochastic way, both prices and the trend in them will also evolve stochastically which is precisely what is shown in the transition equations.

2.2.3 EVALUATION OF THE MODELS

Apart from the models presented and analysed so far there are two more equally valuable methodologies for removing non-synchronous trading effects that are worth mentioning. However, it is not possible to apply them in our research because they suffer from drawbacks. The first model is by Stoll and Whaley (1990), who consider both the CME's S&P 500 and the CBOT's MMI futures contracts. This models index returns for both non-synchronous trading and bid-ask effects. The transaction prices that are used in computing the index price returns fluctuate randomly between bid and ask levels. Such a random price movement between bid and ask prices in successive transactions can contaminate the true price returns. Roll (1984) shows that this bid/ask bounce may induce negative first-order auto-correlation in the observed returns even though the true returns are serially independent.

Under the influence of both bid-ask and non-synchronous trading effects, the observed portfolio returns follow an ARMA(p,q) process where the order of p and q is infinite. The error term consists of three components; the true return innovation in the portfolio, the weighted average error from the individual stock bid-ask spreads and the random error from the non-synchronous trading case. The true portfolio returns are then acquired by the residuals from the model[1]. The model by Stoll and Whaley (1990)

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[1]For a detailed analysis of the model refer to Stoll and Whaley (1990).

requires for p and q to be infinite, but that is only in theory. In practice, however, the order of the ARMA model will only have to be very high so as to remove the bid-ask and non-synchronous trading effects. Deciding about the order of p and q is more or less subjective and an incorrect selection can be very critical. In addition to this, estimating over-parameterised versions of the model can contaminate the results and induce misleading conclusions.

The second technique also developed for accounting for the effects of non-synchronous trading is by Harris (1989a). This method inspired Antoniou and Garrett (1993). Harris analysed the relationship between the S&P 500 index and futures index over a ten-day period around the October 1987 stock crash event. The data set is very detailed and incorporates the complete transaction history of all the stocks comprising the index. Harris approaches the estimation of the non-synchronous trading adjustment by formulating it as a problem of extracting a factor common to all securities in the index. If the common factor can be estimated, then a new index adjusted for non-synchronous trading can be generated. The observed value of the spot index consists of the true value of the index and an adjustment for non-synchronicity. The Harris approach differs from the Antoniou and Garrett approach in the way both the unobserved and observed components are estimated[1].

[1]For a detailed analysis of the model refer to Harris (1989a).

The drawback of this approach is that the nature and amount of the data required makes that technique very expensive and difficult to implement. The requirements for applying Harris's (1989a) model involve the use of transaction by transaction data on each individual security. This is described as follows:

> "The stock sample consists of all primary market trades of each S&P 500 stock from the opening of trading on Monday, October 12, 1987 to the close of trading on Friday, October 23. The data, ... include the date, time, price, and shares traded for each transaction on each exchange in the United States."
> (Harris 1989a, p 82)

The advantages of the Kalman filter model over other methodologies are mentioned by Antoniou and Garrett (1993) as follows:

> "This (Kalman filter approach) seems a more natural and intuitive way to address the non-synchronous trading problem. The (Kalman filter) model is entirely compatible with... models for returns proposed by Stoll and Whaley (1990), without incurring the identification problems that occur... In addition the model is similar in spirit to that proposed by Harris (1989a)... However, this approach does not

require the detailed data that Harris' (1989a) method requires."

(Antoniou and Garrett 1993, p 1452)

An serious problem generated by the use of all the methodologies mentioned in this chapter apart from the Kalman filter, is the fact that they produce adjusted returns and not adjusted price series. That becomes a severe problem in analysing the relationship between a stock index and a stock index futures market that this thesis is trying to do. The investigation of the existence of profitable arbitrage opportunities in the index futures market is based, among other, on the use of the cost-of-carry model (as demonstrated in later chapters). It is apparent that models like the cost-of-carry formula require adjusted prices than adjusted returns.

On the other hand, as shown in Garrett (1994), it is possible to calculate an adjusted price series from the models that produce adjusted return series with the use of:

$$p_t^* = \sum_{i=0}^{t+1} R_{t-i}^* + p_0^* + n\bar{r}^o \qquad (2.16)$$

where:

p^* : the log of the adjusted price

R^* : the adjusted returns

p^*_o : the log of the adjusted price in the period 0

$\bar{r}^o$: the mean of observed returns

n : takes values 1,2,...,t

However, in order to produce an adjusted price series, p^*_t according to equation (2.16), it is important to have a value for p^*_0 which, unfortunately, the models that generate adjusted returns do not provide.

The conclusion derived from this section is obvious. Concentrating on the purpose of this thesis, which lies in the examination of the relationship between FTSE 100 index and futures index in terms of arbitrage opportunities, not all models adjusting for non-synchronicity are appropriate. On the contrary, only the Kalman filter approach seems to fit better to the current and specific requirements of our study. The Kalman filter method not only can remove non-synchronous trading effects relatively easier than other approaches but can also produce an adjusted price series from which an adjusted return series is easy to calculate. However, for comparison reasons the analysis continuous with the use of both the Miller *et al.* (1994) model and the Kalman filter approach in order to remove the non-synchronous trading effects.

2.2.4 THE IMPLIED INDEX

This section presents a new method of measuring the index, which has not previously been applied, to the best of our knowledge, in the existent literature. This method involves the extraction of the Implied Index from the option contracts. It is possible to provide a different way to test for mispricing in the futures market by using data from the highly liquid and closely related options market. If we assume that the option market is efficient and can offer a sound benchmark for testing mispricing then spot series calculated from option premia can be used to calculate mispricing. This section explores and applies this method.

There are two types of option contracts traded on the FTSE 100; European and American. The European Style Options[1] can only be exercised on the expiration day, while the American Style Options[2] can be exercised either on the expiration day or on any day before that date. The owner of an American Call Option has the right but not the obligation to buy the underlying asset at a specified price on or before the expiration date. The seller of a call has the obligation to deliver the asset should the call owner decide to exercise his option. However, he receives a premium from the buyer of the call no matter whether the option is

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[1]The European-style FTSE 100 Index Option was introduced in the U.K. in February 1990.

[2]The American-style FTSE 100 Index Option started trading at the same time as the FTSE 100 Index futures.

exercised or not. A call is said to be in-the-money if the current stock price is greater than the exercise price (it is deep in-the-money when the difference is the largest).

The owner of an American Put Option has the right but not obligation to sell the underlying asset at a specified price on or before the expiration date. The seller of a put has the obligation to take delivery of the asset should the put owner decide to exercise his option. However, he receives a premium (option's price) from the buyer of the put no matter whether the option is exercised or not. A put is said to be in-the-money if the current stock price is below the contract's exercise price (it is deep in-the-money when the exercise price is much higher than the stock price) as shown in Table 2.1 where S_t represents the underlying index price and W the options contract's exercise price.

Table 2.1

Option status for the relationship between exercise price and underlying price

	Calls	Puts
In the money	$S_t > W$	$S_t < W$
Out of the money	$S_t < W$	$S_t > W$
At the money	$S_t \sim W$	$S_t \sim W$

It should be remarked that in common with Index Futures, Index Options do not require delivery of the underlying asset. Instead, index options are settled by the payment of cash upon exercise. At any time in the market there are bid and ask prices on an option contract. These are prices that are quoted by one or more market makers, who provide liquidity for those who wish to trade. They offer to buy the asset at the bid price and sell it at the ask price. As a consequence, the ask price is higher than the bid price with the difference representing the market makers' profit.

The reasons why an agent such as an investor would buy an options contract are easy to understand. If the current situation of the market is volatile or the market shares are currently overpriced/underpriced, an investor can either protect his portfolio (hedge) or simply profit (speculate) from undertaking a position in the options market. In case the expectations about the future are not realised then, the option does not have to be exercised and the investor will only lose the premium paid initially.

Most options that are actively traded in the world are American style options and in the case of the FTSE 100, American options are much more liquid than European. As a consequence, this research concentrates on the use of the American style options. The difference between the exercise price (W) and the underlying asset price (S) is called the intrinsic value of the option. For an out-of-the-money option, the intrinsic value is zero. For an in-the-money option the intrinsic value is the difference between W and S. The option premium however, consists of a second element in addition to the intrinsic value; the time value. The time value represents the period of opportunity (or the market expectations) in which an out-of-the-money (i.e. zero intrinsic value) option will become in-the-money, or that an in-the-money option will become deeper in-the-money. In short, the time value represents the extra risk to the seller of the option that losses will be made and is affected among others, by the time to expiry and volatility. At expiration, the time value of the option is zero and therefore the option premium will equal the intrinsic value. At all other times, the time value will be positive and so the option premium will be at least equivalent to the intrinsic value.

Specifically, a put option should sell for at least zero or the difference between the exercise price (W) and the underlying asset price (S), whichever is greater. This is illustrated in the following inequality.

$$P \geq MAX\,[0,\, W - S] \tag{2.17}$$

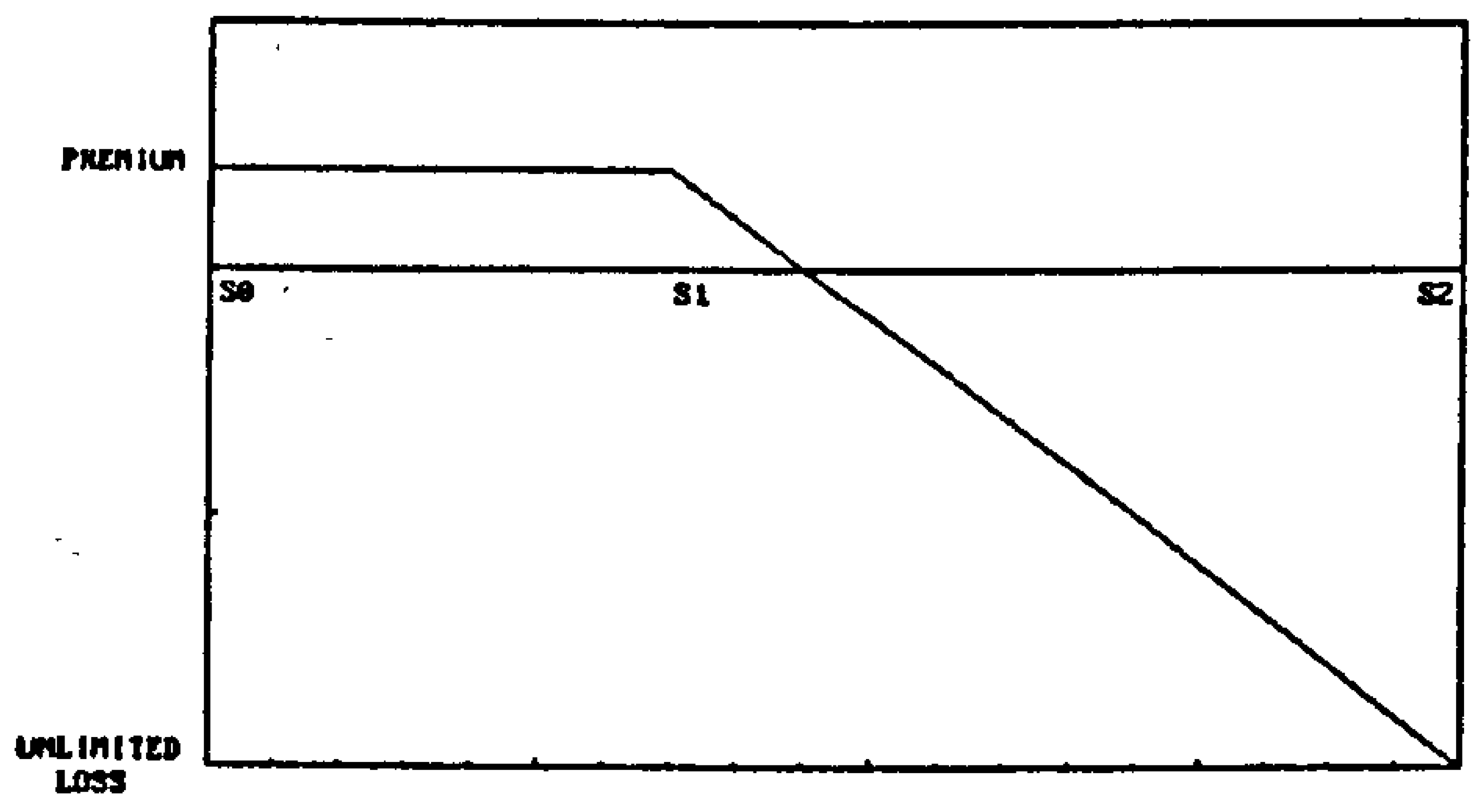
On the other hand, a call option should sell for at least zero or the difference between the underlying asset price and the exercise price, whichever is greater. This is also expressed as follows:

$$C \geq MAX\,[0, S - W] \tag{2.18}$$

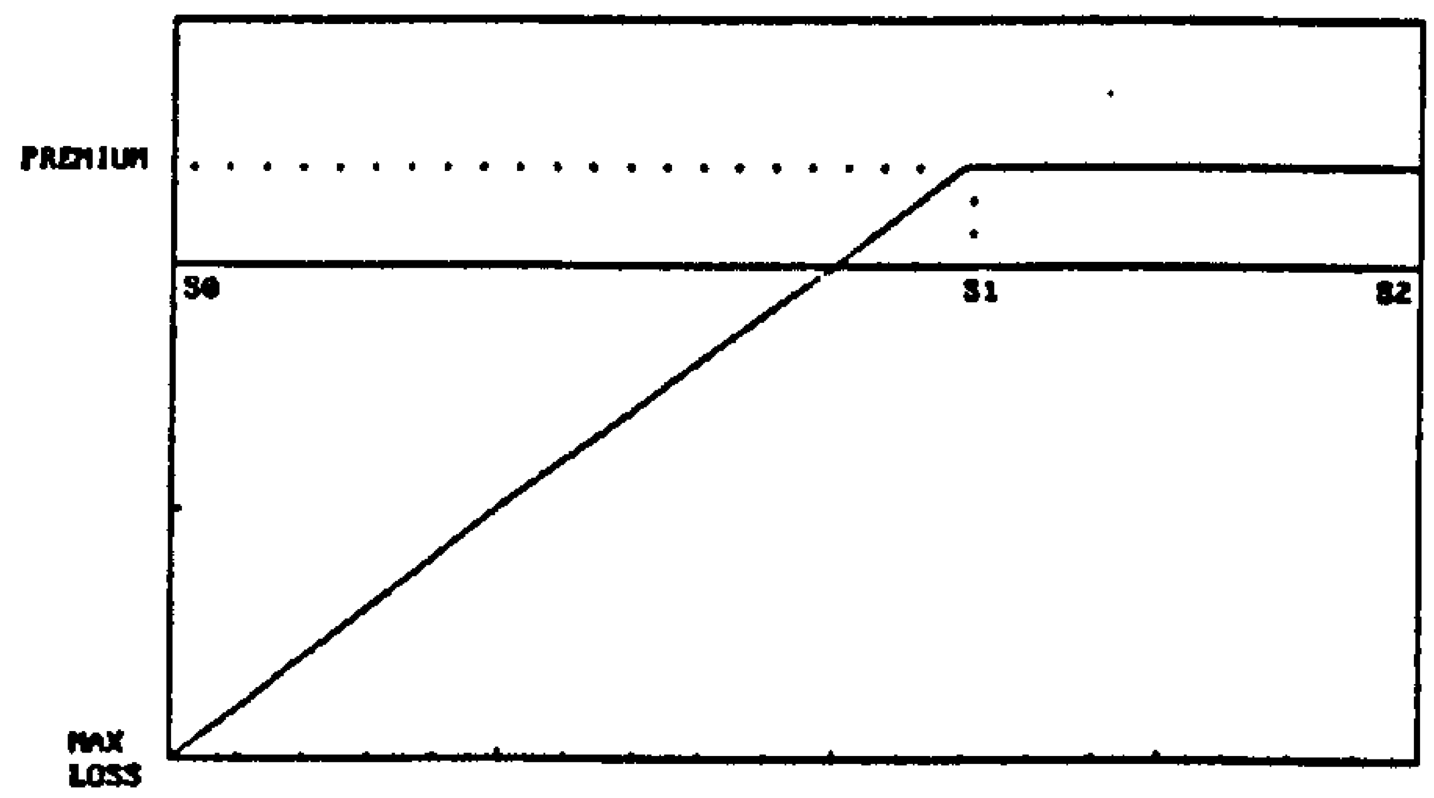
In our study we rely on the use of the put options in order to extract the Implied Index (underlying index). Our decision to apply the put options is justified by the fact that risk averse traders are more likely to select put options rather than call options due to the limited loss that put options can incur as opposed to the unlimited loss that call options can incur. This can be better illustrated in Figure 2.1.

Figure 2.1

Profit and Loss of writing a Call Option



Profit and Loss of writing a Put Option



For the call option the writer experiences losses when the share price rises above S_1 and towards S_2 and beyond. Since the increase in price of the share is theoretically unlimited, so too are the losses of the option writer. As the share price falls below S_1 to S_0 the call option writer receives the premium as profit. In the case of the put option the writer receives the premium when the share price rises above S_1 towards S_2 and beyond. Conversely, as the share price declines from S_1 the option writer experiences losses. The losses of the put writer, however, are limited in that the share price cannot fall below zero (S_0). As such, while the call option writer faces limited profits and unlimited losses the put option writer faces limited profits but limited losses too. For this reason an option writer faces a limited maximum risk in the case of put options which makes it a preferable investment.

As a result, we apply the put options in our analysis so as to acquire the Implied Index[1]. This Implied Index will then be used in the cost-of-carry formula to estimate the theoretical futures price, and eventually any mispricing that might exist. The advantage of using this Implied Index range as opposed to the spot series discussed so far[2] is that it does not suffer from any problems such as non-synchronous trading. Therefore, it overcomes the problem of non-synchronous trading without having to rely on any methods for adjusting the data. In addition, it overcomes the a-synchronicity that exists between the closing time of the spot and the futures market. The two markets close with approximately twenty-minute difference, which could induce noise to the empirical calculations of the theoretical futures price. A solution to this problem is provided by the estimation of the implied index based on the options market, which closes at the same time as the futures market. Finally, the use of the implied index has a further significance. When the index futures contract is not correctly priced then arbitrage trading could be initiated to exploit the observed profits. However, this strategy involves the simultaneous purchase/sale of the futures index and the sale/purchase of the spot index.

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[1]For convenience we ignore any possible arbitrage opportunities that may exist between options and futures prices, since this is beyond the scope of this study. It is also assumed that the options contracts are correctly priced, for the same reasons.

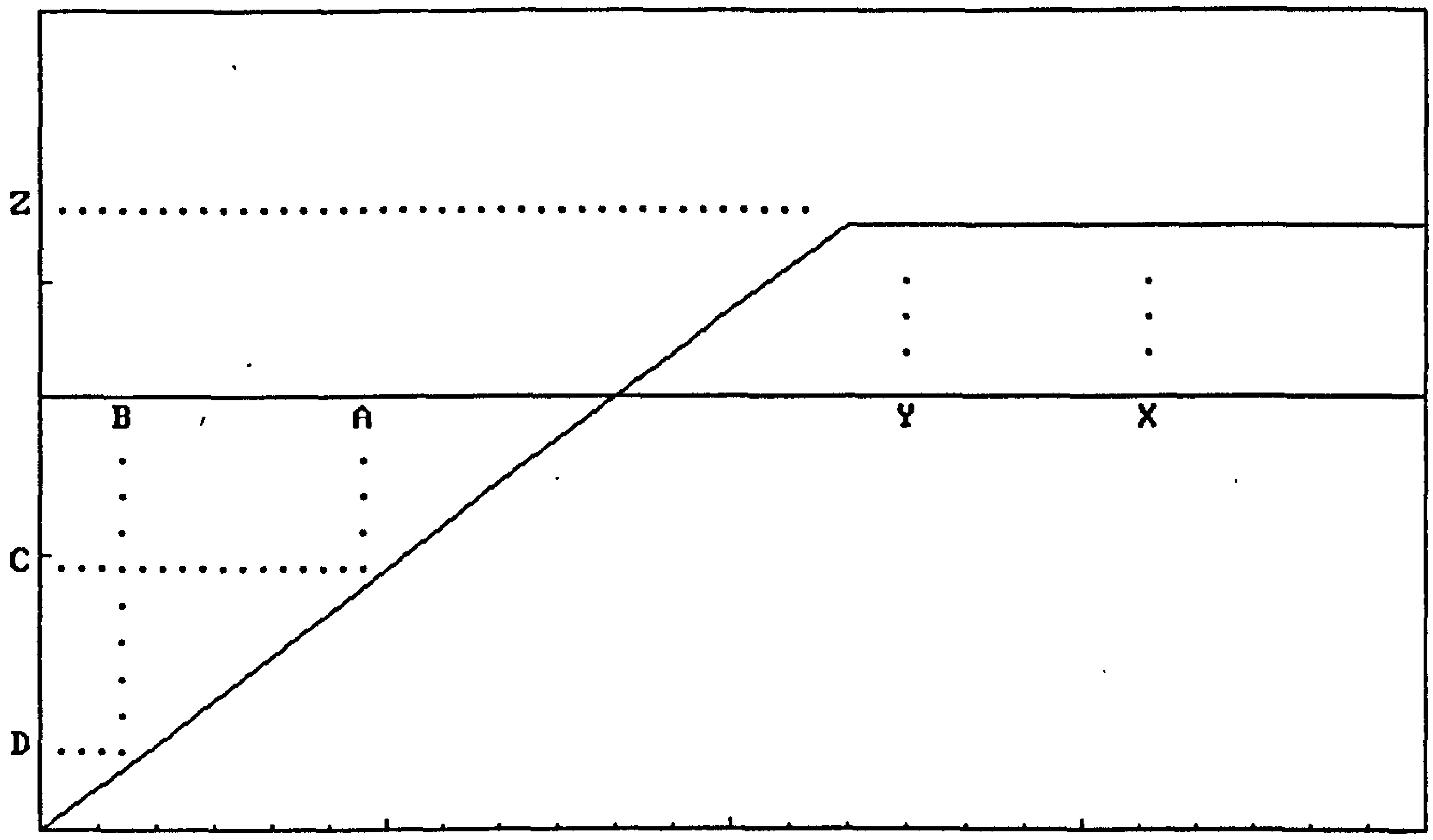
[2]The spot series from Datastream, which due to non-synchronous trading has to be adjusted producing an adjusted spot series.

Trading on the entire spot index is both difficult and expensive to achieve because it requires the trading of 100 stocks each one separately. As a consequence, when investors observe the futures to profitably diverge from the spot index, they tend to buy/sell an options contract instead of buying/selling the spot index, while still opening a position in the futures index market. As a result of the reasons mentioned above, the use of the implied index derived from options contracts is more reliable in the pricing of the futures contracts.

We examine the case of in-the-money options because an in-the-money option is more reflective of current changes and responds to changes in the spot price. This is not necessarily the case for an out-of-the money option whose premium represents only the time value element (i.e. it has no intrinsic value) and where changes in the spot price may not have any consequence for the value of the option since out-of-the money options are not actively traded. Since the in-the-money option has an intrinsic value, and that intrinsic value represents real gains or losses to option traders, changes in the premiums on these options should be representative of changes in the spot price of the underlying asset.

Figure 2.2

Profit and Loss of writing a Put Option



The diagram above shows the realised profit or loss at exercise of an option. It demonstrates that for a change in the stock price (decrease) from point A to point B, the loss to the seller of an in-the-money put option is from point C to point D. This is clearly directly related to the size of the spot price change. In contrast to this, a similar change in price from point X to point Y when the option is out-of-the money results in no change to the profit Z (the premium).

As a consequence of the changing potential losses that an option writer faces as the underlying spot price changes, the writer will adjust the option premium to reflect the changing intrinsic value of the option caused by the changing spot price. In the case of the in-the-money option, since there is a positive intrinsic value (the spot price is below the exercise price) real potential losses are faced by the option seller. As such, we would expect the option premium to be adjusted to reflect these potential losses. However, for the out-of-the money option there is no intrinsic value and so the premium charged for the option will show little change in response to spot price changes. Any change will be due to the time value of the option, and this will be more pronounced when the spot price approaches the exercise price. Therefore, it is more appropriate to use in-the-money options to calculate the spot price.

The Implied Index is produced based on the already shown formula (2.17). During the life of the contract the time value is present and positive which is reflected in expressing equation (2.17) as an inequality. However, the time value is not possible to be estimated so as to acquire the Implied Index. We therefore, examine the case of deep in-the-money options. This is used because the deep option is expected to be less likely to move out-of-the money as opposed to the simple in-the-money options. Therefore, the time value of the option is so small that it can be disregarded and allow us to derive the Implied Index by looking at formula (2.17) as an equality. Based on equation (2.17) the implied index is given from the subtraction of the option's premium P, of the deepest-in-the-money put option contract (P) from its exercise price (W). The premium of the options contract is calculated from adding the bid and offer prices of the option contract and dividing it by two.

2.3 Data Description And Sources

The data used in this chapter covers the period between June 1, 1984 and May 31, 1995, 2,869 observations in total. The stock market opens at 8:30 a.m. and closes at 4:30 p.m. This chapter requires initially, daily closing prices of the FTSE 100 stock index. The FTSE 100 index is constructed as a market weighted average using the middle of the best bid and offer quoted prices displayed on the SEAQ (Stock Exchange Automated Quotation System). The calculation is done once per minute during opening and closing time of the exchange. The chapter also uses daily data for the trading volume of the FTSE 100 stock index so as to demonstrate its increase over the years. The trading volume data covers the period October 27, 1986 to May 31, 1995. The data mentioned so far were provided by *Datastream*.

Finally, for the calculation of the Implied Index the chapter uses daily closing prices of the FTSE 100 put options which are traded in LIFFE. Trading starts at 8:35 a.m. and finishes at 4:10 p.m. Due to unavailability of data the period examined is from March 13, 1992 to May 31, 1995, 839 observations in total. The expiration months are June, September, December and March. This period covers thirteen options contracts starting with the June 92 contract and finishing with the June 95 contract. The data for the options contracts which were acquired from *LIFFE* include daily closing option exercise prices as well as the closing bid and offer option prices. All these daily data represent values of the day at 4:10 p.m. The data set used is built on the near contract. This is supported by a number of studies (Cornell (1985), MacKinlay and Ramaswamy (1988), Kawaller *et al.* (1987), Klemkosky and Lee (1991), Stoll and Whaley (1990) and Miller, Muthuswamy and Whaley (1994)) among which the one by Yadav and Pope (1990) states:

> "An examination of daily trading volume reveals that the near contract is almost always the most heavily traded contract on LIFFE. Volume in the second nearest contract starts to build up about four weeks before expiration of the near contract."
>
> (Yadav and Pope 1990, p 578)

We also know that for the investigation of mispricing in the following chapters, between the actual and its fair futures price at expiration they are both indistinguishable. Consequently, we need to know if deviations occur further away from expiration. For these reasons the data set constructed is based on the near contract shifting to the next contract just before the expiration month starts. This effectively leaves the entire period of the delivery month out of the data series for each contract analysed.

The sample period analysed is shown in detail in Table 2.2. The maximum number of observations for a contract is sixty six days while the minimum is fifty three days. For example the June 92 contract, which expires on June 19, 1992, covers the period between March 13, 1992 and May 29, 1992, leaving the expiration month out. The next contract, September 92, which expires on September 18, 1992, starts on June 1, 1992 and ends on August 31, 1992.

Table 2.2

The Options Contracts analysed based on the U.K. Stock Index FTSE 100

CONTRACT ANALYSED	NUMBER OF OBSERVAT.	EXPIRAT. DAY	PERIOD EXAMINED	
			START	END
June 1992	53	19/06/92	13/03/92	29/05/92
September 1992	66	18/09/92	01/06/92	31/08/92
December 1992	65	18/12/92	01/09/92	30/11/92
March 1993	64	19/03/93	01/12/92	26/02/93
June 1993	66	18/06/93	01/03/93	31/05/93
September 1993	66	17/09/93	01/06/93	31/08/93
December 1993	65	17/12/93	01/09/93	30/11/93
March 1994	64	18/03/94	01/12/93	28/02/94
June 1994	66	17/06/94	01/03/94	31/05/94
September 1994	66	16/09/94	01/06/94	31/08/94
December 1994	65	16/12/94	01/09/94	30/11/94
March 1995	64	17/03/95	01/12/94	28/02/95
June 1995	66	16/06/95	01/03/95	31/05/95

A demonstration of how the implied index is calculated is given for the June 92 options contract. For the first day of the period, March 13, 1992, the June 92 options contract has a number of exercise prices along with different closing offers and bids. For this day the value of the reported spot index is given to be 2476. This data is presented in the following Table.

Table 2.3

The exercise price, closing offer and bid for the June 92 options contract on March 13, 1992. The reported spot index value for the same day.

Trade_Date	Expire	Exercise_Price	Closing_Offer	Closing_Bid	Spot Index
13/3/92	Jun-92	2100	14	12	2476
13/3/92	Jun-92	2200	26	23	2476
13/3/92	Jun-92	2250	33	30	2476
13/3/92	Jun-92	2300	42	40	2476
13/3/92	Jun-92	2350	55	50	2476
13/3/92	Jun-92	2400	70	65	2476
13/3/92	Jun-92	2450	88	83	2476
13/3/92	Jun-92	2500	110	105	2476
13/3/92	Jun-92	2550	143	133	2476
13/3/92	Jun-92	2600	175	168	2476
13/3/92	Jun-92	2650	215	205	2476
13/3/92	Jun-92	2700	255	245	2476
13/3/92	Jun-92	2750	300	290	2476
13/3/92	Jun-92	2800	345	335	2476
13/3/92	Jun-92	2850	395	385	2476
13/3/92	Jun-92	2900	444	435	2476

The first step involves the identification of the contracts which are *in-the-money* for this day (the exercise price greater than the spot price). I then select the highest one that which will be the *deep in-the-money* contract. As a result I have:

Trade_Date	Expire	Exercise_Price	Closing_Offer	Closing_Bid	Spot Index
13/3/92	Jun-92	2900	444	435	2476

The formula that produces the Implied Index Value is given as follows:

Implied index value = exercise price - [(ask+bid)/2]

= 2900 -(444+435)/2]

= 2460.5

For the following day, March 14, 1992 I repeat the process in order to find the deep-in-the-money contract. Once the period for the June 92 contract ends on May 29, 1992, I continue with the next contract, September 1992 in the same way.

Figure 2.3 shows the reported spot index series for the years between 1986 and 1995 as well as its trading volume for the same years. In addition, Table 2.4 presents the mean and standard deviation of the two series for each year between 1986 and 1995. It is observed that over the years, trading volume in the FTSE 100 index has increased. It is also noted that the level of the index has grown consistently since the 1987 stock market crash.

Figure 2.3a
Average yearly trading volume of the FTSE 100 stock index during the period 27/10/86 and 31/05/95 (due to unavailability of volume data the period 01/06/84 to 26/10/86 is not shown). Year 1986 consists of 48 observations while year 1995 consists of 108 observations.

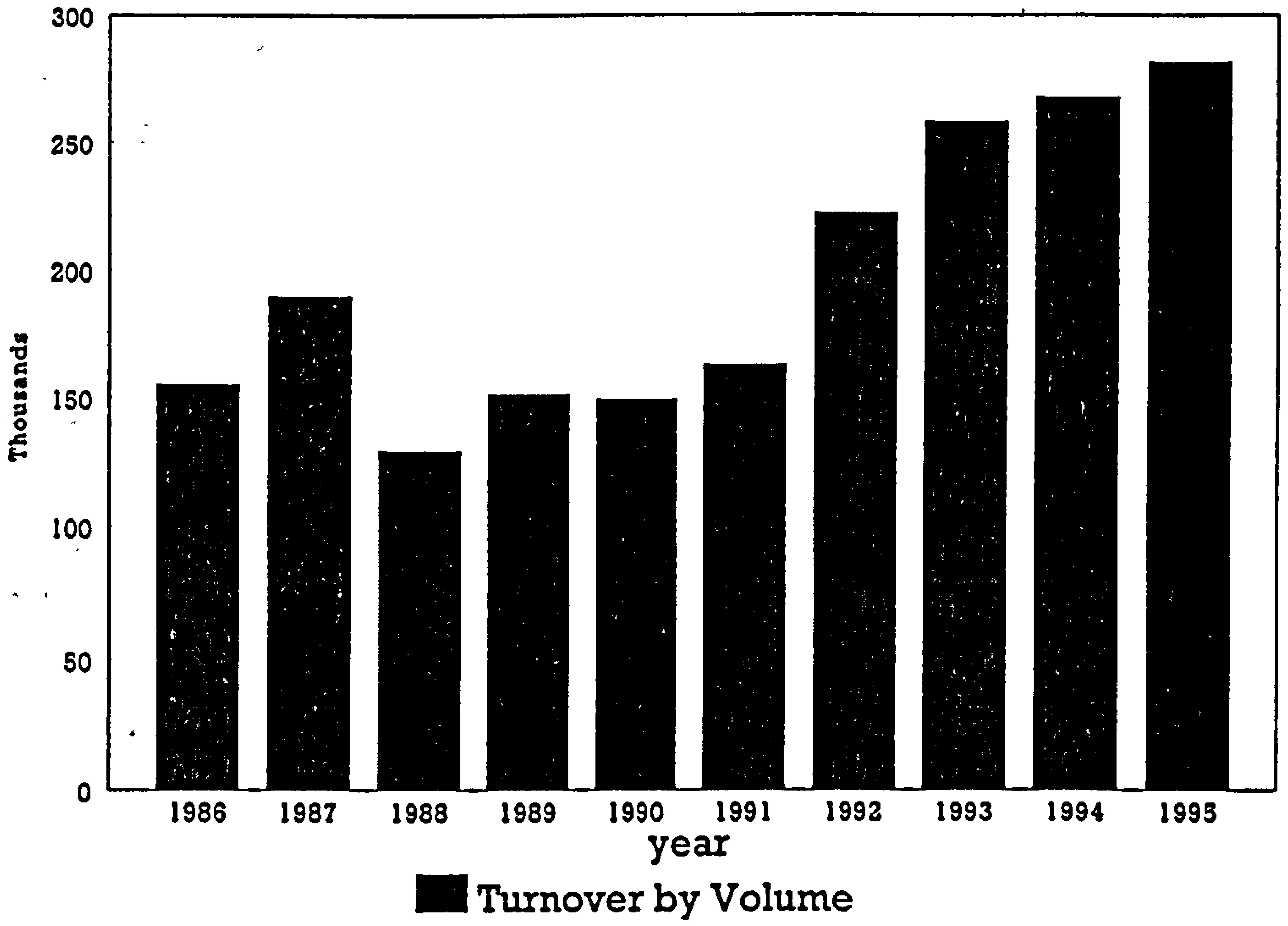


Figure 2.3b
Average yearly value of the FTSE 100 stock index during the period 27/10/86 and 31/05/95 (due to unavailability of volume data the period 01/06/84 to 26/10/86 is not shown). Year 1986 consists of 48 observations while year 1995 consists of 108 observations.

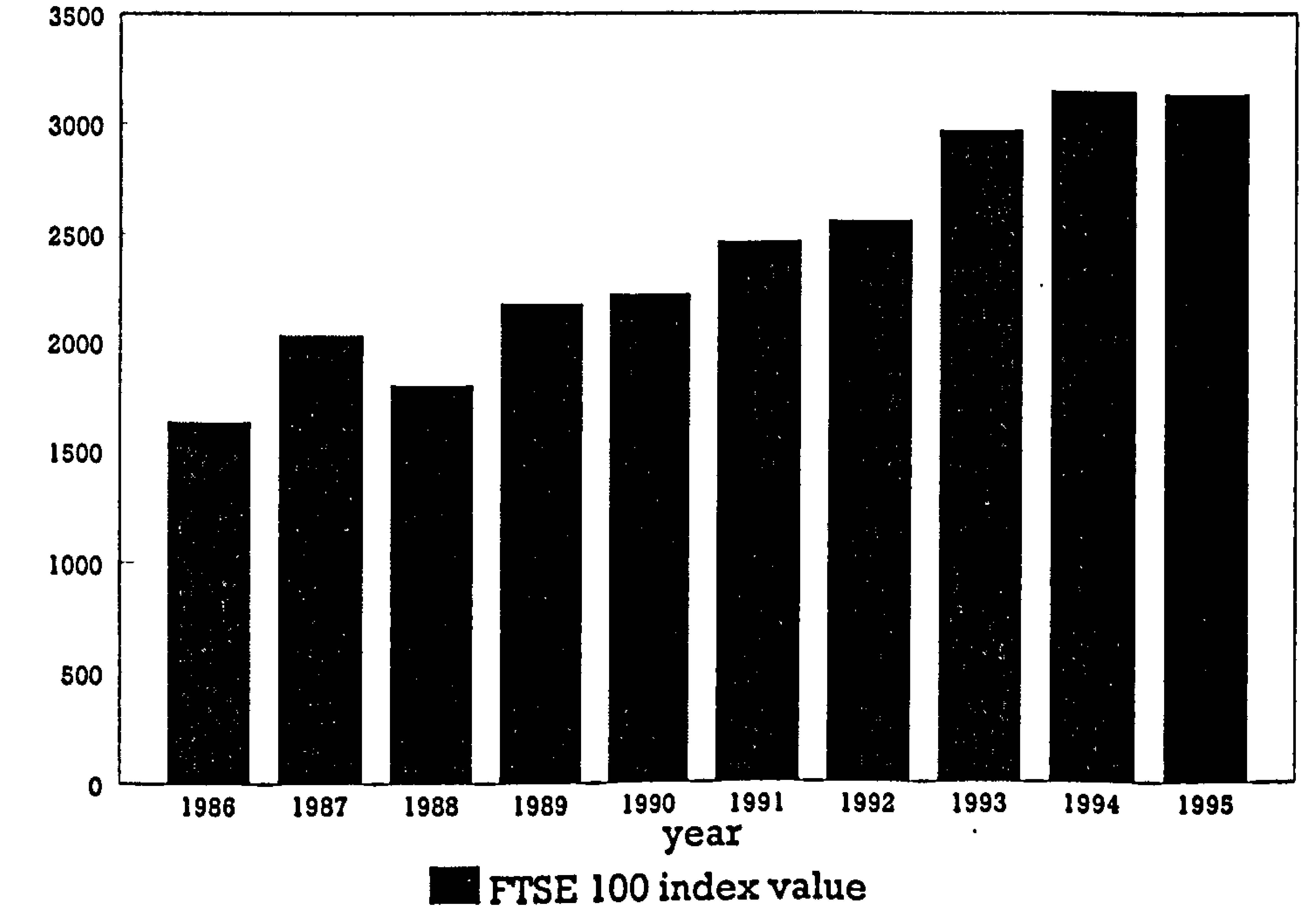


Table 2.4

The average value and the standard deviation of the FTSE 100 index and its trading volume for the period 27/10/86 and 31/05/95 (due to unavailability of volume data the period 01/06/84 to 26/10/86 is not shown). Year 1986 consists of 48 observations, while year 1995 consists of 108 observations.

Year	Trading Volume		Spot Index Value	
	Mean	Stand.Deviation	Mean	Stand.Deviation
1986	155456	136359	1635	21.788
1987	189956	68089	2035	255.878
1988	129400	39439	1801	41.697
1989	151666	50034	2175	146.836
1990	149768	51184	2224	114.522
1991	163570	45742	2465	145.508
1992	222557	79083	2561	134.121
1993	258655	65573	2963	161.136
1994	268416	64551	3140	143.950
1995	282090	72045	3130	107.287

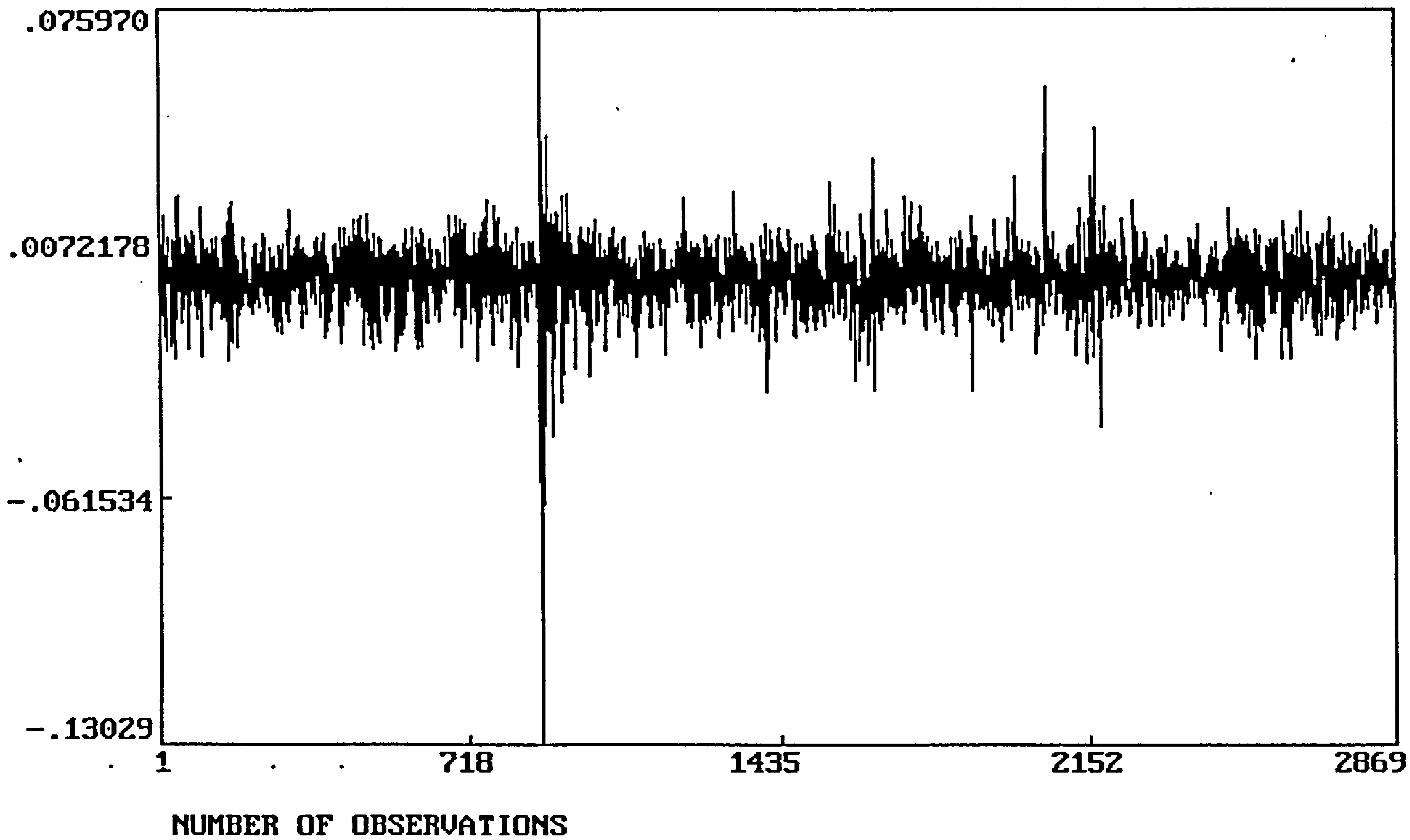
2.4 EMPIRICAL RESULTS

2.4.1 THE SPOT INDEX ADJUSTED WITH THE MODIFIED AR(1) MODEL

We begin by analysing the performance of the Miller *et al.* modified AR(1) model of non-synchronous trading as presented in equations (2.12) and (2.13). Using logs, the change in the observed index level for the whole period, June 1, 1984 through May 31, 1995, is plotted in Figure 2.4. The observed price changes in the FTSE 100 stock index is analysed for first-order auto-correlation with the results shown in Table 2.5.

Figure 2.4

The change in the observed spot index[1]



[1]The big outlier in the diagram reflects the October 87 market crash.

Table 2.5

Estimated first-order auto-correlation ($\hat{\rho}_1$) of observed FTSE 100 index changes (s). The sample period extends from June 1, 1984 through May 31, 1995. Figures in parentheses are t statistics. Auto-correlation coefficients are slope coefficients in the regression $y_t=\rho_1 y_{t-1}+e_t$.Heteroscedasticity was detected for some of the sub-samples investigated. In those cases white heteroscedasticity consistent standard errors were used. Reject H_0 : ρ_1 = 0 at the 5% level of significance if t-value > $|1.960|$.

Period		No. of	$\hat{\rho}_1(s)$
Begins	Ends	Obs.	
01/06/84	31/05/95	2,869	0.072 (2.653)*
01/06/84	31/12/84	152	0.133 (2.734)*
01/01/85	31/12/85	261	0.047 (1.752)
01/01/86	31/12/86	261	0.105 (2.708)*
01/01/87	31/12/87	261	0.074 (1.303)
01/01/88	31/12/88	261	0.084 (2.381)*
01/01/89	31/12/89	260	0.133 (2.150)*
01/01/90	31/12/90	261	0.034 (1.545)
01/01/91	31/12/91	261	0.021 (1.330)
01/01/92	31/12/92	262	0.090 (1.060)
01/01/93	31/12/93	261	0.087 (2.569)*
01/01/94	31/12/94	260	0.012 (1.037)
01/01/95	31/05/95	108	0.037 (1.382)

* The autocorrelation figures are statistically significant

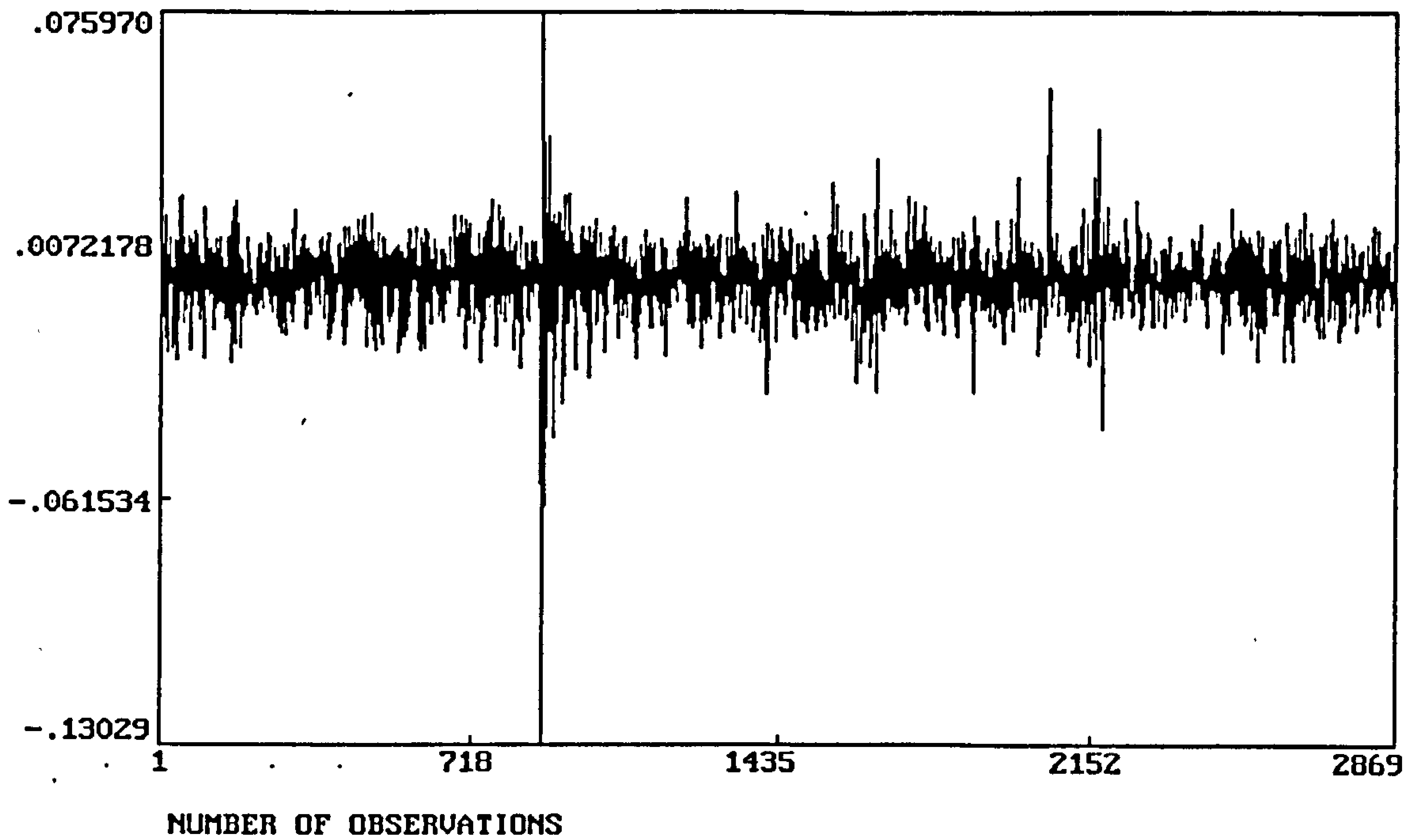
Analysis of the observed price changes series is presented in Table 2.5 and indicates the presence of small positive first-order auto-correlation. Over the entire sample period, the auto-correlation of index level changes is 0.072. Such a relationship would not be expected in an efficiently functioning market, assuming permissible transaction costs. This behaviour, is consistent with that reported by Miller *et al.* (1994) for the S&P 500 stock index. With the use of intraday data they found the auto-correlation of index level changes to be 0.128 and attribute it to non-synchronous trading. As Fisher (1966) first mentioned the lagged adjustment of a portfolio stock prices to new market information induces positive first-order auto-correlation in the observed index level changes.

The positive auto-correlation in the FTSE 100 index level changes has dropped over the sample period from 0.133 in the first year, 1984, to only 0.037 in 1995, the last year. As shown in Figure 2.3a the average trading volume of stocks on the LSE for each year has also increased dramatically over the same period. This rise in the stock market trading volume could be responsible for the reduction in the effects of non-synchronous trading on auto-correlation in the index. This is because higher trading volume implies that the shares within the index trade more often reflecting new information. As a result the reported index will suffer less from the problem of non-synchronous trading.

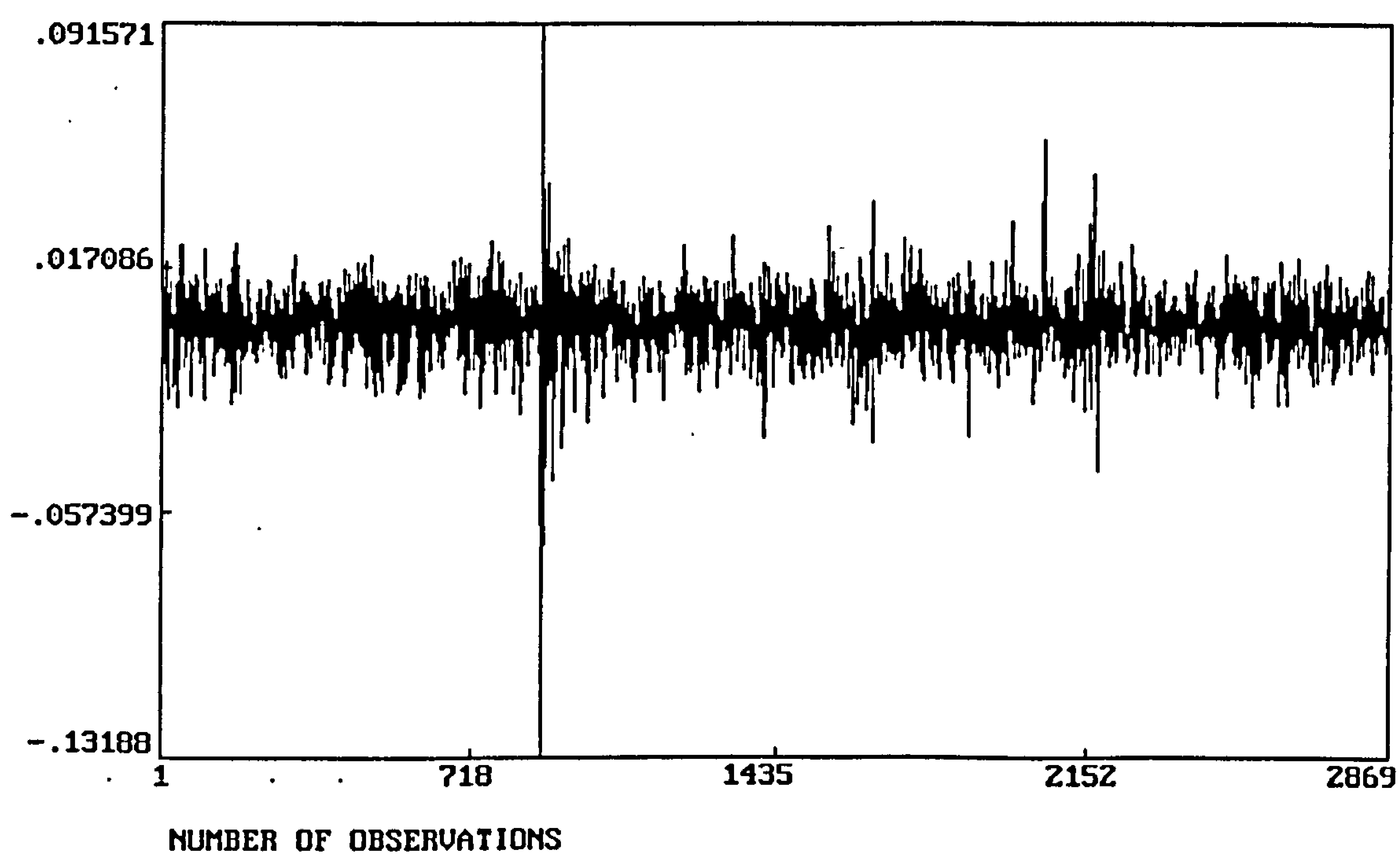
The hypothesis held here is that the auto-correlation that is present in the observed price change series is due to non-synchronous trading rather than pricing inefficiency. In order to test this, we apply the Miller *et al*. modified AR(1) model given by the system (2.12) and (2.13) to the observed price changes series. The true change in the index level is then estimated and shown against the observed one in Figure 2.5. The removal of the non-synchronous trading effects has removed the first-order auto-correlation in the observed index changes. The results of the empirical tests are presented in Table 2.6. For comparison reasons, the results about the observed index price changes showed in Table 2.5 are also presented in Table 2.6.

Figure 2.5[1]

(A) The change in the observed spot index



(B) The change in the adjusted spot index using the Miller *et al.* model.



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[1]The big outlier in the diagrams reflect the October 87 market crash.

Table 2.6

Estimated first-order auto-correlation ($\hat{\rho}_1$) of both observed (s) and adjusted for non-synchronicity FTSE 100 index changes (s*). The sample period extends from June 1, 1984 through May 31, 1995. Figures in parentheses are t statistics. Auto-correlation coefficients are slope coefficients in the regression $y_t = \rho_1 y_{t-1} + e_t$. Heteroscedasticity was detected for some of the sub-samples investigated. In those cases white heteroscedasticity consistent standard errors were used. Reject $H_o : \rho_1 = 0$ at the 5% level of significance if t-value > $|1.960|$.

Period	No. of Obs.	$\hat{\rho}_1(s)$	$\hat{\rho}_1(s*)$
01/06/84 ... 31/05/95	2,869	0.072 (2.653)**	0.582E-3 (0.007)
1984	152	0.133 (2.734)**	0.073 (0.890)
1985	261	0.047 (1.752)	-0.018 (-0.296)
1986	261	0.105 (2.708)**	0.036 (0.589)
1987	261	0.074 (1.303)	0.848E-3 (0.003)
1988	261	0.084 (2.381)**	0.020 (0.332)
1989	260	0.133 (2.150)**	0.065 (1.052)
1990	261	0.034 (1.545)	-0.032 (-0.605)
1991	261	1.021 (1.330)	-0.060 (-1.427)
1992	262	0.090 (1.060)	0.021 (0.245)
1993	261	0.087 (2.569)**	0.026 (0.424)
1994	260	0.012 (1.037)	-0.028 (-1.164)
1995	108	0.037 (1.382)	-0.036 (-0.376)

** The autocorrelation figures are statistically significant

The results presented in Table 2.6 indicate that the application of the AR(1) model for removing the effects of non-synchronous trading remove the auto-correlation dictated in the price change series. For the whole period examined the adjusted stock index changes have first-order auto-correlation of 0.582E-3, while the observed index changes have significant auto-correlation of 0.072. The year-by-year results are on the whole consistent with those of the entire sample period with the adjusted index changes not being auto-correlated. This could be an indication that the observed auto-correlation can be partly attributed to non-synchronous trading. However, it should be noted that part of the auto-correlation removed could be genuine reflecting predictability in the price series.

Having acquired the results from the use of the modified AR(1) model that Miller *et al.* developed in order to remove non-synchronous trading effects we proceed with the application of the Kalman Filter methodology in order to examine whether similar results and conclusions can be reached.

2.4.2 THE SPOT INDEX ADJUSTED WITH THE KALMAN FILTER MODEL

The observation of auto-correlation in the observed price change series reported previously is supported for the price level itself. In a similar fashion to that listed previously the Kalman Filter method is applied to the observed index price series, again to remove the effects of non-synchronous trading. In order to adjust the index for non-synchronicity and acquire the non-synchronous trading adjustment we estimate the system of equations (2.14) and (2.15a,b) using the log of the daily FTSE 100 index price series for the sample period. Quantitative measure of the tracking performance of the observed price level in the FTSE 100 stock index for the period June 1, 1984 through May 31, 1995, is presented in Table 2.7.

Table 2.7

Estimated first-order auto-correlation ($\hat{\rho}_1$) of observed FTSE 100 index (S). The sample period extends from June 1, 1984 through May 31, 1995. Figures in parentheses are t statistics. Auto-correlation coefficients are slope coefficients in the regression $y_t=\rho_1 y_{t-1}+e_t$. Heteroscedasticity was detected for some of the sub-samples investigated. In those cases white heteroscedasticity consistent standard errors were used. Reject H_o : ρ_1 = 0 at the 5% level of significance if t-value > |1.960|.

Period		No. of	$\hat{\rho}_1$(S)
Begins	Ends	Obs.	
01/06/84	31/05/95	2,869	0.999 (1735)*
01/06/84	31/12/84	152	0.994 (72.205)*
01/01/85	31/12/85	261	0.985 (74.767)*
01/01/86	31/12/86	261	0.979 (96.528)*
01/01/87	31/12/87	261	0.990 (118.312)*
01/01/88	31/12/88	261	0.935 (46.067)*
01/01/89	31/12/89	260	0.983 (134.945)*
01/01/90	31/12/90	261	0.980 (89.700)*
01/01/91	31/12/91	261	0.982 (110.113)*
01/01/92	31/12/92	262	0.990 (83.107)*
01/01/93	31/12/93	261	1.008 (139.985)*
01/01/94	31/12/94	260	0.977 (87.774)*
01/01/95	31/05/95	108	0.990 (59.255)*

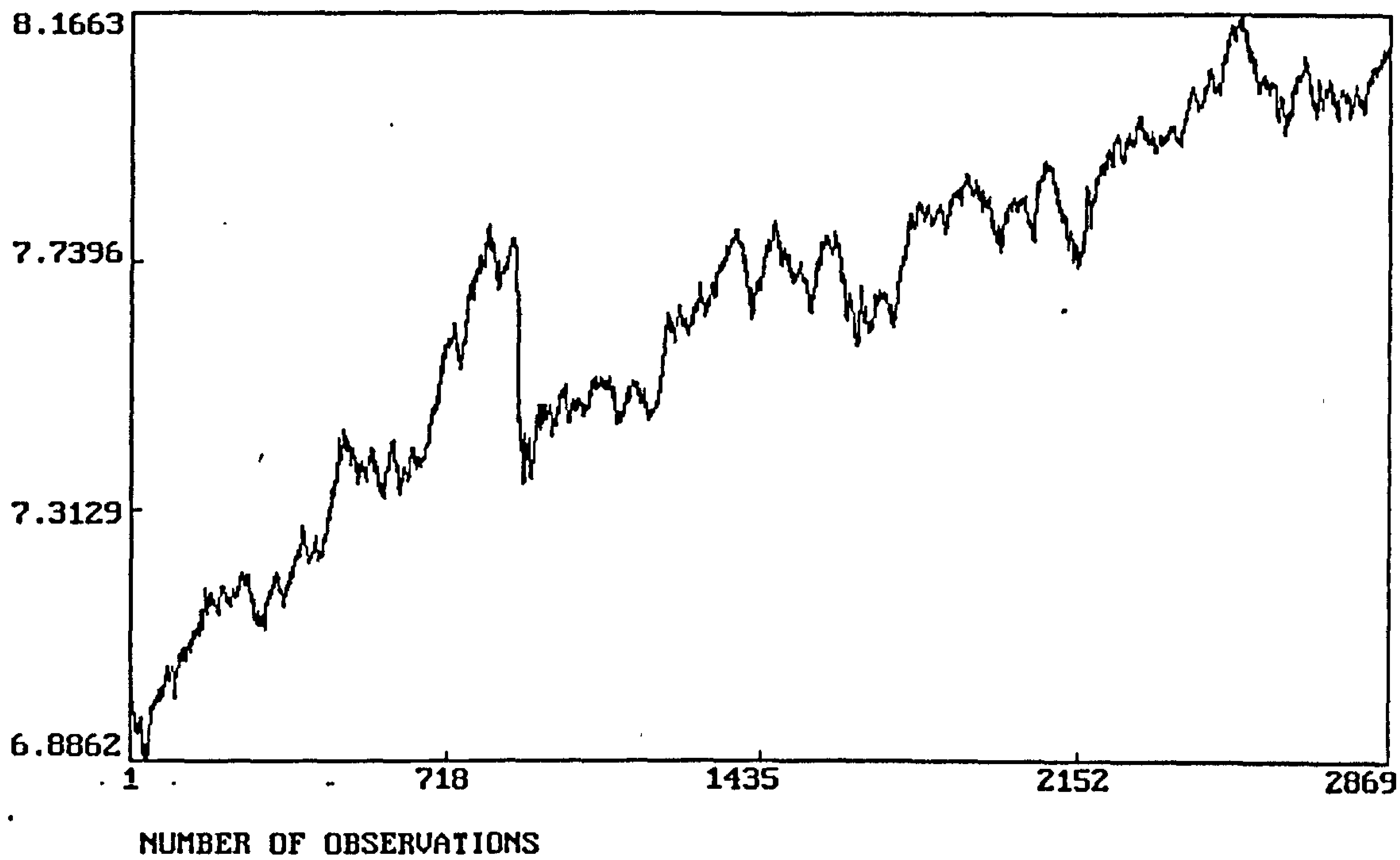
* The autocorrelation figures are statistically significant

Table 2.7 shows that the observed index exhibits significant positive first-order auto-correlation. Over the entire sample period, the auto-correlation of index level is 0.999. The observed auto-correlation is expected given that the index should represent a fair game such that the market's best expectation of the index price in the next period is the current period's value. However, it would be interesting to see whether part of the observed auto-correlation is due to non-synchronous trading or is genuine auto-correlation.

After adjusting for non-synchronous trading, the true stock index level was estimated and is shown against the observed one in Figure 2.6. The removal of the non-synchronous trading effects has not brought significant reduction in the auto-correlation of the stock index. The results of the empirical tests are presented in Table 2.8. For comparison reasons, the results about the observed index price changes showed in Table 2.7 are also presented in Table 2.8.

Figure 2.6

(A) The observed spot index



(B) The adjusted spot index using the Kalman Filter model.

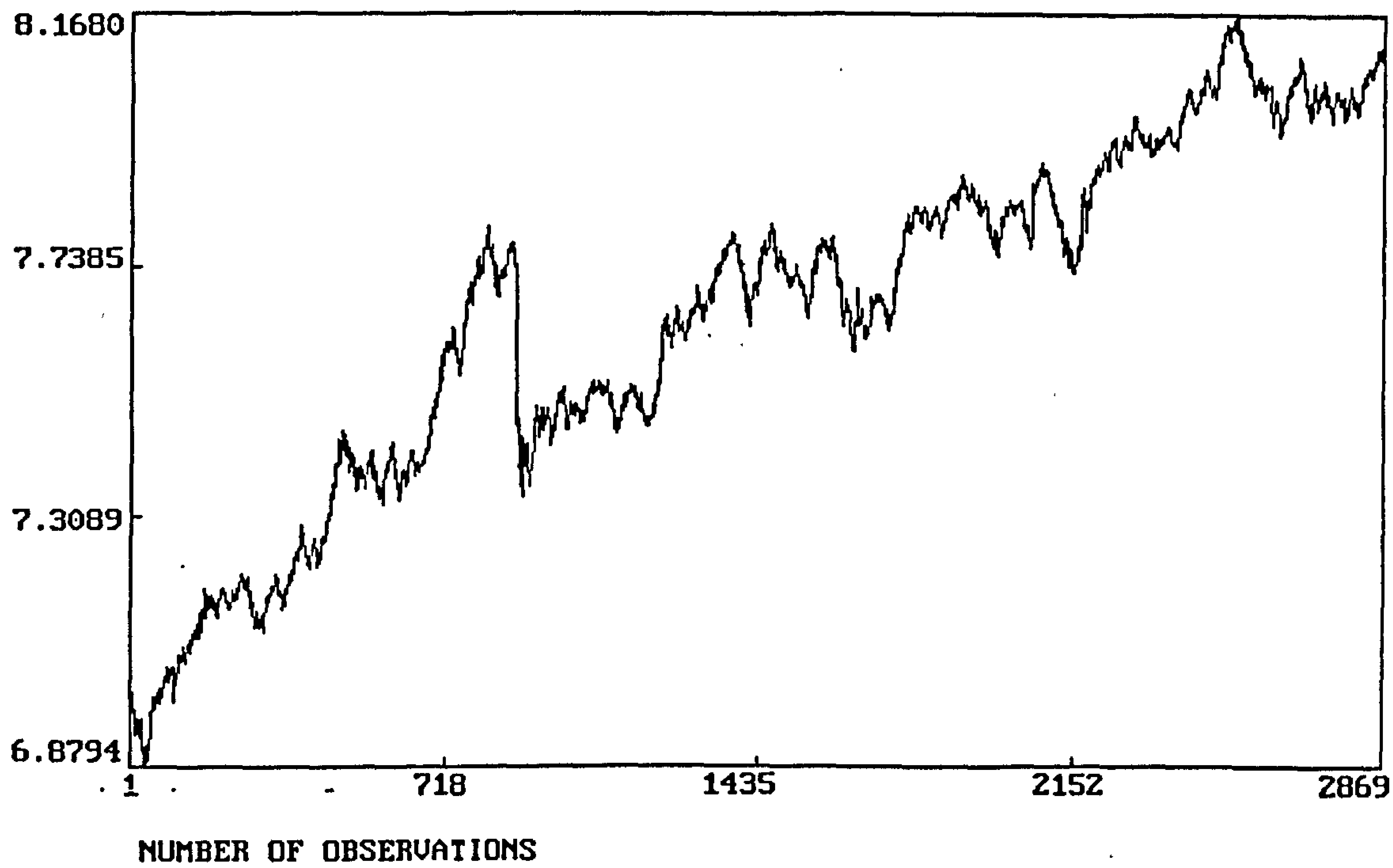


Table 2.8
Estimated first-order auto-correlation ($\hat{\rho}_1$) of both observed (S) and adjusted for non-synchronicity FTSE 100 index (S^*). The sample period extends from June 1, 1984 through May 31, 1995. Figures in parentheses are t statistics. Auto-correlation coefficients are slope coefficients in the regression $y_t=\rho_1 y_{t-1}+e_t$.Heteroscedasticity was detected for some of the sub-samples investigated. In those cases white heteroscedasticity consistent standard errors were used. Reject $H_o : \rho_1 = 0$ at the 5% level of significance if t-value > $|1.960|$.

Period	No. of Obs.	$\hat{\rho}_1(S)$	$\hat{\rho}_1(S^*)$
01/06/84 ... 31/05/95	2,869	0.999 (1735)**	0.998 (840.967)**
1984	152	0.994 (72.205)**	0.767 (4.389)**
1985	261	0.985 (74.767)**	0.980 (73.884)**
1986	261	0.979 (96.528)**	0.976 (86.385)**
1987	261	0.990 (118.312)**	0.987 (106.942)**
1988	261	0.935 (46.067)**	0.931 (41.519)**
1989	260	0.983 (134.945)**	0.982 (122.268)**
1990	261	0.980 (89.700)**	0.980 (88.668)**
1991	261	0.982 (110.113)**	0.981 (108.672)**
1992	262	0.990 (83.107)**	0.988 (80.442)**
1993	261	1.008 (139.985)**	1.007 (132.550)**
1994	260	0.977 (87.774)**	0.976 (85.496)**
1995	108	0.990 (59.255)**	0.989 (57.140)**

** The autocorrelation figures are statistically significant

As the results presented in Table 2.8 show, the auto-correlation in the price series was found to be reduced from 0.999 only to 0.998 by the removal of non-synchronous trading. The year-by-year results are on the whole consistent with those of the entire sample period with the price series being only slightly less auto-correlated. Based on the results it appears that the effects of non-synchronous trading are less severe in the U.K. compared to the U.S..

2.4.3 COMPARING BOTH METHODOLOGIES' RESULTS

One of the tests still remaining to take place is the calculation of the non-synchronous trading adjustment which is generated from the models investigated. As mentioned in Garrett (1994)

> "...based on Lo and MacKinlay's (1990a) model of nonsynchronous trading ..., the nontrading adjustment should be a mean zero, serially uncorrelated one."
> (Garrett 1994, p 16)

Consequently, both the Miller *et al.* and the Kalman Filter approaches are expected to derive such a series. In particular, a zero-mean, serially uncorrelated adjustment series could be given by the Miller *at al.* modified AR(1) process since it bares similarities with the Lo and MacKinlay (1990a) model and they assume that the non-synchronous trading is serially uncorrelated.

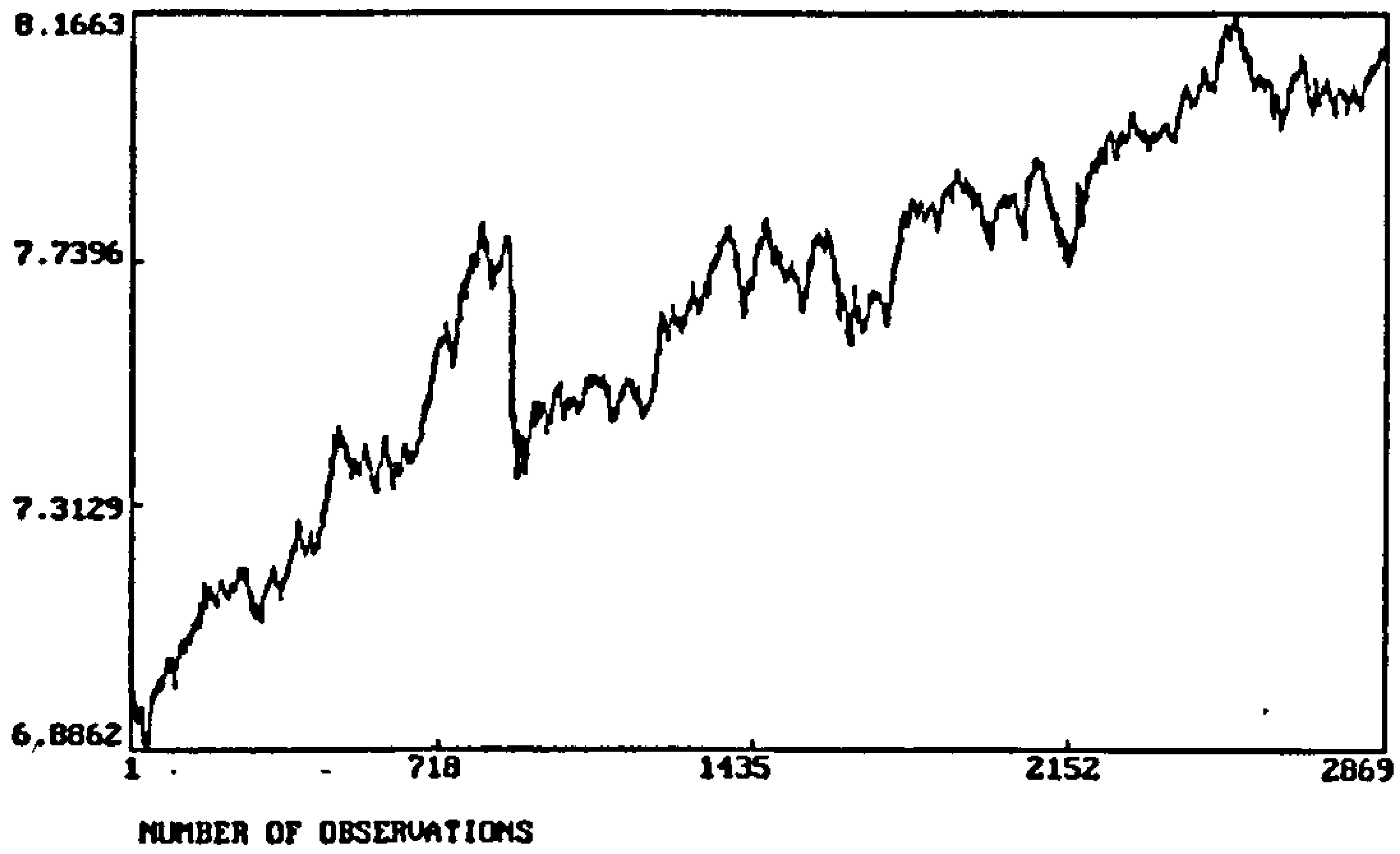
On the other hand, the model which is developed based on the Kalman Filter technique treats the non-synchronous trading adjustment, u_t shown in equation (2.14), as an error term which is from the start assumed to be of zero-mean and serially uncorrelated. After estimating both adjustment series they will be examined for serial correlation and the results from the two different models will be compared.

We begin with the estimation of the non-synchronous trading adjustment generated by the Miller *et al.* model. Since their model investigates price changes the value of the price series p^*_t is derived according to the expression described by equation (2.16). In order to acquire the series, a value of the price at time 0, p^*_o, is needed. The best value that can be used is the corresponding value from the price series, S^* which is derived from the Kalman Filter model in the system (2.14) and (2.15a,b). There is an apparent upward trend in the price series of the FTSE 100 index as shown in Figure 2.6a which justifies the use of the trend component, $n\bar{r}^o$, in equation (2.16).

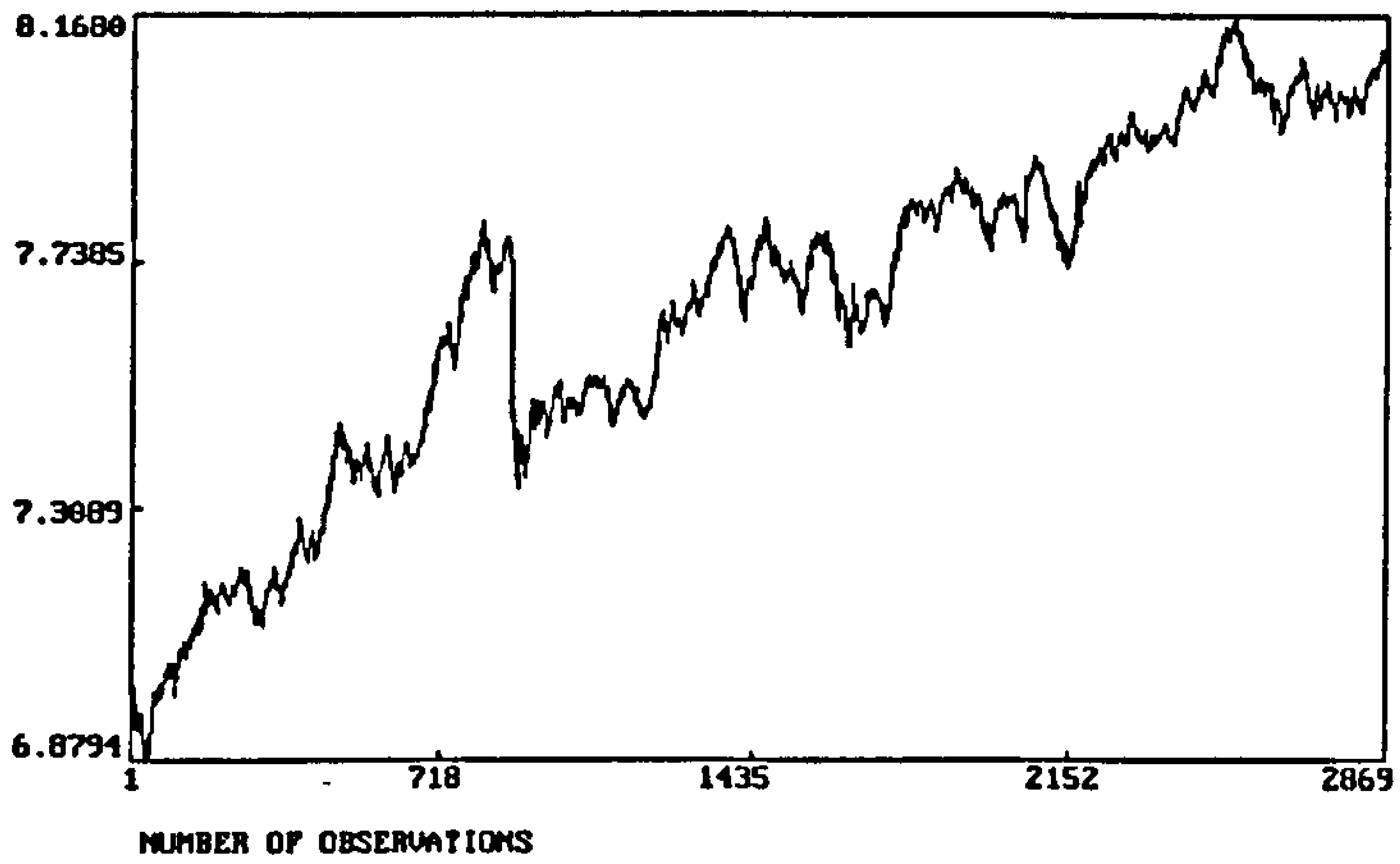
The adjusted for non-synchronicity price series of the FTSE 100 index, P^*, from the Miller *et al.* model, is plotted in Figure 2.7 against the observed one and the adjusted one with the Kalman Filter method. The similar behaviour of the series can also be seen in Table 2.9, which exhibits the statistics estimated for these series. As shown, all the series are very similar with the average value being the same, 7.653. The similarity is further exhibited in the correlation coefficients which are very high for all cases. Table 2.10 exhibits the results after examining the series for first-order auto-correlation. For comparison reasons, Table 2.10 also shows the auto-correlation results of the observed index series and the adjusted series acquired with the Kalman Filter model.

Figure 2.7

(A) The observed spot index



(B) The adjusted spot index using the Kalman Filter model.



© The adjusted spot index using the Miller *et al.* model.

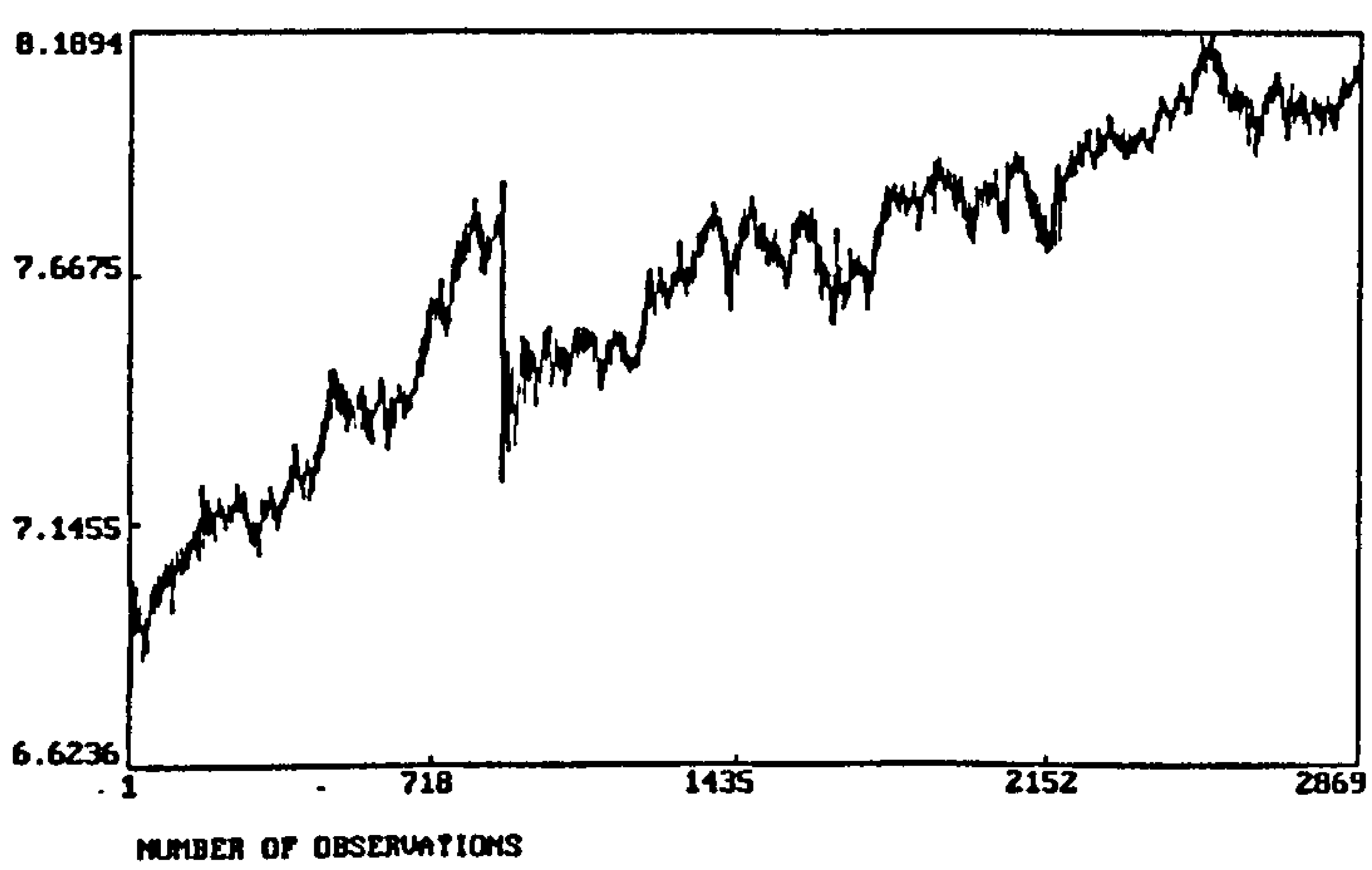
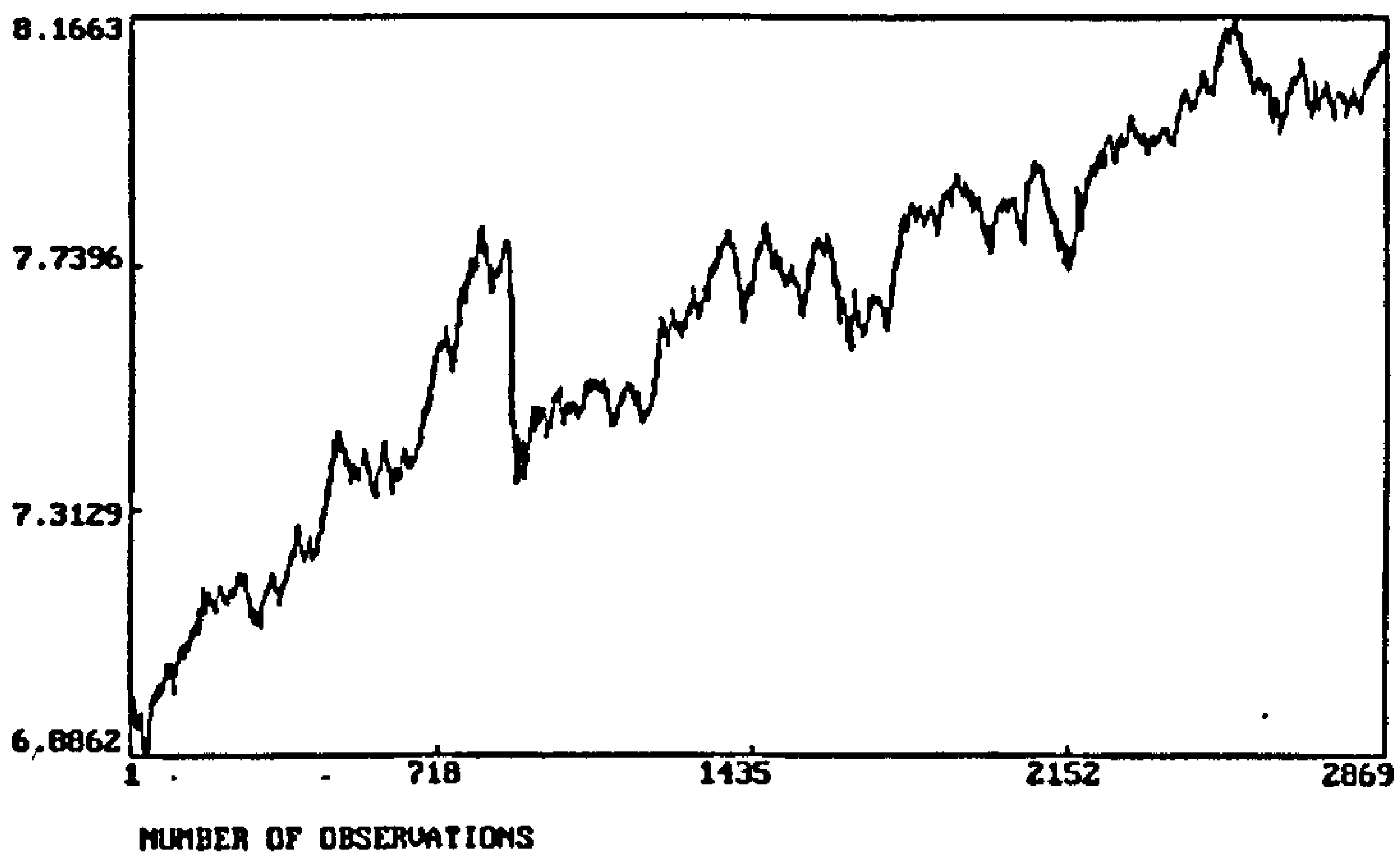
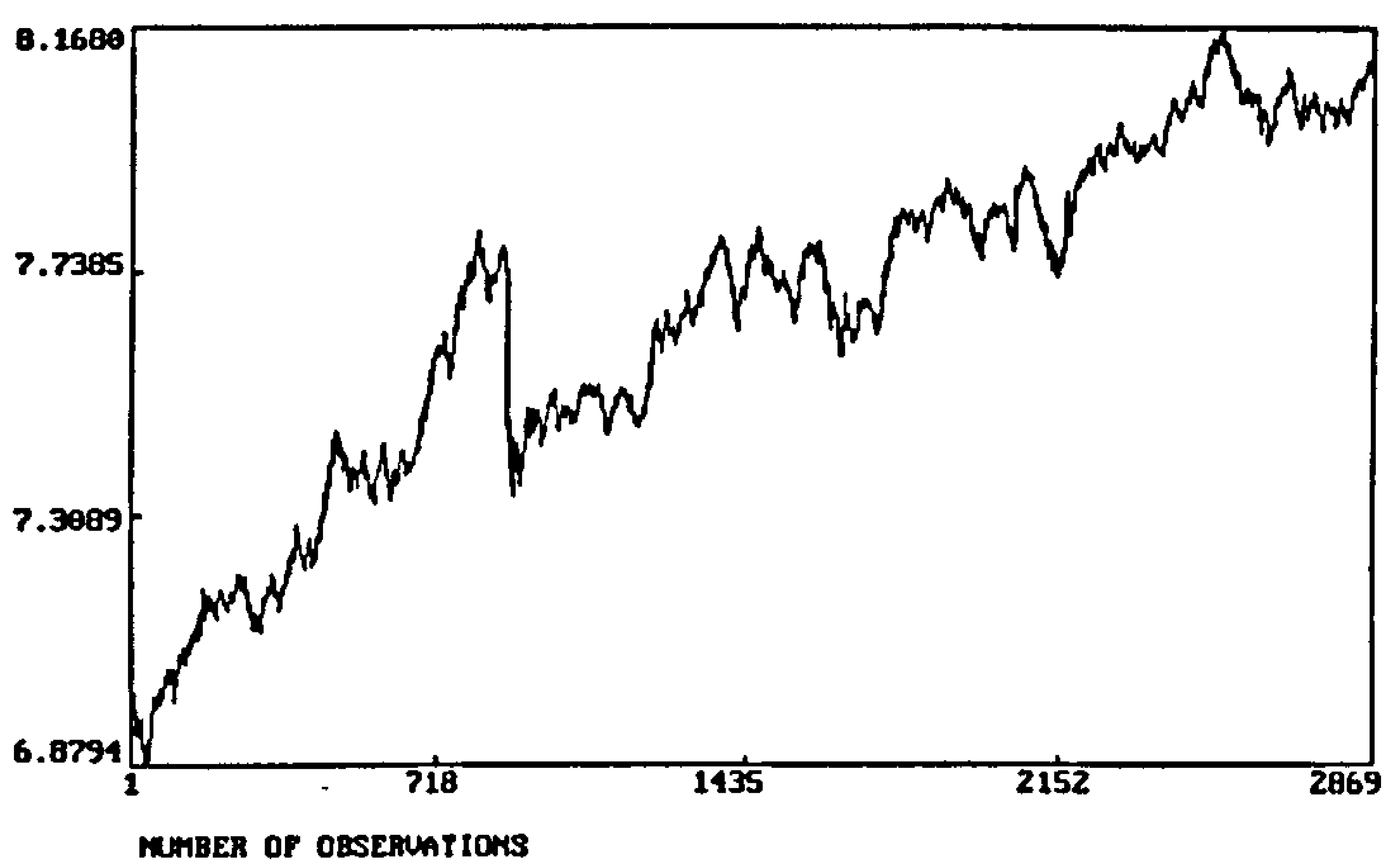


Figure 2.7

(A) The observed spot index



(B) The adjusted spot index using the Kalman Filter model.



© The adjusted spot index using the Miller *et al.* model.

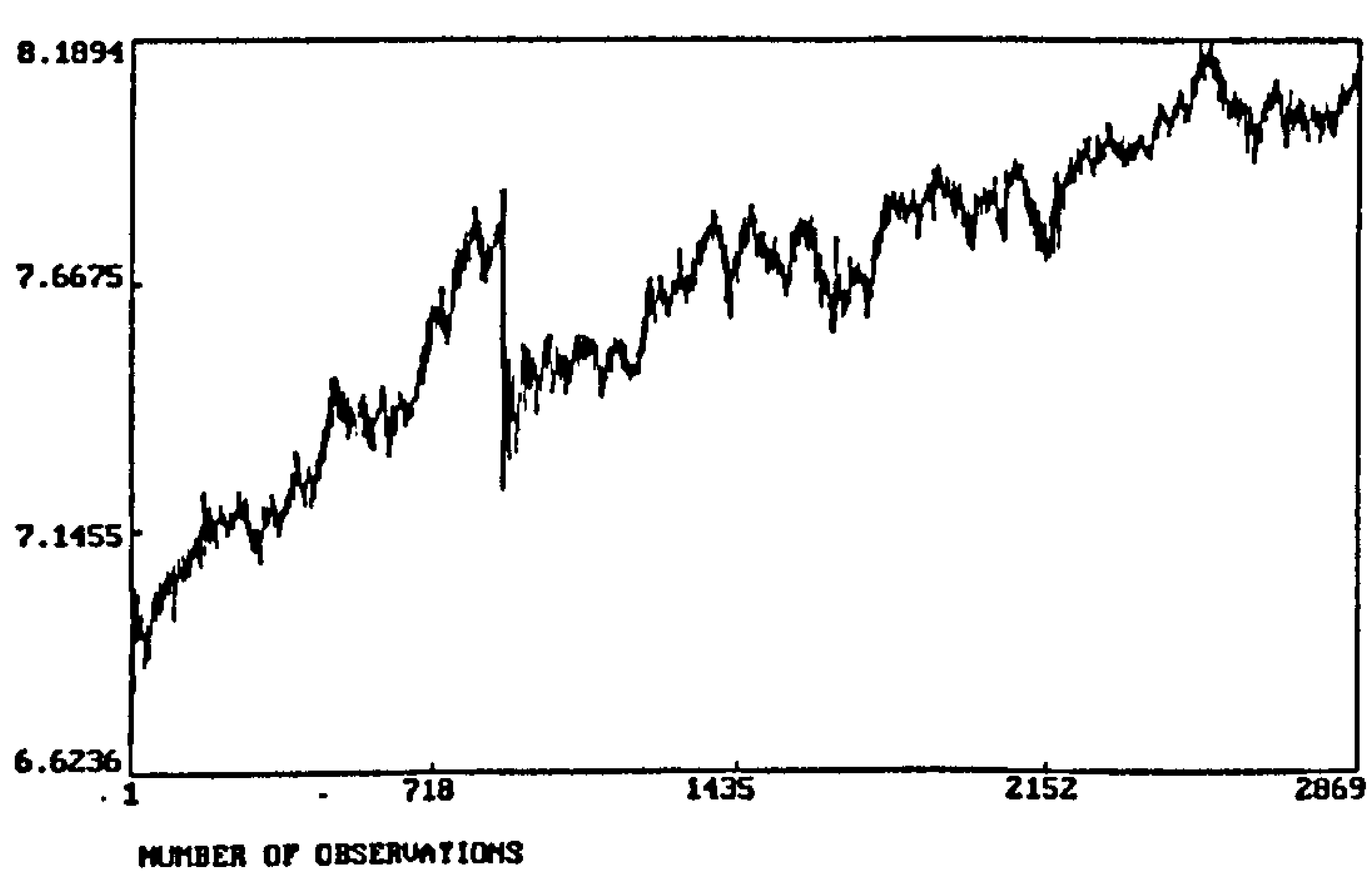


Table 2.9

Summary statistics of the observed spot index S, the adjusted for non-synchronicity through Kalman Filter Spot Index S* and the adjusted for non-synchronicity through Miller et al. Spot Index P*. The sample period has 2,869 observations and covers the period 01/6/84 - 31/5/95.

VARIABLES	S	S*	P*
MAXIMUM	8.166	8.168	8.189
MINIMUM	6.886	6.879	6.624
MEAN	7.653	7.653	7.653
STD.DEVIATION	0.305	0.305	0.306

ESTIMATED CORRELATION COEFFICIENTS	
S vs S*	0.999
S vs P*	0.997
S* vs P*	0.999

Table 2.10

Estimated first-order auto-correlation ($\hat{\rho}_1$) of both observed (S) and adjusted for non-synchronicity FTSE 100 index acquired from both the Kalman Filter, S^* and Miller *et al.*, P^*, models. The sample period extends from June 1, 1984 through May 31, 1995. Figures in parentheses are t statistics. Auto-correlation coefficients are slope coefficients in the regression $y_t=\rho_1 y_{t-1}+e_t$. Heteroscedasticity was detected for some of the sub-samples investigated. In those cases white heteroscedasticity consistent standard errors were used. Reject $H_o : \rho_1 = 0$ at the 5% level of significance if t-value > $|1.960|$.

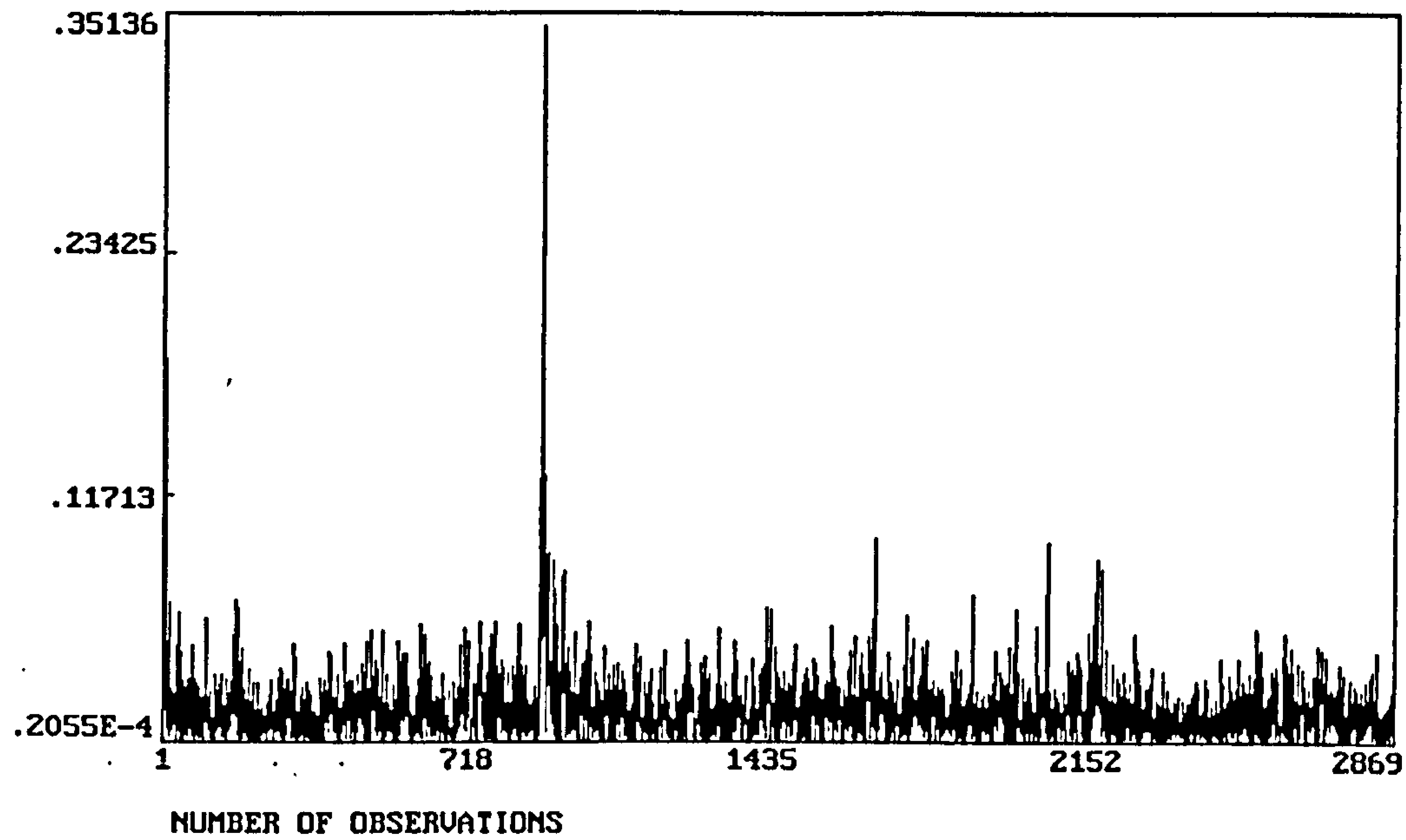
Period	No. of Obs.	$\hat{\rho}_1(S)$	$\hat{\rho}_1(S^*)$	$\hat{\rho}_1(P^*)$
01/06/84 ... 31/05/95	2,869	0.999 (1735)**	0.998 (840.967)**	0.992 (424.739)**
1984	152	0.994 (72.205)**	0.767 (4.389)**	0.730 (5.613)**
1985	261	0.985 (74.767)**	0.980 (73.884)**	0.802 (21.205)**
1986	261	0.979 (96.528)**	0.976 (86.385)**	0.847 (24.471)**
1987	261	0.990 (118.312)**	0.987 (106.942)**	0.890 (20.486)**
1988	261	0.935 (46.067)**	0.931 (41.519)**	0.550 (10.616)**
1989	260	0.983 (134.945)**	0.982 (122.268)**	0.916 (38.300)**
1990	261	0.980 (89.700)**	0.980 (88.668)**	0.831 (24.276)**
1991	261	0.982 (110.113)**	0.981 (108.672)**	0.897 (28.031)**
1992	262	0.990 (83.107)**	0.988 (80.442)**	0.830 (22.861)**
1993	261	1.008 (139.985)**	1.007 (132.550)**	0.936 (39.358)**
1994	260	0.977 (87.774)**	0.976 (85.496)**	0.815 (22.905)**
1995	108	0.990 (59.255)**	0.989 (57.140)**	0.829 (16.094)**

** The autocorrelation figures are statistically significant

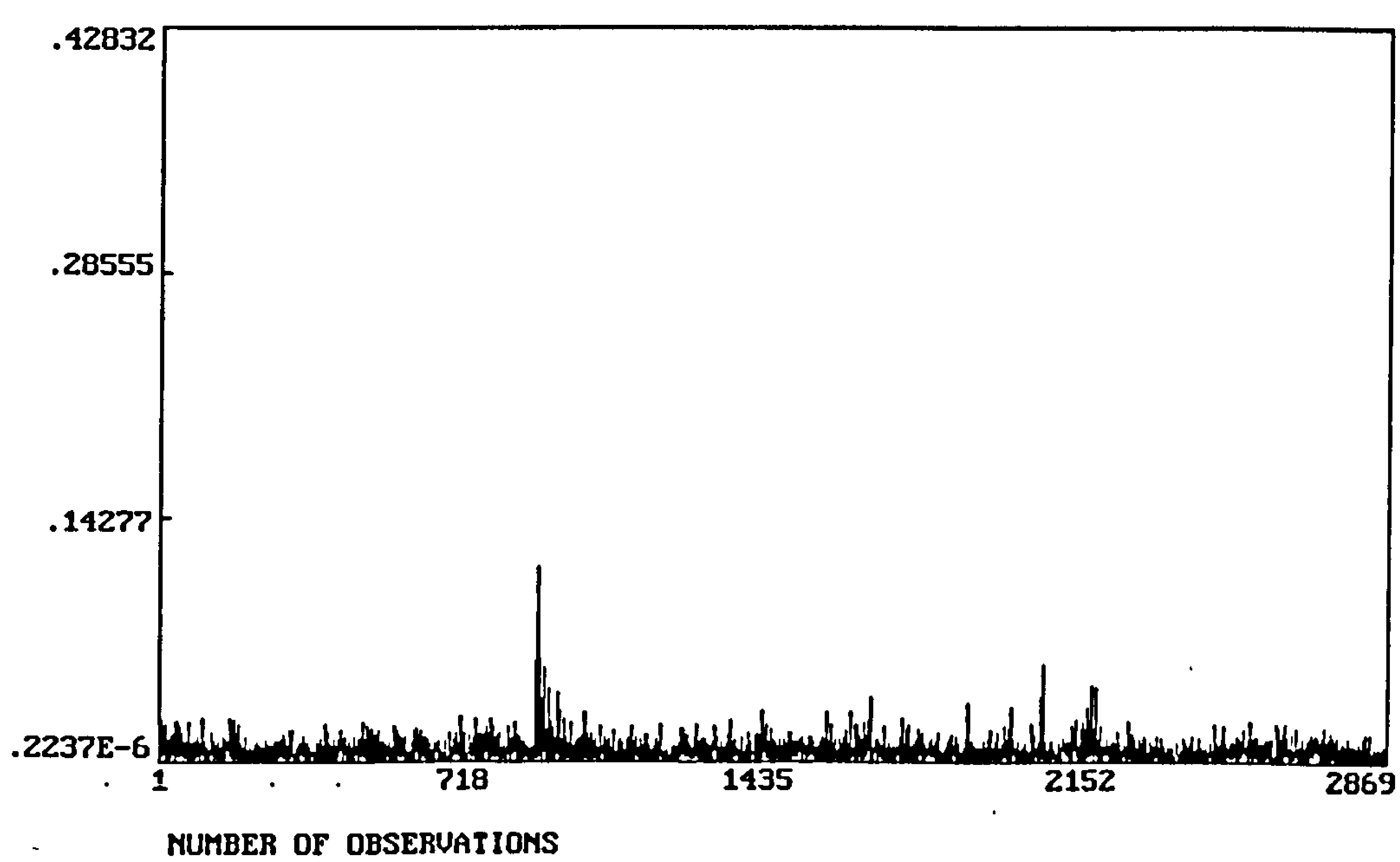
As shown in Table 2.10 the index series adjusted with the the application of the Miller *et al.* model, P^*, experiences lower auto-correlation than the Kalman Filter produced index, S^*. Such a result indicates that the non-synchronous trading removed is more in the case of P^*, still though not a lot different. These results are confirmed by the presentation of the absolute values of the non-synchronous trading adjustments derived from the two methodologies and plotted in Figure 2.8.

Figure 2.8[1]

(A) The absolute value of the non-synchronous trading adjustment generated using the Miller, Muthuswamy and Whaley method for the FTSE 100 Index.



(B) The absolute value of the non-synchronous trading adjustment generated using the Kalman Filter method for the FTSE 100 Index.



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[1]The big outlier in the diagram reflects the October 87 market crash.

As can be seen from the graphs, the non-synchronous trading adjustment is small throughout the whole sample in both cases (the mean of the absolute value of the adjustment and the absolute value of the adjustment relative to the index for the Kalman Filter case are 0.007 and 0.0009 respectively and 0.016 and 0.002 for the Miller *et al.* case). We also examine the correlation between the two adjustments which is found to be 0.80. As a result, we could say that both methodologies produce close results about the non-synchronous trading adjustment.

However, what is left to examine is whether the non-synchronous trading adjustment series derived are zero-mean, serially uncorrelated series. Lo and MacKinlay (1990a) considered the problem of non-synchronous trading on portfolio returns using the returns of twenty portfolios for daily, weekly and monthly data from 1962 to 1987. They state that if the probability for a security of not trading at time t is independent of the probability for the security of not trading in any different time, then the non-synchronous trading adjustment should be serially uncorrelated. Although we could allow for dependence in the probability of non-synchronous trading, Lo and MacKinlay comment about it as follows:

> "...several experiments indicate the degree of persistence in nontrading required to yield weekly autocorrelations of 30 percent is empirically implausible."
> (Lo and MacKinlay 1990a, p 204)

Table 2.11 presents the auto-correlation properties of the estimated adjustment for both of the models.

Table 2.11

Estimated auto-correlations ($\hat{\rho}_I$) of the non-synchronous trading adjustment acquired with the use of both the Kalman Filter and the Miller, Muthuswamy and Whaley AR(1) models. The sample period extends from June 1, 1984 through May 31, 1995. Figures in parentheses are t statistics. The auto-correlation coefficients are slope coefficients in the regression $y_t = \rho_1 y_{t-1} + e_t$. Heteroscedasticity was detected for some of the sub-samples investigated. In those cases white heteroscedasticity consistent standard errors were used. Reject $H_o : \rho_1 = 0$ at the 5% level of significance if t-value > $|1.960|$.

Auto-correlation Coefficients	Kalman Filter Non-synchronous Trading Adjustment	Miller *et al.* Non-synchronous Trading Adjustment
ρ_1	0.015	-0.498
	(0.210)	(-6.877)*
ρ_2	-0.058	-0.314
	(-1.069)	(-4.158)*
ρ_3	-0.041	-0.198
	(-1.145)	(-3.614)*
ρ_4	0.036	-0.067
	(1.740)	(-1.980)*

* The autocorrelation figures are statistically significant

The results presented in Table 2.11 show that the Miller, Muthuswamy and Whaley (1994) method does not produce a serially uncorrelated non-synchronous trading adjustment as implied by the Lo and MacKinlay's (1990a) non-synchronous trading model. On the contrary after removing the non-synchronous trading effects the adjustment is still, both persistently and highly serially correlated. On the other hand, the Kalman Filter model derives a serially uncorrelated adjustment consistent with the Lo and MacKinlay's (1990a) implications. As a consequence, the adjusted for non-synchronicity series required for the empirical investigation of this thesis is going to be the one derived based on the use of the Kalman Filter method.

2.4.4 THE IMPLIED INDEX SERIES

We complete the empirical investigation of this chapter by adopting a different route in order to produce a reliable and accurate spot series referred to as the Implied Index derived from the use of the put option contracts. As explained before, the use of this series is expected to be more reliable mainly because it overcomes the problem of non-synchronous trading without having to rely on any method for adjusting the data. As a result, this empirical work is of particular interest and importance. Since the existent literature has not applied a similar method when dealing with the problem of non-synchronous trading our findings represent a contribution to the literature which provides some useful and interesting insights into the issue of mispricing.

The Implied index series derived is illustrated in Figure 2.9, while, for comparison reasons, we also plot in Figures 2.10 and 2.11[1] the spot series which is both unadjusted and adjusted for non-synchronicity (with the use of Kalman Filter). The period examined is March 3, 1992 to May 31, 1995. The figures seem to suggest that the three series are very closely related. Table 2.12 presents the first-order auto-correlation coefficient of the implied index series. For comparison reasons the Table also shows the first-order auto-correlation coefficients of the observed

[1]The series are plotted separately for clarity of illustration given the closeness of the series to each other and automatic scaling of graphs.

spot index price series (S) and the spot index price series adjusted for non-synchronicity with the Kalman Filter method (S^*). The comparison between the three different series is taken further by displaying the statistics estimated in Table 2.13. The results suggest that the series examined are very closely related with a high correlation of 0.999. In addition to this their average values are very close being 2941.2 for the unadjusted series, 2933.4 for the implied index series and 2942.1 for the adjusted series. However, Table 2.12 shows that although the adjusted for non-synchronicity series exhibits lower auto-correlation than the observed series, the implied index price series experiences the lowest auto-correlation among the three series. As a result, although, the three series of spot prices exhibit similarities, they are not identical and could lead to different conclusions in the analysis of mispricing and arbitrage opportunities. The latter issues are extensively investigated in the chapters to follow.

Figure 2.9
The Implied Index based on the Put
FTSE 100 Index Option's for the period 13/03/92-31/05/95.

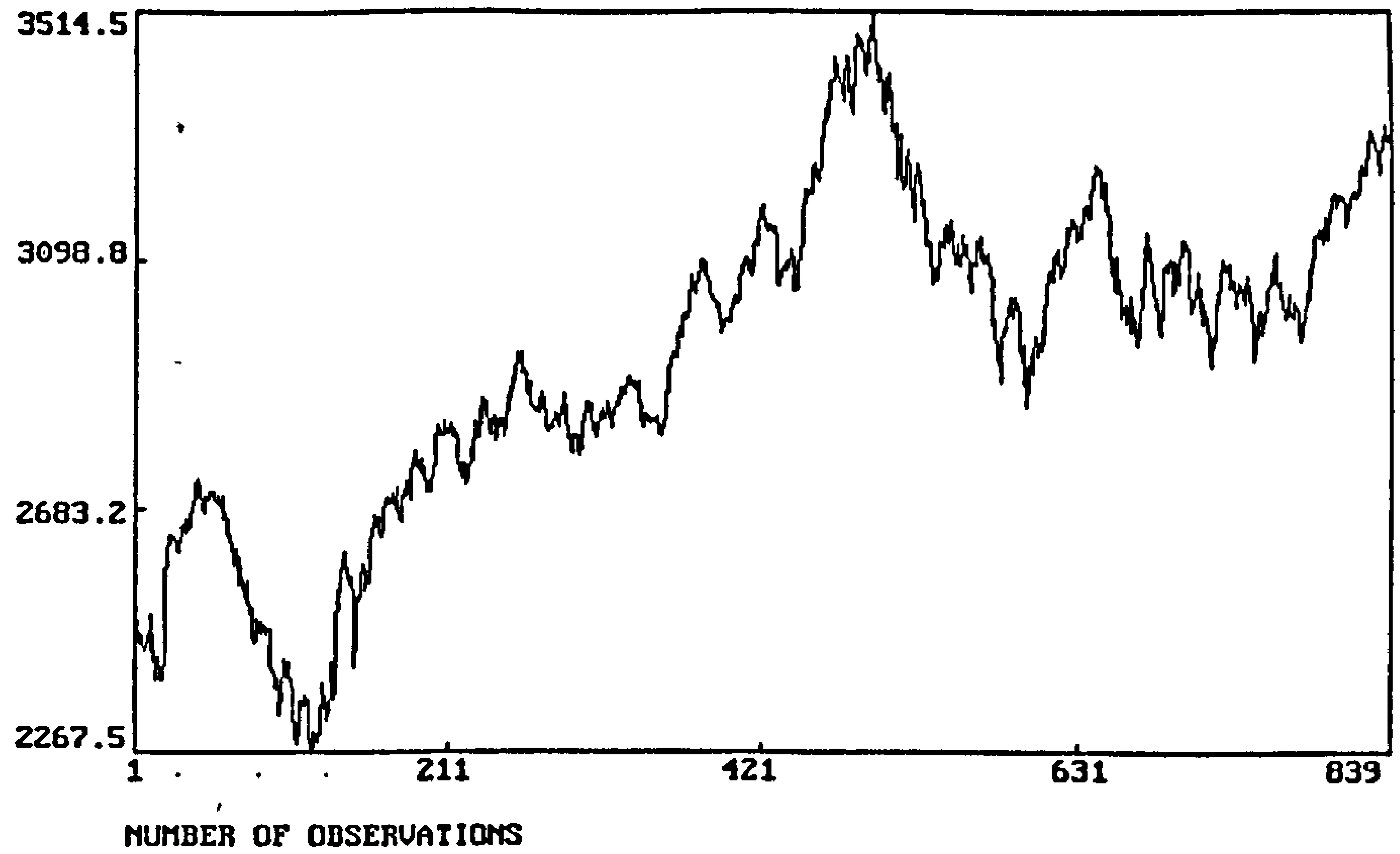

Figure 2.10
The unadjusted for non-synchronicity FTSE 100 Spot Index
for the period 13/03/92 - 31/05/95.

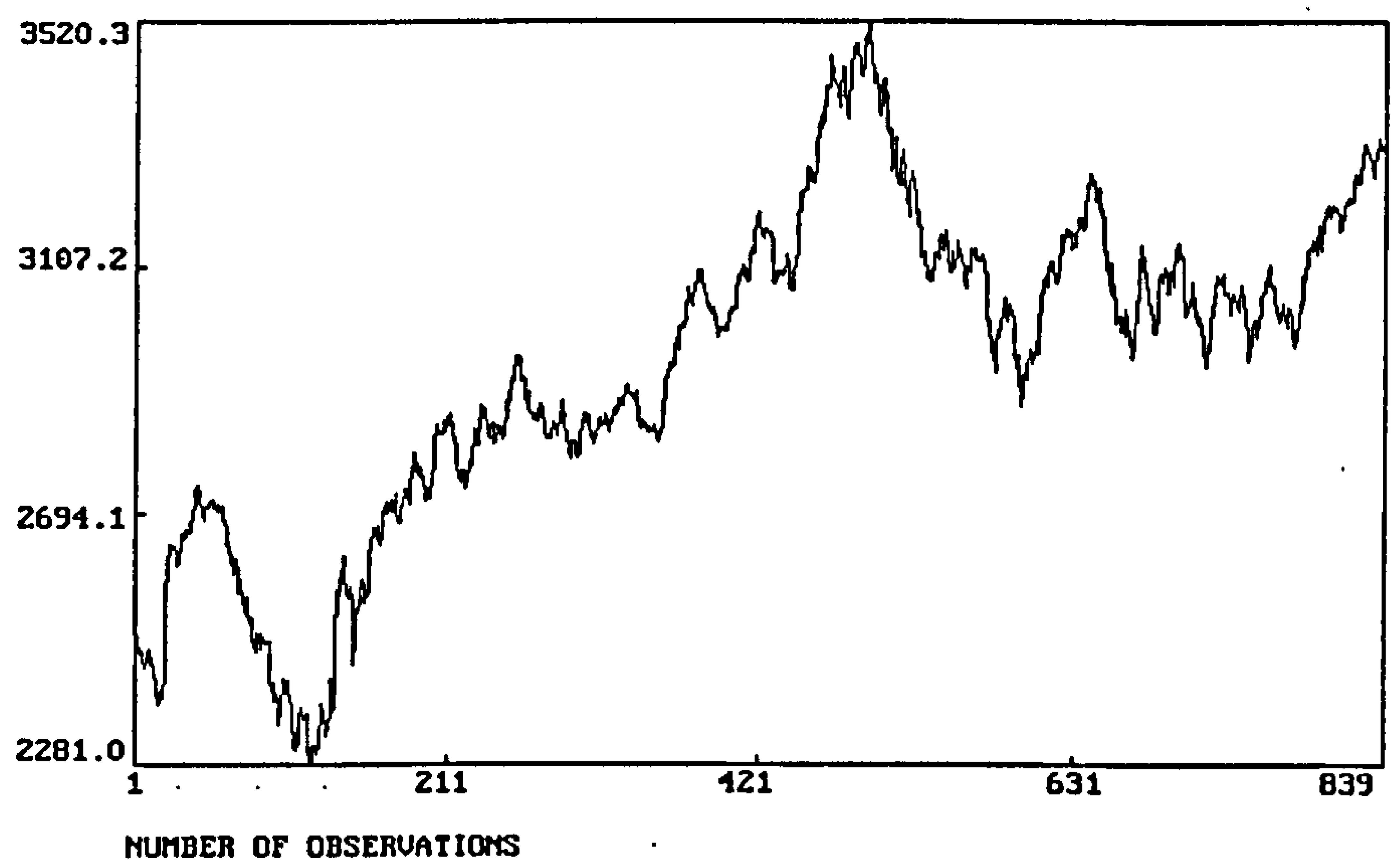

Figure 2.11
The adjusted for non-synchronicity (through Kalman Filter)
FTSE 100 Spot Index for the period 13/03/92 - 31/05/95.

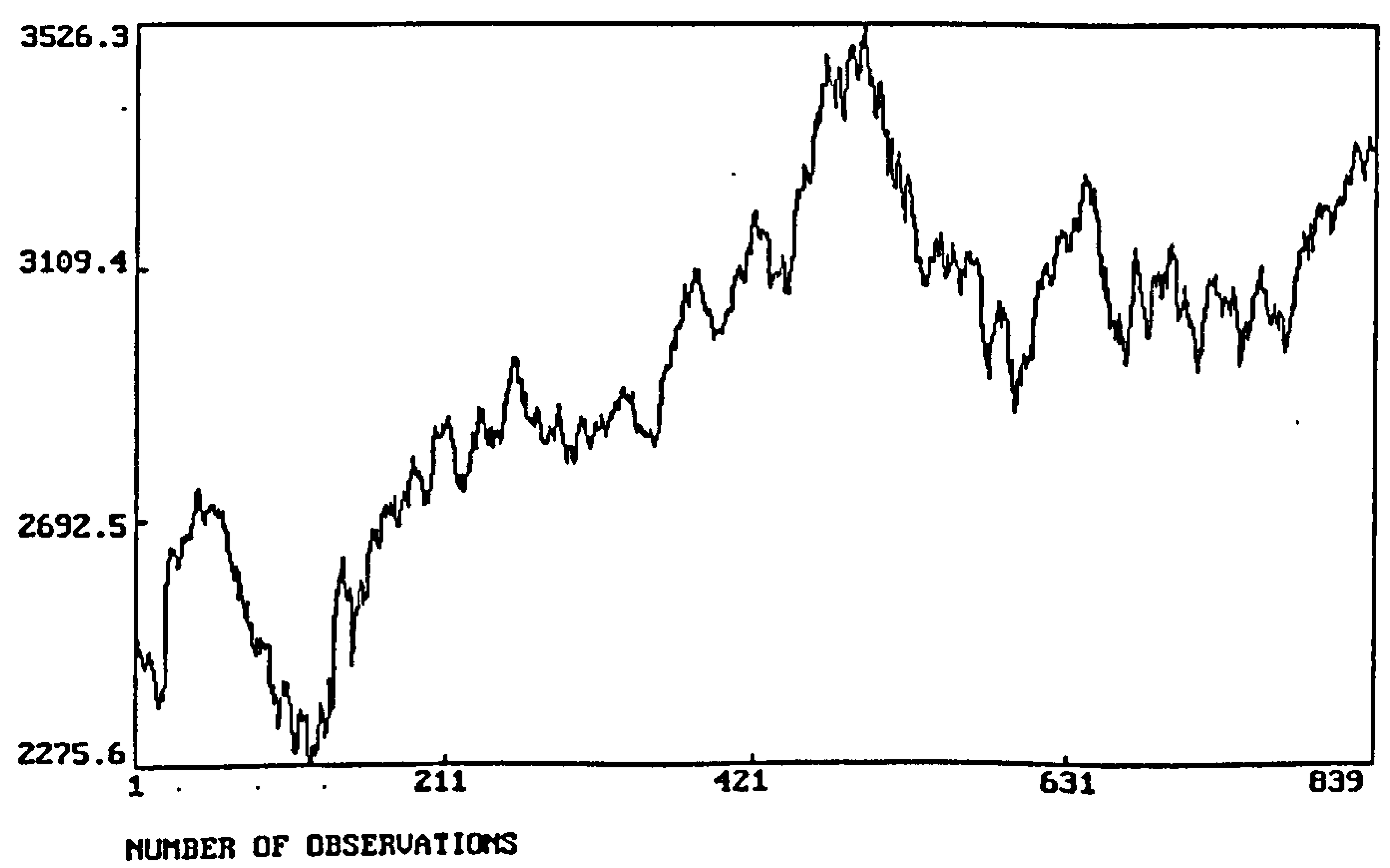

Table 2.12

Estimated first-order auto-correlation ($\hat{\rho}_1$) of the observed (S), the adjusted for non-synchronicity (through Kalman Filter) FTSE 100 index (S^*) and the Implied index (D). The sample period extends from March 13, 1992 through May 31, 1995. Figures in parentheses are t statistics. Auto-correlation coefficients are slope coefficients in the regression $y_t = \rho_1 y_{t-1} + e_t$. Reject H_o: $\rho_1 = 0$ at the 5% level of significance if t-value > $|1.960|$.

Period	No. of Obs.	$\hat{\rho}_1(S)$	$\hat{\rho}_1(S^*)$	$\hat{\rho}_1(D)$
13/03/92 ... 31/05/95	839	0.996 (338.487)**	0.995 (328.544)**	0.994 (297.973)**
1992	210	0.992 (84.002)**	0.991 (81.327)**	0.987 (73.319)**
1993	261	1.008 (139.985)**	1.007 (132.550)**	1.005 (129.757)**
1994	260	0.977 (87.774)**	0.976 (85.496)**	0.971 (74.029)**
1995	108	0.990 (59.255)**	0.989 (57.140)**	0.993 (51.204)**

** The autocorrelation figures are statistically significant

Table 2.13

Summary statistics of the estimated Implied Index, the unadjusted for non-synchronicity Spot Index and the adjusted for non-synchronicity (through Kalman Filter) Spot Index. The sample period has 839 observations and covers the period 13/3/92 - 31/5/95.

VARIABLES	IMPLIED INDEX	UNADJUSTED SPOT INDEX	ADJUSTED SPOT INDEX
MAXIMUM	3514.5	3520.3	3526.3
MINIMUM	2267.5	2281.0	2275.6
MEAN	2933.4	2941.2	2942.1
STD.DEVIATION	270.128	270.598	271.552

ESTIMATED CORRELATION COEFFICIENTS	
IMPLIED SPOT vs UNADJUSTED SPOT	0.999
IMPLIED SPOT vs ADJUSTED SPOT	0.999
UNADJUSTED SPOT vs ADJUSTED SPOT	0.999

A final point in the empirical investigation of this chapter is the presentation of the summary statistics and the first-order auto-correlation of the spot price series estimated with the Miller *et al.* (1994) approach for the smaller sample of 839 observations. The results are shown in Table 2.14. When comparing the results to those of the other series analysed for the same sample period we find that even the spot series based on the Miller *et al.* model is very similar to the other series and they are all highly correlated. In addition, the Miller *et al.* Index series exhibits the lowest first-order auto-correlation among the series examined. On the other hand, the adjusted series through Kalman filter appears to be more closely related to the Implied index series than the Miller *et al.* case. The Implied index, being estimated without the need of any adjusting methods, is expected to be a better and more reliable measure. Furthermore, as shown in section 2.4.3, unlike the Kalman filter case, the Miller *et al.* non-synchronous trading adjustment is not a zero-mean, serially uncorrelated series as implied by the Lo and MacKinlay's (1990a) model.

Table 2.14

Summary statistics and first-order auto-correlation of the adjusted for non-synchronicity FTSE 100 index series acquired from the Miller *et al.* model. The sample period has 839 observations and covers the period 13/3/92-31/5/95.Figures in parentheses are t statistics. Auto-correlation coefficients are slope coefficients in the regression $y_t = \rho_1 y_{t-1} + e_t$. Reject $H_0 : {}_1\rho = 0$ at the 5% level of significance if t-value > |1.960|.

VARIABLES	Miller *et al.* case
MAXIMUM	3602.6
MINIMUM	2239.5
MEAN	2943.2
STD.DEVIATION	275.799

ESTIMATED CORRELATION COEFFICIENTS	
Miller *et al.* case vs Implied Spot	0.992
Miller *et al.* case vs Kalmam filter case	0.992
Miller *et al.* case vs observed spot	0.991

Period	No. of Obs.	$\hat{\rho}_1$(Miller *et al.* case)
13/03/92 ... 31/05/95	839	0.957 (96.762)*
1992	210	0.858 (23.444)*
1993	261	0.943 (40.861)*
1994	260	0.820 (23.410)*
1995	108	0.835 (15.110)*

* The autocorrelation figures are statistically significant

2.5 Summary And Conclusions

The purpose of this chapter is to use daily data on the FTSE 100 index in order to investigate the issue of non-synchronous trading in the index. For that reason we examined the models that have been developed recently with the purpose of removing the effects of non-synchronous trading from the observed stock and index values. However there are drawbacks in these methods. Firstly, the models require assumptions about the process which drives the observed returns when non-synchronous trading effects are detected. By assuming an auto-regressive structure in the returns we are exposed to the danger that genuine auto-correlation might be interpreted as auto-correlation caused by the existence of non-synchronous trading. It could be equally inaccurate, damaging and misleading to ignore non-synchronous trading effects if they are proven to be present and severe, as much as to wrongly account for them. This is also shown in the results where the observed auto-correlation is mainly genuine and not solely the result of non-synchronicity.

A second problem that occurs is that these methods are interested in removing non-synchronous trading effects from observed returns and not price series. However, investigating the existence of arbitrage opportunities between index and index futures market requires the use of an index price series. Models such as Stoll and Whaley (1990) and Miller *et al.* (1994) cannot generate such a series and in order to use their return series we would have to make assumptions about a starting value in the adjusted, real price series which could end to be incorrect.

Among these existing models which remove non-synchronicity, the un-observed components model applied with the use of Kalman Filter appears to be more appropriate for this thesis by producing an adjusted price series instead of returns. The subject investigated in this thesis requires price series and not returns. Although it is possible to derive a price series from returns, the problem which arises is the need of an initial value to start the series from. Finally, although this method is closely related to the Harris's (1989a) model, it does not require the same immense amount of data.

However, for comparison reasons, we tested both the model by Miller, Muthuswamy and Whaley (1994) (which produces a returns series) and the un-observed components model and found that only the latter generates a serially uncorrelated adjustment series as also implied in the Lo and MacKinlay (1990a) study. Consequently, the Kalman Filter model is more appropriate for the production of the true FTSE 100 index price series which will then be used in the following chapters for further investigation.

Nevertheless, the non-synchronous trading adjustment estimated with both models is found to be small. This finding leads to the conclusion that non-synchronous trading in the U.K. for the FTSE 100 index is not very severe. This result can be justified by the fact that the majority of the shares that comprise the index represent big companies, therefore, they are expected to trade more frequently. In addition to this, the number of shares that the index comprises is very small, only one hundred, which makes it more likely for them to trade frequently. Even in the U.S., research has shown that when the index is smaller, such as the MMI which comprises only twenty shares in contrast to S&P 500 index, there is less non-synchronous trading problem (Stoll and Whaley 1990).

If we compare the results found for the U.K. with those found for the U.S. we see that the non-synchronous trading effects are more significant in the U.S. even though they do not fully explain the observed behaviour of the subjects being under investigation. More specifically, Stoll and Whaley (1990) who investigated the lead-lag relationship between index futures contracts and stocks in the U.S. found that non-synchronous trading has little effect. On the other hand, Miller, Muthuswamy and Whaley (1994) for the U.S. market experienced a significant reduction of the serial correlation in the basis changes after removing the non-synchronous trading effects from the observed stock index. Harris (1989a) who tried to explain what happened during the market crash in October 1987 shows that non-synchronous trading, by itself, cannot account for the observed autocorrelation in daily index returns. Finally, Antoniou and Garrett (1993) who analyse the pricing relationship between stock index and index futures in the U.K. during the stock market crash of October 1987, reach similar results to Harris (1989a). Since it is not clear the degree of the effect of the non-synchronous trading problem on the examination of mispricing and arbitrage, this chapter produced the Implied Index from the use of American put FTSE 100 options. This approach overcomes the problem (small or large) of non-synchronous trading without having to rely on any methods for adjusting the data and exhibits the lowest auto-correlation than the observed spot series and the adjusted for non-synchronicity spot price series.

The empirical work presented in this chapter is the first step in modelling the daily pricing relationship between the FTSE 100 index and the FTSE 100 index futures contract. Having accounted for the non-synchronous trading effects from the FTSE 100 stock index price series we continue in the following chapters using the unadjusted and adjusted for non-synchronicity spot price series as well as the implied index series so as to investigate the issue of the pricing of the index futures contracts.

CHAPTER 3

THE ELASTICITY OF SUPPLY OF ARBITRAGE AND PRICE DOMINANCE.

3.1 INTRODUCTION

Futures markets are generally accepted to have two main functions: discovering prices and transferring price risk. After considering the effects of the presence of non-synchronous trading in the previous chapter, the aim of this chapter is twofold. The first aim focuses on the ability of the stock index spot and futures markets to react to new information by analysing the level of price dominance that occurs between them. The second aim of this chapter is to examine how well the futures market performs its hedging role. This is achieved by investigating the short-run persistence of arbitrage opportunities by estimating the elasticity of supply of arbitrage.

In order for the futures market to fulfil its functions, both the spot and the futures prices have to remain closely related. Arbitrage is important to these functions because arbitrage trading preserves the link between the two markets and restores it whenever spot and futures prices drift apart. To examine this function, we apply two methods for testing for the closeness of the relationship between the two markets, thus allowing us to test for arbitrage in the market. The first method involves calculating the elasticity of supply of arbitrage based on a notion by Garbade and Silber (1983). The greater the elasticity of arbitrage supply, the more willing arbitrageurs will be to enter the market when they detect price discrepancies between spot and futures prices and the more closely those prices will be related, and the more quickly the pricing relations will be restored.

The second way of testing the close relationship between the spot and the futures markets is by looking for price dominance. Price dominance has the ability to indicate the closeness of the two markets by showing that spot and futures markets move together. Both markets would be expected to have a similar reaction to the arrival of information. This expectation can be justified with the fact that both markets trade on the same asset, and are therefore closely related. This is particularly true at maturity of futures contracts when , it could be argued, the Spot and Futures are the same asset and so have a common price. If however, the link between the two markets breaks down, then the usefulness of futures markets for hedging and price discovery will be compromised. Such a situation would occur when arbitrageurs are absent, and the price discrepancy is not traded away through their actions.

As shown in the literature review in chapter one, studies examining the lead-lag relationship between spot and futures markets either use the Granger causality tests or regression analysis of error correction terms. Antoniou and Foster (1994) and Foster (1996) combined both approaches and it is the generalised model that is applied in this chapter for analysing the price dominance between the spot and futures markets and to model the elasticity of supply of arbitrage for the U.K. FTSE 100 index. The analysis begins by using cointegration tests to establish the link between spot and futures markets in the long-run. In addition, given the growing recognition in the literature that the pricing relationship between spot and futures changes over time (see chapter one), we use rolling regression analysis to calculate time-varying values for arbitrage elasticity and price dominance.

Neither the Garbade and Silber model nor the model by Antoniou and Foster (1994) and Foster (1996) have ever before been applied to the U.K. stock index. Therefore, we add an international perspective to the issue by investigating the U.K. market and in particular the financial index market. Furthermore, we account for the effects of non-synchronous trading, where previous studies have not directly considered this problem in the context of price dominance. If non-synchronous trading is present and assuming that its effects are severe, it could be suggested price dominance by one market when, in fact, the markets have the same speed of response to information. Finally, we examine how both the elasticity of supply of arbitrage and the price dominance relationship are affected by the arrival of bad and good news because recent research (Glosten *et al.* (1989)) has found asymmetric response of price changes to the nature of news.

The main results of our research can be summarised as follows. Mispricing does not persist over the long run but is present in the short-run. This is shown by the supply of arbitrage, which despite varying over time is, on the whole, highly inelastic. However, this chapter does not distinguish between profitable and non-profitable arbitrage opportunities, which is the subject of the following chapters. As a result, the observed mispricing could be located within the transaction costs bounds, thus deterring any arbitrage trading from taking place. Moreover, the futures market seems to be effective in its role of price discovery and tends to lead the spot market, but both the size and direction tend to vary over time. Non-synchronous trading does not appear to affect the results, and so dominance cannot be explained by the presence of non-synchronous trading. Finally, both the elasticity of supply of arbitrage and the price dominance relationship are not affected by the nature of news.

The rest of the chapter is organised as follows; Section two presents the methodology, section three describes and explains the data, section four presents and analyses the empirical findings, while the chapter finishes with section five, which provides a summary and conclusions.

3.2 METHODOLOGY

3.2.1 THE GENERALISED DOMINANCE MODEL

The Garbade and Silber model

The Garbade and Silber (1983) requires adjustment to the forward-looking futures price so that it can be directly compared with the current spot price. The cost-of-carry formula is utilised for this purpose[1]. This adjustment involves subtracting the carry charge from the observed futures price to derive the spot-equivalent futures price, denoted F^* and is defined in the following expression. For ease of description, the price series are expressed in natural logarithms.

$$F_t^* = LF_{t,T} - (r-d) * (T-t) \tag{3.1}$$

where $LF_{t,T}$ is the observed futures price at time t for a contract maturing at time T, r is the risk-free interest rate (for practical purposes the 3-month UK Treasury Bill rate is used as a proxy), d is the dividend yield on the index and T-t is the time remaining to maturity. The spot-equivalent futures price extracts the cost-of-carry from the observed futures price so that any remaining differences between the spot and futures prices can be attributed to mispricings between these markets. This approach allows the model to show the response of the spot and the spot-equivalent futures prices to arbitrage opportunities.

---

[1]The cost-of-carry model is presented and explained in detail in chapter four, section 4.2.1.

The Garbade and Silber model asserts that in the short-run, the spot and futures markets will be held together through the supply of arbitrage as arbitrageurs detect and exploit price deviations. This relationship is expressed in the following vector auto-regressive, VAR(1) model, where the price series are expressed in natural logarithms;

$$\begin{bmatrix} S_t \\ F_t^* \end{bmatrix} = \begin{bmatrix} a_0 \\ b_0 \end{bmatrix} + \begin{bmatrix} 1-a_1 & a_1 \\ b_1 & 1-b_1 \end{bmatrix} \begin{bmatrix} S_{t-1} \\ F_{t-1}^* \end{bmatrix} + \begin{bmatrix} \varepsilon_t \\ \upsilon_t \end{bmatrix} \quad (3.2)$$

The above expression can be rewritten in the following form;

$$\begin{bmatrix} S_t - S_{t-1} \\ F_t^* - F_{t-1}^* \end{bmatrix} = \begin{bmatrix} a_0 \\ b_0 \end{bmatrix} + \begin{bmatrix} a_1 \\ -b_1 \end{bmatrix} \begin{bmatrix} F_{t-1}^* - S_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_t \\ \upsilon_t \end{bmatrix} \quad (3.3)$$

Finally, the above can take the form of single linear equations consisting of an error correction term as follows;

$$\begin{aligned} \Delta S_t &= a_0 + a_1 (F^* - S)_{t-1} + \varepsilon_t \\ \Delta F_t^* &= b_0 + b_1 (S - F^*)_{t-1} + \upsilon_t \end{aligned} \quad (3.4)$$

The parameters a_1 and b_1 can be estimated using standard OLS procedures and are then used to calculate the elasticity of supply of arbitrage, δ' and the coefficient of dominance, Γ'. The measures δ' and Γ' are defined in the following equations;

$$\delta' = 1 - a_1 - b_1 \qquad (3.5)$$

$$\Gamma' = \frac{a_1}{a_1 + b_1} \qquad (3.6)$$

The measure δ' is used to infer the elasticity of supply of arbitrage forces between the spot and futures markets, and so indicates the speed with which they converge when mispricings occur. The greater the rate by which mispricings are removed, the more closely related the spot and futures markets will be. By construction of the model the measure δ' is constrained to take a value between zero and one. In addition, the measure is inversely related to the supply of arbitrage, such that a value of δ' close to zero indicates that relatively little of the mispricing in period t-1 will persist to period t. A value of δ' close to one, however, indicates that much of the mispricing in period t-1 will still be present in period t, suggesting persistence in arbitrage opportunities (still without distinguishing between profitable and non-profitable arbitrage opportunities).

The coefficient Γ' is a measure of the ability of the spot and the futures markets to respond to information. By construction, Γ' can only take a value between zero and one. If Γ' is zero then by implication a_1 is zero and the spot market strongly dominates the futures market. If Γ' is one then by implication b_1 is zero and the futures market always leads the spot market. When Γ' is 0.5 neither market dominates the other because information is contemporaneously impounded in the prices of both markets. In this case both markets are perfectly integrated. Finally, for any values between zero and 0.5 the spot market weakly dominates the futures, while for values between 0.5 and one the futures market weakly dominates the spot.

THE GRANGER CAUSALITY MODEL

The Granger causality model (Granger (1969)) is frequently used to identify lead-lag relationships between markets and so infer price dominance as shown in the following formulae, where the price series are expressed in natural logarithms;

$$\begin{aligned} \Delta S_t &= \psi_0 + \psi_1 \Delta F^*_{t-1} + \psi_2 \Delta S_{t-1} + \eta_t \\ \Delta F^*_t &= \zeta_0 + \zeta_1 \Delta S_{t-1} + \zeta_2 \Delta F^*_{t-1} + \iota_t \end{aligned} \qquad (3.7)$$

The flow of information between the spot and the futures markets is exhibited by the significance of ψ_1 and ζ_1. If the former is statistically different to zero while the latter is not, then the futures market tends to strongly dominate the spot market. When this relationship is reversed then the spot market strongly dominates the futures market.

THE GENERALISED DOMINANCE MODEL

The Generalised Dominance Model (GDM), produced by Antoniou and Foster (1994) and Foster (1996), is actually a synthesis of the Garbade and Silber (1983) model and the Granger (1969) model. The studies by Antoniou and Foster (1994) and Foster (1996) focus on the spot and the futures markets of the crude oil in the U.K. and U.S.A. during the 1990-1991 Gulf conflict. They find that although the futures markets for crude oil tend to perform their price discovery function, there are times that the spot market incorporates information first. The model developed assumes the presence of three types of traders; hedgers, speculators and arbitrageurs. The first two are assumed to react to price changes, while arbitrageurs exploit price discrepancies between the spot and futures markets. Hedgers and speculators will rebalance their positions, and therefore trade, as a response to changing prices. For example, a hedger with a balanced hedged position will need to trade to rebalance the hedge as spot and futures prices change. Similarly, a speculator will trade as prices rise or fall to take advantage of price trends. Consequently, there are two routes for the transmission of information to the market, which has been overlooked by previous research. At a market equilibrium the following expressions hold;

$$
\begin{aligned}
Q_s^{S} &= Q_s^{D_a} + Q_s^{D_h} \\
Q_f^{S} &= Q_f^{D_a} + Q_f^{D_h}
\end{aligned}
\qquad (3.8)
$$

Where Q^D and Q^S are quantities demanded and supplied, while the s and f subscripts stand for spot and futures market respectively and the a and h subscripts represent arbitrageurs and hedgers/speculators respectively.

The traders acting as suppliers to the market are guided by current price changes defined as Δ in the following formulae;

$$Q_s^S = f(\Delta S_t)$$
$$Q_f^S = f(\Delta F_t^*) \qquad (3.9)$$

The demand functions of the arbitrageurs are described by price discrepancies between the spot and the futures markets shown in the following expressions;

$$Q_s^{D_a} = f(F^* - S)_{t-1}$$
$$Q_f^{D_a} = f(S - F^*)_{t-1} \qquad (3.10)$$

The demand functions of the hedgers and speculators are defined by previous price changes as shown in the following equations. Hedgers hold offsetting positions in both the spot and the futures markets. The number of futures contracts relative to the value of the spot asset is called the hedge ratio. As spot and futures prices move relative to each other, i.e. as the difference between them changes, the hedge ratio may need adjusting. Adjustments to the hedge ratio in response to changes in the relative prices of the spot and the futures is called dynamic hedging.

Thus, hedgers adjust their portfolios to the changes in prices.

Speculators hold a position in either the spot asset or futures contract; this being a naked position. A speculator using techniques such as technical analysis, will take spot or futures positions in response to patterns in the prices of the spot asset or futures contracts. As such, the trading activity of a technical analyst is directly related to price changes. Other speculators may simply use recent changes in prices as an indication of the way the market is moving and so use that information to aid their forecasts of future prices. It is the speculators' view of future prices which drives their trading decisions.

$$\begin{aligned} Q_s^{D_h} &= f(\Delta S_{t-1}\ ,\ \Delta F_{t-1}^{*}) \\ Q_f^{D_h} &= f(\Delta S_{t-1}\ ,\ \Delta F_{t-1}^{*}) \end{aligned} \qquad (3.11)$$

After substituting formulae (3.9), (3.10) and (3.11) in formulae (3.8), the Generalised Dominance Model is given by the following formulae;

$$\begin{aligned} \Delta S_t &= \alpha_0 + \alpha_1 \Delta S_{t-1} + \alpha_2 \Delta F_{t-1}^{*} + \alpha_3 (F^{*} - S)_{t-1} + u_t \\ \Delta F_t^{*} &= \beta_0 + \beta_1 \Delta F_{t-1}^{*} + \beta_2 \Delta S_{t-1} + \beta_3 (S - F^{*})_{t-1} + e_t \end{aligned} \qquad (3.12)$$

The GDM describes the possible channels via which information is transmitted from one market to another keeping them linked. These channels capture both the arbitrage trading reflected in the error-correction term and the hedger/speculator trading reflected in the lagged returns. These variables represent the different ways for information to be transmitted between markets. Such information transmission arises from the trading activity of speculators, hedgers and arbitrageurs. The GDM can be viewed as an error correction model because it consists of lagged first differences from the cointegrating market with a lagged error correction term.

It is assumed that the market contains a number of arbitrage traders who enter the market when mispricings occur. The elasticity of supply of arbitrage may vary for different markets. Where even small mispricings are quickly removed, then the supply of arbitrage is said to be very elastic. Where arbitrageurs are reluctant to enter the market, even when substantial price discrepancies exist, the supply of arbitrage is inelastic. This observation is central to the use of the Generalised Dominance model for testing arbitrage relations. Markets which have highly inelastic arbitrage will be effectively independent and their prices will not be held together. In this case futures markets will not demonstrate price discovery or hedging functions. Where arbitrage is highly elastic, however, spot and futures markets will be very closely related. In theory, if arbitrage was infinitely elastic, then spot and spot-equivalent futures prices would be identical.

The supply of arbitrage will, therefore, be directly related to the closeness of the spot and futures prices which, in turn, has important implications for hedging effectiveness and price discovery. The effectiveness of arbitrage in maintaining a close price relationship is reflected in the persistence of price discrepancies.

Furthermore, it has been established that information can be transmitted between markets through hedgers/speculators but also through arbitrageurs whose actions are demonstrated not by lead-lag relations, but through contemporaneous relations such as those represented by an error-correction term. Investigations of pricing relations should account for both of these aspects. By not considering the role of arbitrageurs, the Granger model may ignore an important aspect of information transmission summarised by the error-correction term. In a similar way the Garbade and Silber model can be seen to fail to account for the role of hedgers and speculators which are captured by the lagged difference terms of the Granger model.

The GDM includes only the variables that are identified to be able to explain the links between markets. As a result, the GDM captures information flows between spot and futures markets through two channels, the lagged difference terms (hedger/speculator) and the lagged error-correction term (arbitrageur). Consequently, tests based on the Garbade and Silber model could be exposed to misspecification by imposing restrictions on the generalised model (α_1, α_2, β_1 and β_2 of system 3.12 are restricted to be zero). In a similar way, studies which have applied the Granger model fail to capture the arbitrage links between markets, since the error-correction term is absent from such specifications (α_3 and β_3 of system 3.12 are restricted to be equal to zero).

The GDM can be used to provide numerical measures of both the elasticity of supply of arbitrage and the coefficient of price dominance. Coefficients of elasticity of arbitrage, δ, and price dominance, Γ, are defined for the GDM as follows, and are generalised versions of those presented by Garbade and Silber. The generalisation is achieved by including parameters α_2 and β_2 which capture the effects of hedgers and speculators trading futures contracts on the spot price, and spot contracts on the futures price. This adds the effects of hedgers/speculators in transmitting information to the information transmitted by arbitrageurs as in the GS model. This development (i.e. the addition of the hedger/speculator parameter) was made by Antoniou and Foster in their development of the GDM.

$$\delta = 1 - \alpha_3 - \beta_3 \tag{3.13}$$

$$\Gamma = \frac{\alpha_2 + \alpha_3}{\alpha_2 + \alpha_3 + \beta_2 + \beta_3} \tag{3.14}$$

In the calculation of the coefficient of dominance ratio the coefficients α_1 and β_1 of the lagged own returns are excluded because we are only interested in the response to information between markets rather than within them.

3.2.2 Time Varying Relationships

A number of studies have detected evidence that the relationship between spot and futures returns varies, see for example, Koontz *et al.* (1990), Chan (1992), Schwarz and Laatsch (1991) and Schroeder and Goodwin (1991). The reason for investigating arbitrage elasticity and price discovery in a time-varying sense, comes from the observation that the frequency and characteristics of information flows to the market can vary. Therefore, information does not arrive at a uniform rate. In addition, different types of information may lead to different trading responses by hedgers, speculators and arbitrageurs. For example, if a number of minor news events arrive closely together, a trader may not trade on each piece of information but wait for the cumulative effect of the small events to make trading attractive. This is unlikely to be the case for major news events. A further example for an index trader could be the scope of a news event. A market wide event, which has implications for the entire index is more likely to lead to index trading than a single stock specific event, which has a small influence on the index. As a result, point estimates cannot fully account for the true time-varying nature of the elasticity of arbitrage or the level of price dominance. To study these factors properly, therefore, we need to explore arbitrage and price discovery over time. Therefore, our empirical work also incorporates rolling regression estimation of the GDM so that time-varying estimates of the coefficients δ and Γ can be found.

3.2.3 COINTEGRATION

The Generalised Dominance Model is itself an example of an error correction model, and consequently, allows arbitrage elasticity to be tested using cointegration techniques. Based on the work by Engle and Granger (1987), it is known that if there is a stationary relationship between two series of the same order of integration, then those series will be cointegrated and an error correction model can describe their relationship. We can therefore, begin our empirical section of investigating the relationship between spot and futures prices by applying cointegrating techniques.

The theory of cointegration is very useful for examining the relationship between spot and futures markets. When applied to futures markets, cointegration states that while observed spot and futures prices may differ in the short-run, those differences should not exceed those defined by the cost-of-carry relationship in the long-run. As a consequence, when cointegration is detected between spot and futures prices, those prices will be closely related to each other over the long-run. Where the markets fail to obey this condition prices can drift apart without limit over the long-run, thus offering the possibility of infinite arbitrage opportunities. Such a situation would imply that arbitrage forces are insufficient to correct even extreme pricing anomalies even over the long-run period. Granger noted the improbability of such a situation arising;

> "... certain pairs of economic variables should not diverge by too great an extent, at least in the long run ... if they continue to drift apart in the long-run, then economic forces, such as the market mechanism ... will begin to bring them together again."
> (Granger 1986, p213)

In the case of this investigation, the *market mechanism* noted by Granger can be thought of as being the supply of arbitrage. The finding of cointegration between spot and futures prices therefore, can be viewed as a test of them not offering persistent arbitrage opportunities over the long-run period of time. This will then suggest that the futures market will be effective in its hedging and price discovery functions in the long-run.

Before explaining cointegration in detail it is necessary to define the notion of integration in times series data. When a data series such as the spot price, S_t, is non-stationary in levels, but becomes stationary after it has been differenced d times, that series is described as being integrated of order d, written $S_t \sim I(d)$. Similarly, an I(0) series is one which is already stationary in levels, since it does not have to be differenced at all to become stationary.

Cointegration is based on the notion of integration, but may be said to look at the integration between a number of series. When two series such as a spot price and a futures price are both integrated with order d in levels, then we could expect a linear combination of those series also to be integrated of order d. Engle and Granger (1987) state, however, that a linear combination of two I(d) series can be integrated of an order which is less than d. When this situation occurs then, the two series are said to cointegrate. A special case of this cointegrating relationship which has been found to be very useful when examining the relationships between markets is that where the linear combination of two non-stationary series is actually stationary, that is, I(0) in levels. Such a special form of cointegration implies that there is a long-run stationary relationship between the cointegrating series. This situation has been described as follows,

> "...cointegration implies that deviations from equilibrium are stationary, with finite variance, even though the series themselves are nonstationary and have infinite variance."
> (Engle and Granger 1987, p251)

For example, if we define a linear combination of a non-stationary spot price series S_t, and a non-stationary futures series $F_{t,T}$, as follows, then B_t represents the linear combination of those series.

$$B_t = F_{t,T} - S_t \qquad B_t \sim I(0) \qquad (3.15)$$

In the above equation for spot and futures prices, B_t may be thought of as being the basis given by the difference between the futures price, $F_{t,T}$ and the underlying stock index level, S_t at time t. If the basis is stationary ($B_t \sim I(0)$) then, the difference between the futures and the spot prices will be stable and spot and futures price will not drift apart, so preventing limitless arbitrage opportunities over the long-run. Cointegration also implies the presence of an error correction term which describes the mechanism holding the prices together. This error correction term effectively represents the basis.

3.2.4 Johansen Cointegration Technique

The notion of cointegration was developed by Engle and Granger (1987) as discussed above, and although they provided the first methodology for testing cointegration, the Johansen methodology has become increasingly used due to a number of advantages that it has over Engle and Granger's technique. The key advantage as far as this study is concerned is that Johansen's technique does not require prior judgements to be made about the specification of the cointegrating regression i.e. one does not have to specify which variable (spot or futures prices) is the dependent, and which variable is the independent variable.

The Johansen technique differs from that of Engle and Granger in that where Engle & Granger regress one variable against the other and test the residual (the basis in the case of spot and futures prices) for stationarity, the Johansen technique tests a Vector Auto-regression (VAR) of variables (in this case a vector consisting of spot and futures prices) to ascertain whether there exist any cointegrating vectors between the variables. This is achieved by testing a null hypothesis of there being no cointegrating vectors, against the alternative hypothesis that there are one (or more) cointegrating vectors. An explanation of the Johansen technique is provided below.

$$O_t = \alpha + \Pi_1 O_{t-1} + \dots + \Pi_n O_{t-n} + \omega_t \qquad (3.16)$$

Where,

- O_t is the vector of I(1) variables being tested for cointegration. In this case, spot and spot equivalent futures prices such that $O_t=(S_t\ F_t^*)$.
- O_n represents the n lags in the vector auto-regression.
- Π_n is an N x N matrix of parameters, where N is equivalent to the number of variables in the vector O_t; this is the cointegrating matrix.
- α is a vector of constants.
- ω_t is a vector of error terms.

In equation (3.16) the cointegrating matrix Π_n reflects the number of cointegrating vectors between the variables in O_t. As shown by Johansen, the maximum number of independent rows in the matrix Π_n (also known as the rank of the matrix), corresponds to the number of cointegrating vectors (r) between the variables in O_t. Since Π_n is an N x N matrix, Johansen shows how the matrix can take one of the three following forms.

- The rank of Π_n equals N, i.e. r=N. This suggests that the vector O_t is stationary, i.e. all variables in the vector (S_t and $F^*_{t,T}$) are already I(0) stationary and therefore, any linear combination will be stationary.

- The rank of Π_n equals zero, i.e. r=0. This suggests that all the variables in O_t are non-stationary, and that any linear combination will be non-stationary. The variables in O_t do not cointegrate.

- The rank of Π_n is greater than zero but less than N, i.e. $0<r<N$. There will be r cointegrating vectors such that the variables in O_t cointegrate.

Given that the vector in this study O_t contains two variables, the cointegrating vector is 2x2, the rank of Π_n can be zero, one, or two. Where it is two, the variables will be stationary in levels and where it is zero the variables will not cointegrate as established above. Thus, a value of $r=1$ will indicate that the spot and futures series cointegrate. It is this which we test in this study.

It is important when applying Johansen's technique to properly specify the order of the vector auto-regression. Hall (1991) suggests that if the VAR level is set too low then the model may suffer from serial correlation. On the other hand, if the VAR level is set too high, the excessive number of lags can lead to small sample effects. In this study, a number of different VAR orders were used in the cointegration tests to establish whether the VAR length had any effect on the decision to reject or accept the hypothesis of a cointegrating relationship.

3.3 Data Description And Sources

The tests that follow utilise, at first, daily[1] closing transaction prices of the FTSE 100 index and the FTSE 100 stock index futures contract. LIFFE index futures contracts expire four times a year at the following months: March, June, September and December. In September 1991, the LIFFE exchange announced the change of the expiration day of the FTSE 100 contracts. Until then the expiration day used to be the last business day of the expiration month. It was then changed to the third Friday of the month. The first contract to be affected was the June 1992.

Trading on LIFFE for stock index futures starts at 8:35 a.m. and ends at 4:10 p.m.. On the other hand, while trading in the spot market starts at 8:30 a.m. it, however, ends at 4:30 p.m. As a consequence, the daily closing settlement price in LIFFE reflects the value of the index futures at 4:10 p.m., while the FTSE index closing series is the index value as computed at 4:30 p.m. As a result there is an a-synchronicity in the closing prices, which could produce noise in our estimations. Yadav and Pope (1990) argue that it should not lead to systematic

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[1]The choice of daily data was dictated by its ability to monitor the development of the index futures market over the years since its introduction. In addition, this allows for direct comparisons to be made with previous studies that have also used daily data.

differences between the theoretical index futures price and the actual index futures price. Despite this, the observed a-synchronicity is a potential source of error, which our research manages to overcome by also applying the implied index series generated in the previous chapter from the use of Option contracts. Since the option market closes at 4:10 p.m. as the futures market, the implied index represents prices of the same time as the futures prices.

As shown in the previous chapter the data used is built on the near contract shifting to the next contract just before the expiration month starts. The data consists of 2,869 daily observations on 44 different contracts, covering the period June 1, 1984 to May 31, 1995 and includes the 1987 stock market crash. The first futures contract ever traded, June 1984, is not included since there is little data available for it. The sample period analysed is shown in detail in Table 3.1. The maximum number of observations for a contract is sixty six days while the minimum is sixty four days.

Table 3.1
The Futures Contracts analysed based on the U.K. Stock Index FTSE 100

CONTRACT ANALYSED	NUMBER OF OBSERVAT.	EXPIRAT. DAY	PERIOD EXAMINED	
			START	END
September 1984	66	28/09/84	01/06/84	31/08/84
December 1984	65	31/12/84	03/09/84	30/11/84
March 1985	64	29/03/85	03/12/84	28/02/85
June 1985	66	28/06/85	01/03/85	31/05/85
September 1985	65	30/09/85	03/06/85	30/08/85
December 1985	65	31/12/85	02/09/85	29/11/85
March 1986	65	27/03/86	02/12/85	28/02/86
June 1986	65	30/06/86	03/03/86	30/05/86
September 1986	65	30/09/86	02/06/86	29/08/86
December 1986	65	31/12/86	01/09/86	28/11/86
March 1987	65	31/03/87	01/12/86	27/02/87
June 1987	65	30/06/87	02/03/87	29/05/87
September 1987	66	30/09/87	01/06/87	31/08/87
December 1987	65	31/12/87	01/09/87	30/11/87
March 1988	65	31/03/88	01/12/87	29/02/88
June 1988	66	30/06/88	01/03/88	31/05/88
September 1988	66	30/09/88	01/06/88	31/08/88
December 1988	65	30/12/88	01/09/88	30/11/88
March 1989	64	31/03/89	01/12/88	28/02/89
June 1989	66	30/06/89	01/03/89	31/05/89
September 1989	66	29/09/89	01/06/89	31/08/89
December 1989	65	29/12/89	01/09/89	30/11/89
March 1990	64	30/03/90	01/12/89	28/02/90
June 1990	66	29/06/90	01/03/90	31/05/90
September 1990	66	28/09/90	01/06/90	31/08/90
December 1990	65	31/12/90	03/09/90	30/11/90
March 1991	64	28/03/91	03/12/90	28/02/91
June 1991	66	28/06/91	01/03/91	31/05/91
September 1991	65	30/09/91	03/06/91	31/08/91
December 1991	65	31/12/91	02/09/91	29/11/91
March 1992	65	31/03/92	02/12/91	28/02/92
June 1992	65	19/06/92	02/03/92	29/05/92
September 1992	66	18/09/92	01/06/92	31/08/92
December 1992	65	18/12/92	01/09/92	30/11/92
March 1993	64	19/03/93	01/12/92	26/02/93
June 1993	66	18/06/93	01/03/93	31/05/93
September 1993	66	17/09/93	01/06/93	31/08/93
December 1993	65	17/12/93	01/09/93	30/11/93
March 1994	64	18/03/94	01/12/93	28/02/94
June 1994	66	17/06/94	01/03/94	31/05/94
September 1994	66	16/09/94	01/06/94	31/08/94
December 1994	65	16/12/94	01/09/94	30/11/94
March 1995	64	17/03/95	01/12/94	28/02/95
June 1995	66	16/06/95	01/03/95	31/05/95

The data used was provided by Datastream. This includes, at first, the daily closing price of the LIFFE FTSE 100 futures contracts and the dividend yield on the index. Additionally, since the FTSE 100 index futures contracts are on a quarterly expiration cycle, the risk-free interest rate used is the corresponding daily three-month Treasury Bill, provided by Datastream, which matures on the day that is closest to the last trading day of the futures contract.

In addition, the empirical work that follows requires the daily prices for the FTSE 100 stock index, denoted S_t. This series was obtained from Datastream. However, apart from using this spot series we also use the adjusted for non-synchronicity spot series and the implied index series, which were produced in chapter two. While the first two series cover the period between June 1, 1984 to May 31, 1995 (2,869 observations), due to unavailability of data the implied index can only give results for the period March 13, 1992 to May 31, 1995 (839 observations).

Finally, in order to examine the supply of arbitrage and the dominance relationship between the spot and the futures markets in relation to time to maturity, each futures contract's data was constructed in a way so as to include its expiration month. In total, that section of the empirical work looks at the last seven months of a futures contract's life. This additional daily index futures contracts observations, which are only used in this chapter, were acquired from Datastream.

3.4 Empirical Results

3.4.1 Cointegration Results

This section examines the long-run pricing relationship between the spot and the futures markets by applying cointegration tests developed by Johansen (1988), as described in section 3.2.4. We test for the presence of unit roots (nonstationarity) in levels spot and futures price series. This is achieved by using Johansen's methodology to test for cointegration in only one variable, thus testing for integration. In case of integration O_t is equal to S_t for the spot test, while it is equal to F_t for the futures test in equation (3.16). The Johansen method for testing for integration is preferred so as to be consistent with the Johansen tests for cointegration. The null hypothesis states that there is no integration, this is because the rank (r) of the cointegrating matrix is zero and it was explained in section 3.2.4 that where r=0 the variables in the cointegrating vector are non-stationary. When using cointegration tests to establish the order of integration, the cointegrating vector will contain only one variable, in this case either the spot or the spot equivalent futures price, and as such the rank of the cointegrating vector can be either 1 implying stationarity or zero implying non-stationarity. The null hypothesis of no integration (H_0:r=0) is found to be accepted both when looking at the overall sample period but also on a 3-year and a year by year basis. Differencing the series once and reapplying the unit root tests we see that, all the price series reject the null hypothesis and are stationary I(0) series in first differences. Therefore, all series considered are found to be I(1) in levels and I(0) in first differences. Since the spot and futures price series are of the same order of integration they suggest the possibility of cointegration. Results for integration tests are shown in Table 3.2. Our empirical work considers all three cases of price series, as described in section 3.3.

Table 3.2

Johansen Tests for Stationarity in the Spot and Futures Stock Indices. The null hypothesis for the tests is that there are no cointegrating relationships. The critical value for stationarity tests at 5% is 8.176.

3-YEAR	SERIES	Stationarity Tests Maximal eigenvalue Levels* $H_o:r=0$ $H_1:r=1$	Stationarity Tests Maximal eigenvalue Differences** $H_o:r=0$ $H_1:r=1$
OVERALL SAMPLE 01/06/84 ... 31/05/95	Spot Equivalent Futures	2.850	1685.0
	Unadjusted Spot	2.477	1567.0
	Adjusted Spot	2.603	1592.8
1984-1986	Spot Equivalent Futures	1.229	463.1
	Unadjusted Spot	1.495	414.3
	Adjusted Spot	0.927	409.5
1987-1989	Spot Equivalent Futures	2.449	501.2
	Unadjusted Spot	1.786	478.4
	Adjusted Spot	2.270	493.1
1990-1992	Spot Equivalent Futures	1.426	554.4
	Unadjusted Spot	0.775	508.5
	Adjusted Spot	0.869	509.4
1993-1995	Spot Equivalent Futures	3.645	464.4
	Unadjusted Spot	2.459	410.1
	Adjusted Spot	2.637	411.4

continued...

*The Ho:r=0 is accepted
**The Ho:r=0 is rejected

YEAR	SERIES	Stationarity Tests	
		Maximal eigenvalue	
		Levels*	Differences**
		$H_o:r=0$ $H_1:r=1$	$H_o:r=0$ $H_1:r=1$
SAMPLE PERIOD 13/03/92 ... 31/05/95	Spot Equivalent Futures	2.985	583.7
	Unadjusted Spot	2.293	525.3
	Adjusted Spot	2.438	526.8
	Implied Index	2.643	590.9
1992	Spot Equivalent Futures	1.108	168.010
	Unadjusted Spot	0.703	157.344
	Adjusted Spot	0.770	157.728
	Implied Index	1.045	139.557
1993	Spot Equivalent Futures	0.139	168.035
	Unadjusted Spot	0.823	156.785
	Adjusted Spot	0.735	156.908
	Implied Index	0.299	163.256
1994	Spot Equivalent Futures	5.173	206.579
	Unadjusted Spot	4.205	179.659
	Adjusted Spot	4.303	179.641
	Implied Index	4.912	205.158
1995	Spot Equivalent Futures	0.213	81.474
	Unadjusted Spot	0.037	70.872
	Adjusted Spot	0.136	72.329
	Implied Index	0.156	79.153

*The Ho:r=0 is accepted
**The Ho:r=0 is rejected

Since all price series are found to integrate of the same order we continue by testing the spot and the futures price for cointegration. The null hypothesis states that there are zero cointegrating vectors between the spot and futures series, while the alternative hypothesis states that there is one cointegrating vector. The tests suggest the presence of cointegration for all three cases of spot index.

The results of the cointegration tests show that the spot and the futures series cointegrate at 5% level and that there is only one cointegrating relationship between the two series. This result indicates the fact that in the long-run both the spot and the futures prices are kept close and do not drift apart without limit. In addition, the close relationship between the spot and the futures prices appears to have been maintained throughout the entire sample as well as on sub-sections of it. This close relationship is attributed to the actions of arbitrageurs as described empirically by the error correction mechanism implied by the cointegrating relationship. Results for the cointegration tests are presented in Table 3.3.

Table 3.3

Johansen Tests for Cointegration in the Spot and Futures Stock Indices. The null hypothesis for the tests is that there are no cointegrating relationships. The critical value at 5% is 14.900. In addition we test for the null hypothesis that there are more than one cointegrating relationships. The critical value at 5% in this case is 8.176.

3-YEAR	Spot Equivalent Futures Unadjusted Spot		Spot Equivalent Futures Adjusted Spot	
	Maximal eigenvalue			
	$H_o:r=0$ $H_1:r=1$	$H_o:r\leq 1$ $H_1:r=2$	$H_o:r=0$ $H_1:r=1$	$H_o:r\leq 1$ $H_1:r=2$
OVERALL SAMPLE 01/06/84 ... 31/05/95	344.650	2.767	303.932	2.744
1984-1986	68.012	1.237	67.983	1.164
1987-1989	144.361	2.403	134.952	2.294
1990-1992	104.731	1.488	96.322	1.460
1993-1995	166.155	3.067	188.431	3.202

continued...

YEAR	Spot Equivalent Futures Unadjusted Spot		Spot Equivalent Futures Adjusted Spot		Spot Equivalent Futures Implied Index	
	Maximal eigenvalue					
	$H_o:r=0$ $H_1:r=1$	$H_o:r\leq 1$ $H_1:r=2$	$H_o:r=0$ $H_1:r=1$	$H_o:r\leq 1$ $H_1:r=2$	$H_o:r=0$ $H_1:r=1$	$H_o:r\leq 1$ $H_1:r=2$
SAMPLE PERIOD 13/03/92 ... 31/05/95	182.860	2.867	218.917	2.907	104.861	3.173
1992	45.622	1.403	51.958	1.228	43.489	1.089
1993	61.051	0.342	60.991	0.224	37.095	0.241
1994	97.819	4.575	114.977	4.601	44.941	5.467
1995	24.420	0.021	27.392	0.140	19.656	0.154

3.4.2 GENERALISED DOMINANCE POINT ESTIMATE RESULTS

The presence of a cointegrating relationship between spot and spot-equivalent futures prices implies the presence of an underlying error-correction model, which can identify the information flows between spot and futures markets. The fact that there is cointegration between the spot and futures prices suggests that in the long-run both markets are closely related. However, in the short-run this relationship may not hold. As a result, it is important to use an error correction model to examine this dynamic relationship. We therefore, apply the Generalised Dominance Model, which is an example of an error correction model. Using this model we can simultaneously measure the source of price discovery and the elasticity of spot and futures arbitrage.

The point estimates of the parameters α_2, α_3, β_2 and β_3 from the GDM in the system of equations (3.12) are presented in Table 3.4, both for the entire sample and for sub-sections of the sample. In addition, the table reports results from using all three types of spot index. An interesting point is that the lagged difference terms α_2 and β_2 reflecting the actions of hedgers/speculators are relatively important. This indicates the improved descriptive ability of the GDM over the original Garbade and Silber model, by including important information channels. Furthermore, between the two coefficients, α_2 and ${}_2\beta$, the former exhibits more statistical significance than the latter when examining the entire sample period. This finding suggests that the futures prices tend to dominate the spot market. Similar findings are documented by Chan (1992), who finds the feedback from the futures market into the spot market to be higher and explains it as the result of the ability of the futures market to update information faster than the spot market.

However, when examining small sections of the sample i.e. three-year periods or even yearly periods, this relationship seems to vary. The dominance pattern changes and even reverses with the spot prices dominating the futures prices (i.e. 3-year period 1987-1989 and year 1995). This observation provides preliminary evidence of time-varying price discovery. When comparing the results between the unadjusted and the adjusted for non-synchronicity series for the large sample of 2,869 observations, we find that there is similarity between them. If the problem of non-synchronous trading is severe then it could lead to a higher dominance of the futures prices over the spot. However, our result implies that the problem of non-synchronous trading in the U.K. is not severe enough to be responsible for the observed price dominance of the futures market. Furthermore, the dominance patterns suggested for sub-periods are similar in both cases. Therefore, both approaches indicate the temporal price dominance relationship between the spot and the futures markets. On the other hand, the analysis of the smaller sample period of 839 observations reveals that in the sub-periods the use of the implied index provides less statistical significance of the coefficients α_2 and β_2. Such a finding suggests that neither market dominates

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Table 3.4

Point estimates of the GDM when applying both the unadjusted and the adjusted for non-synchronicity spot index series, as well as the Option's Implied Index. Figures in parentheses are t-statistics: reject $H_0 : \alpha, \beta = 0$ at 5% level of significance if t-value > $|1.960|$. The sample periods for years 1984 and 1995 do not cover the whole year, and the number of observations for those years is 152 and 108 respectively.

3-YEAR	UNADJUSTED CASE				ADJUSTED CASE			
	α_2	α_3	β_2	β_3	α_2	α_3	β_2	β_3
OVERALL SAMPLE 01/06/84 ... 31/05/95	0.350 (2.995)*	0.047 (2.065)*	-0.071 (-1.326)	0.052 (2.602)*	0.390 (3.133)*	0.038 (1.991)*	-0.069 (-1.413)	0.064 (2.456)*
1984-1986	0.181 (2.410)*	0.057 (1.975)*	0.124 (1.854)	0.023 (0.616)	0.202 (2.448)*	0.080 (2.109)*	0.131 (1.767)	0.012 (0.342)
1987-1989	0.480 (6.392)*	0.086 (1.985)*	-0.195 (-2.105)*	0.096 (1.968)*	0.580 (6.895)*	0.017 (1.969)*	-0.256 (-2.679)*	0.135 (2.679)*
1990-1992	0.247 (2.426)*	0.099 (1.988)*	-0.044 (-0.327)	0.040 (0.576)	0.255 (2.411)*	0.118 (2.067)*	-0.046 (-0.348)	0.038 (0.535)
1993-1995	0.181 (1.394)	0.140 (1.962)*	0.012 (0.065)	0.088 (0.740)	0.152 (1.119)	0.211 (1.978)*	0.023 (0.130)	0.053 (0.394)

continued...

YEAR	UNADJUSTED CASE				ADJUSTED CASE				IMPLIED INDEX CASE			
	α_2	α_3	β_2	β_3	α_2	α_3	β_2	β_3	α_2	α_3	β_2	β_3
SAMPLE PERIOD** 13/03/92 ... 31/05/95	0.268 (2.434)*	0.167 (2.247)*	-0.068 (-0.464)	-0.005 (-0.060)	0.246 (2.129)*	0.223 (2.569)*	-0.050 (-0.351)	-0.031 (-0.311)	0.282 (2.435)*	0.250 (2.851)*	0.052 (0.341)	-0.129 (-1.968)*
1992	0.446 (2.358)*	0.237 (2.118)*	-0.237 (-1.024)	-0.024 (-0.147)	0.416 (2.057)*	0.331 (2.058)*	-0.223 (-0.967)	-0.043 (-0.219)	0.199 (0.871)	0.431 (2.502)*	0.193 (0.854)	-0.231 (-1.331)
1993	0.335 (2.021)*	0.063 (1.982)*	-0.160 (-0.571)	0.192 (1.966)*	0.322 (1.963)*	0.111 (1.962)*	-0.151 (-0.546)	0.158 (0.772)	0.434 (1.996)*	0.026 (1.982)*	-0.295 (-0.909)	0.132 (0.806)
1994	0.083 (0.409)	0.228 (1.991)*	0.092 (0.316)	0.075 (0.331)	0.031 (0.145)	0.355 (2.077)*	0.112 (0.389)	-0.020 (-0.080)	0.267 (0.525)	0.577 (1.991)*	-0.066 (-0.124)	-0.389 (-1.001)
1995	0.482 (1.008)	-0.205 (-1.401)	-0.498 (-2.104)*	0.404 (1.965)*	0.453 (1.060)	-0.131 (-1.342)	-0.419 (-2.042)*	0.420 (1.971)*	0.601 (0.968)	-0.726 (-1.601)	-0.391 (-0.580)	0.938 (2.257)*

* The coefficients are statistically significant.

** The sample period that the Implied Index case can report results for. As mentioned before, due to unavailability of data it is smaller than the original sample period.

THE ELASTICITY OF SUPPLY OF ARBITRAGE

This part of the empirical investigation deals with the degree to which the spot and futures markets are linked as reflected by the calculation of the elasticity of supply of arbitrage, δ, based on equation (3.13). Increased supply of arbitrage results in greater market linkage which improves the risk transfer or hedging function of the futures market.

Table 3.5 reports the calculated measure of the rate of convergence of spot and futures prices, δ, for both the entire sample period as well as for sub-periods of the sample. The measure, δ is the indication of the rate at which observed mispricing is removed by arbitrageurs. The results produce a relatively high value for δ implying that it would take substantial price discrepancies in order to attract arbitrageurs to the futures markets. Over the entire sample period δ is found to be 0.90 for both the unadjusted and adjusted cases. Without considering transaction costs, this means that in both cases 90% of the price difference between spot price and spot equivalent futures price tends to persist.

It should be noted that the results of this model most probably overestimate persistence of mispricing as they do not distinguish between profitable and non-profitable mispricing, in that the observed mispricing may fall within the transaction costs bounds, where no profits can be made. The apparent lack of arbitrage activity as suggested by the high value of δ could still be consistent with a well functioning market since an arbitrage strategy for exploiting the mispricings would not be profitable. As a result, the 90% figure could partly involve mispricing which cannot be profitably exploited, but also refer to mispricing which can allow for unattractive profits. The distinction between profitable and non-profitable arbitrage opportunities after the consideration of transaction costs is the subject of the following chapters which will also illuminate the findings of this chapter.

Among the three cases investigated for the smaller sample reflecting the period between March 13, 1992 to May 31, 1995, the value of δ is smaller suggesting a smaller persistence in mispricing. However, among the series investigated the Implied index seems to suggest the highest value of δ, and thus the highest persistence in mispricing. The findings based on the Implied index are treated as more accurate than those based on the observed index and the adjusted for non-synchronicity spot index series. This was explained before as the result of using options contracts. Consequently, unlike the reported index, it is neither exposed to the effects of non-synchronous trading nor becomes the subject of adjusting methods the way the adjusted series did.

Finally, when breaking the sample period into smaller sections and examine the value of δ we see that the persistence of the mispricing appears to decrease over the years. We also observe a high degree of variation in the sub-periods computations of the supply of arbitrage measure. This is further analysed in the section with the rolling regression estimation of the GDM, which investigates the pricing relationship between spot and futures markets on a time-varying framework.

Table 3.5

Calculation of the elasticity of supply of arbitrage, δ, based on the GDM and given in equation (3.13). Since δ is an inverse measure of arbitrage elasticity, a small value for δ indicates high elasticity, while a larger value suggests more inelastic supply. The results represent all three cases of using both the unadjusted and the adjusted for non-synchronicity spot index series, as well as the Option's Implied Index. The sample periods for years 1984 and 1995 do not cover the whole year, and the number of observations for those years are 152 and 108 respectively.

3-YEAR	UNADJUSTED CASE	ADJUSTED CASE
OVERALL SAMPLE 01/06/84-31/05/95	0.90	0.90
1984-1986	0.92	0.91
1987-1989	0.82	0.85
1990-1992	0.86	0.84
1993-1995	0.77	0.74

YEAR	UNADJUSTED CASE	ADJUSTED CASE	IMPLIED INDEX CASE
SAMPLE PERIOD* 13/03/92-31/05/95	0.84	0.81	0.88
1992	0.79	0.71	0.80
1993	0.74	0.73	0.84
1994	0.70	0.66	0.81
1995	0.80	0.71	0.79

*The sample period that the Implied Index case can report results for. As mentioned before, due to unavailability of data it is smaller than the original sample period.

At this point we apply the Garbade and Silber model in our price series as described in the system of equations (3.4), in order to compare its results with those of the GDM model. Table 3.6 presents the value of δ' for all three cases and for the entire sample period as well as for sub-periods. When comparing the results among the three cases, we still find the Implied Index to suggest the highest persistence in mispricing. On the other hand, the value of δ' appears to have decreased over the years but not as constantly as the GDM shows. Moreover, the simple GS model produces overall lower values of δ' compared to those of the GDM model by focusing only on the arbitrage traders and ignoring the presence and effect of hedgers/speculators. As a result, failing to consider all possible sources of information the findings can be underestimated due to model mispecification and the conclusions can be misleading.

Table 3.6

Calculation of the elasticity of supply of arbitrage based on the Garbade and Silber (1983) model. The measure of arbitrage elasticity, δ' is defined in equation (3.5). Since δ' is an inverse measure of arbitrage elasticity, a small value for δ' indicates high elasticity, while a larger value suggests more inelastic supply. The results represent all three cases of using both the unadjusted and the adjusted for non-synchronicity spot index series, as well as the Option's Implied Index. The sample periods for years 1984 and 1995 do not cover the whole year, and the number of observations for those years are 152 and 108 respectively.

3-YEAR	UNADJUSTED CASE	ADJUSTED CASE
OVERALL SAMPLE 01/06/84-31/05/95	0.84	0.85
1984-1986	0.89	0.87
1987-1989	0.75	0.70
1990-1992	0.81	0.80
1993-1995	0.70	0.65

YEAR	UNADJUSTED CASE	ADJUSTED CASE	IMPLIED INDEX CASE
SAMPLE PERIOD* 13/03/92-31/05/95	0.77	0.73	0.82
1992	0.75	0.66	0.71
1993	0.71	0.69	0.82
1994	0.59	0.54	0.72
1995	0.71	0.63	0.71

*The sample period that the Implied Index case can report results for. As mentioned before, due to unavailability of data it is smaller than the original sample period.

THE COEFFICIENT OF DOMINANCE

At this part of our investigation we concentrate on the calculation of the relative contribution of the futures market to the price discovery process. This is of great importance because it demonstrates how well the futures market plays its role in providing price information and how well the spot and the futures markets are linked. The calculated coefficient of dominance, Γ, given in equation (3.14) over the entire sample period as well as for sub-periods is reported in Table 3.7.

On the basis of the entire sample, Γ is found to be higher than 0.5, which suggests that overall, the FTSE 100 futures market weakly dominates its underlying spot market. Since our results are the same even when accounting for non-synchronicity, the observed dominance cannot be explained by the presence of non-synchronous trading. More specifically, over the entire sample, Γ is found to be 0.76. This implies that the spot market in the FTSE 100 index is largely a satellite of the futures market for the same index, with 76% of new information incorporated first in futures prices. This is consistent with a large number of studies on both commodities and stock indices. In the first category some of the studies are by Garbade and Silber (1983), Oellermann *et al.* (1989), Schroeder and Goodwin (1991), Koontz *et al.* (1990), while in the second category some of the studies are those by Chan (1992), Merrick (1987), Kawaller *et al.* (1987a), Stoll and Whaley (1990), Schwarz and Laatsch (1991), Harris (1989a) and Witherspoon (1993).

When examining sub-periods of the sample and consistent with the studies mentioned above, our results show that, the dominance relationship between the two markets is not always maintained and can even be reversed (i.e. year 1995). This finding is better illustrated in Figures 3.1 and 3.2. For the sample of 839 observations, the Implied index also suggests a futures price dominance over the spot. However, among the three cases investigated, the implied index generally suggests an even weaker dominance relationship (i.e. Γ is closer to 0.5). This implies a perfect integration between the spot and the futures markets with simultaneous response to new information. This can be seen better in Figure 3.2. One interesting observation is that for the first five months of the year 1995 the level of Γ fell below 0.5 indicating a period were the spot market first discovered information more frequently than the futures market. However, there is no clear market event to explain this observation.

We also calculate the coefficient Γ' based on the original Garbade and Silber model described in the system of equations (3.4). The results are shown in Table 3.8. The results give even smaller values of Γ' for the entire sample period suggesting an even weaker dominance relationship than the one suggested by the GDM. On a year to year basis the Garbade and Silber model suggests even more cases of spot price dominance in contrast to the results of the GDM model. Again this is due to the mispecification of the Garbade and Silber model.

Table 3.7

Calculation of the coefficient of dominance, Γ based on equation (3.14) using absolute coefficient values. The results represent all three cases of using both the unadjusted and the adjusted for non-synchronicity spot index series, as well as the Option's Implied Index. The sample periods for years 1984 and 1995 do not cover the whole year, and the number of observations for those years are 152 and 108 respectively.

3-YEAR	UNADJUSTED CASE	ADJUSTED CASE
OVERALL SAMPLE 01/06/84-31/05/95	0.76	0.76
1984-1986	0.62	0.66
1987-1989	0.66	0.60
1990-1992	0.80	0.82
1993-1995	0.76	0.83

YEAR	UNADJUSTED CASE	ADJUSTED CASE	IMPLIED INDEX CASE
SAMPLE PERIOD* 13/03/92-31/05/95	0.86	0.85	0.75
1992	0.72	0.74	0.60
1993	0.53	0.58	0.52
1994	0.65	0.74	0.65
1995	0.43	0.41	0.50

*The sample period that the Implied Index case can report results for. As mentioned before, due to unavailability of data it is smaller than the original sample period.

Figure 3.1

GDM Dominance Ratio for both cases that the spot index is adjusted and not adjusted for non-synchronicity.

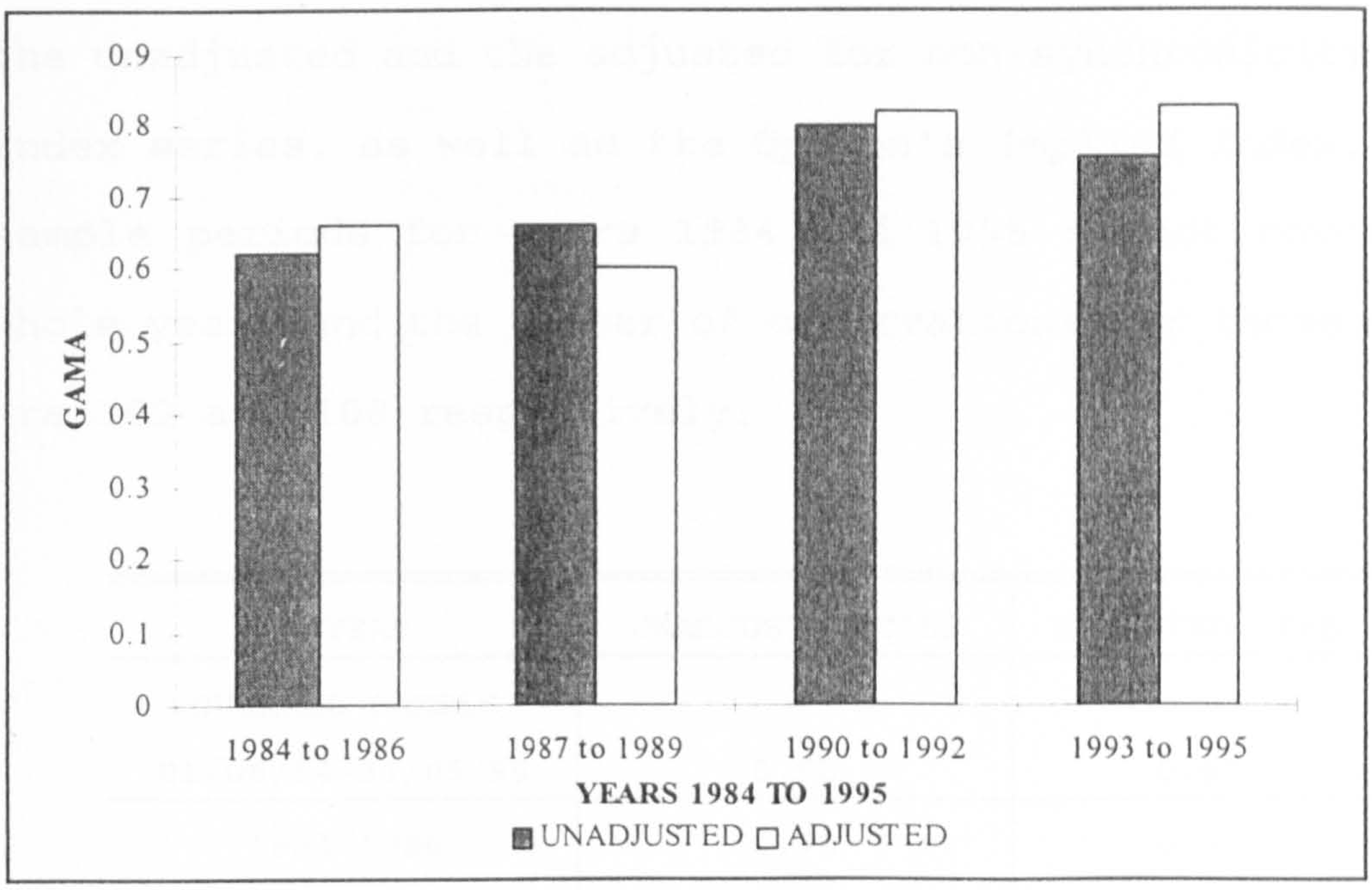


Figure 3.2

GDM Dominance Ratio for both cases of using the adjusted for non-synchronicity spot index as well as the implied index.

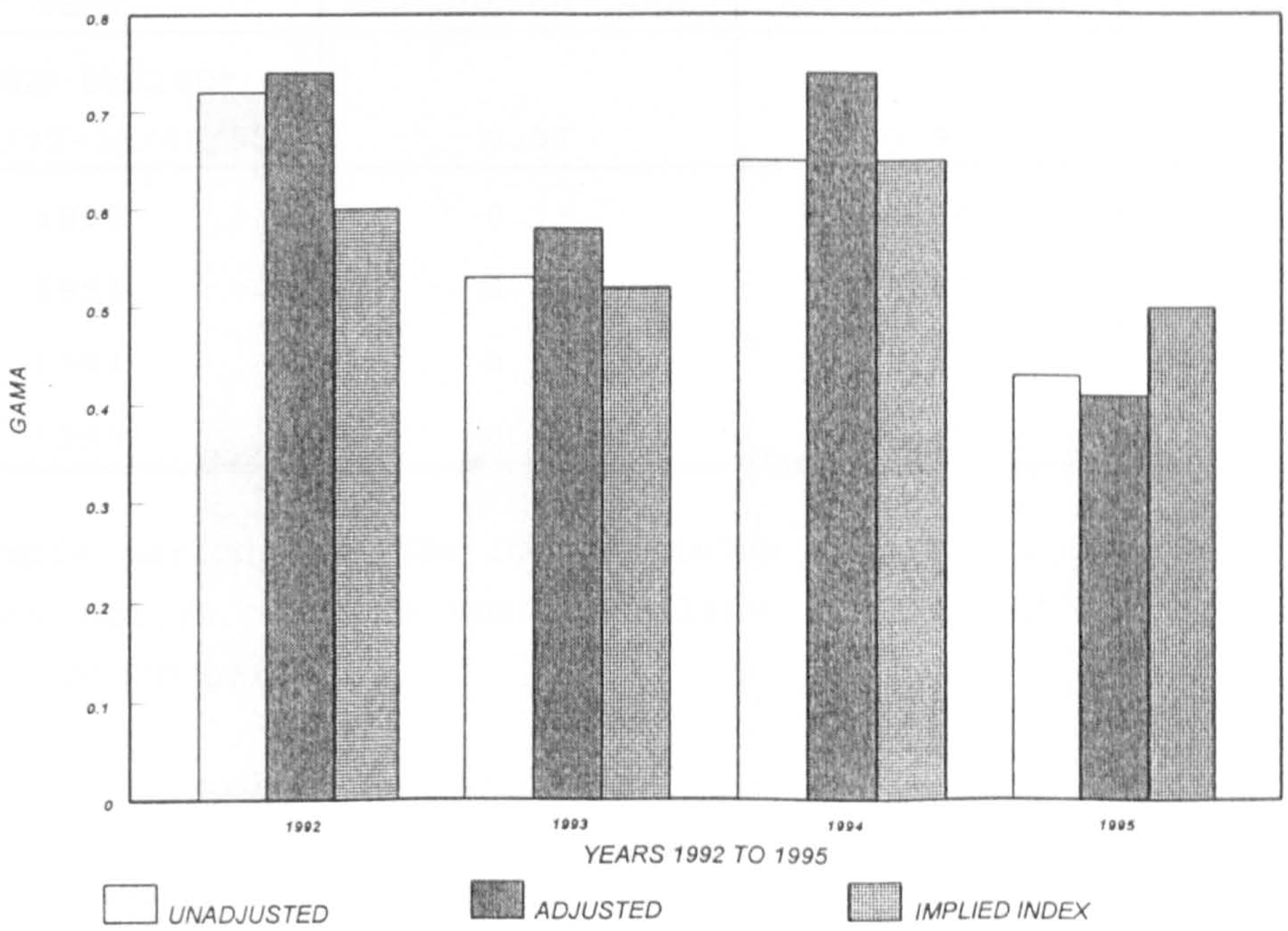


Table 3.8

Calculation of the coefficient of dominance, Γ' based on the Garbade and Silber (1983) model and given be equation (3.6). The results represent all three cases of using both the unadjusted and the adjusted for non-synchronicity spot index series, as well as the Option's Implied Index. The sample periods for years 1984 and 1995 do not cover the whole year, and the number of observations for those years are 152 and 108 respectively.

3-YEAR	UNADJUSTED CASE	ADJUSTED CASE
OVERALL SAMPLE 01/06/84-31/05/95	0.68	0.63
1984-1986	0.72	0.70
1987-1989	0.70	0.67
1990-1992	0.76	0.79
1993-1995	0.61	0.72

YEAR	UNADJUSTED CASE	ADJUSTED CASE	IMPLIED INDEX CASE
SAMPLE PERIOD* 13/03/92-31/05/95	0.97	0.91	0.72
1992	0.79	0.78	0.71
1993	0.70	0.83	0.57
1994	0.46	0.57	0.67
1995	0.18	0.17	0.40

*The sample period that the Implied Index case can report results for. As mentioned before, due to unavailability of data it is smaller than the original sample period.

On the whole, the results of this chapter suggest a relative lack of arbitrage activity and a relatively strong price dominance from the futures market over the spot market. The results here suggest that approximately three quarters of the time the futures price leads the spot price and the rest of the time the spot price leads the futures, thus the futures market dominates the spot market although there is some bidirectional causality. Similar results were also reached by studies which investigated the values of both Γ' and δ' based on the Garbade and Silber model. We refer to Garbade and Silber (1983) as an example of a spot and futures commodity analysis and Schwarz and Laatsch (1991) and Witherspoon (1993) as examples of spot and futures index analysis. Witherspoon explains that the spot and the futures prices can be closely related with the latter leading the former but can also appear to divert due to lack of arbitrage;

> "...cash and futures markets may become too closely linked in the sense that price discovery by futures is dominant over the cash market, but may become too loosely linked in the sense that cash/futures arbitrage is inelastic."
> (Witherspoon 1993, p488)

In a similar manner Schwarz and Laatsch explain that either market can exhibit price dominance and at the same time the two markets can be either closely related or not through arbitrage;

> "...it is possible to have a tightly arbitraged market with either cash or futures displaying price leadership. Conversely, either market can lead in a loosely arbitraged market."
> (Schwarz and Laatsch 1991, p672)

Due to the observance of the degree of variation in the year by year computations of the elasticity of supply of arbitrage and the coefficient of dominance, the next section concentrates on the rolling regression estimation of the GDM, which allows for the parameters to be time-varying.

3.4.3 Rolling Estimation Results

The rolling regression estimation[1] of the relationship defined in the system of equations (3.12) produces results which confirm the fact that the price relationship between the spot and the futures markets is not stable. This, is not surprising since the nature and the speed of information flows vary, and this in turn affects the importance of arbitrageurs and hedgers/speculators in transmitting information across the markets through their trading activity.

THE ELASTICITY OF SUPPLY OF ARBITRAGE

Figures 3.3, 3.4, 3.5, 3.6 and 3.7 graphically illustrate the value of the elasticity of supply of arbitrage, δ after the GDM was estimated using rolling regression. The average value of δ for the entire sample period of 2869 observations of the unadjusted and the adjusted series is found to be 0.84 and 0.82 respectively. As a result, both the adjusted and the unadjusted series seem to produce similar results. On the other hand, for the smaller sample period of 839 observations the average δ for the unadjusted, the adjusted and the implied index case is 0.75, 0.71 and 0.84 respectively. The results of the rolling regression confirm the findings of the point estimation in the sense that the supply of arbitrage is

[1]The window length for the 2,869-observation-sample and the 839-observation-sample was 500 and 150 respectively, which correspond to approximately 2-year and ½-year period.

highly inelastic. However, the Figures show that the elasticity, δ is not at all stable and can vary to a very large degree. This variance in δ cannot be captured by the point estimations and so justify the use of rolling regression estimation.

Possible explanations for the observed variance in arbitrage supply in the U.K. market could be due to difficulties faced by arbitrageurs trying to exploit mispricings. For example, unfavourable transaction costs in any one period, more favourable arbitrage opportunities in other markets diverting finite funds to more profitable trades, or the rate with which arbitrage agents become aware of profitable opportunities.

A small number of studies recognised and attempted to capture the time varying element in the elasticity of supply of arbitrage, such as Schwarz and Laatsch (1991), Oellermann *et al*. (1989) and Schroeder and Goodwin (1991). Although they manage to show the variation in the relationship between spot and futures prices, their investigations are on a relatively preliminary level. This is because they divide the data into sub-periods and end up still comparing point estimates across those samples. Unlike these studies, we encounter the issue of time-variance more effectively by modelling the supply of arbitrage within a time-varying framework.

Figure 3.3

Elasticity of supply of arbitrage, δ, with rolling regression estimation of the GDM when the spot index is not adjusted for non-synchronicity (sample: 2869 observations)

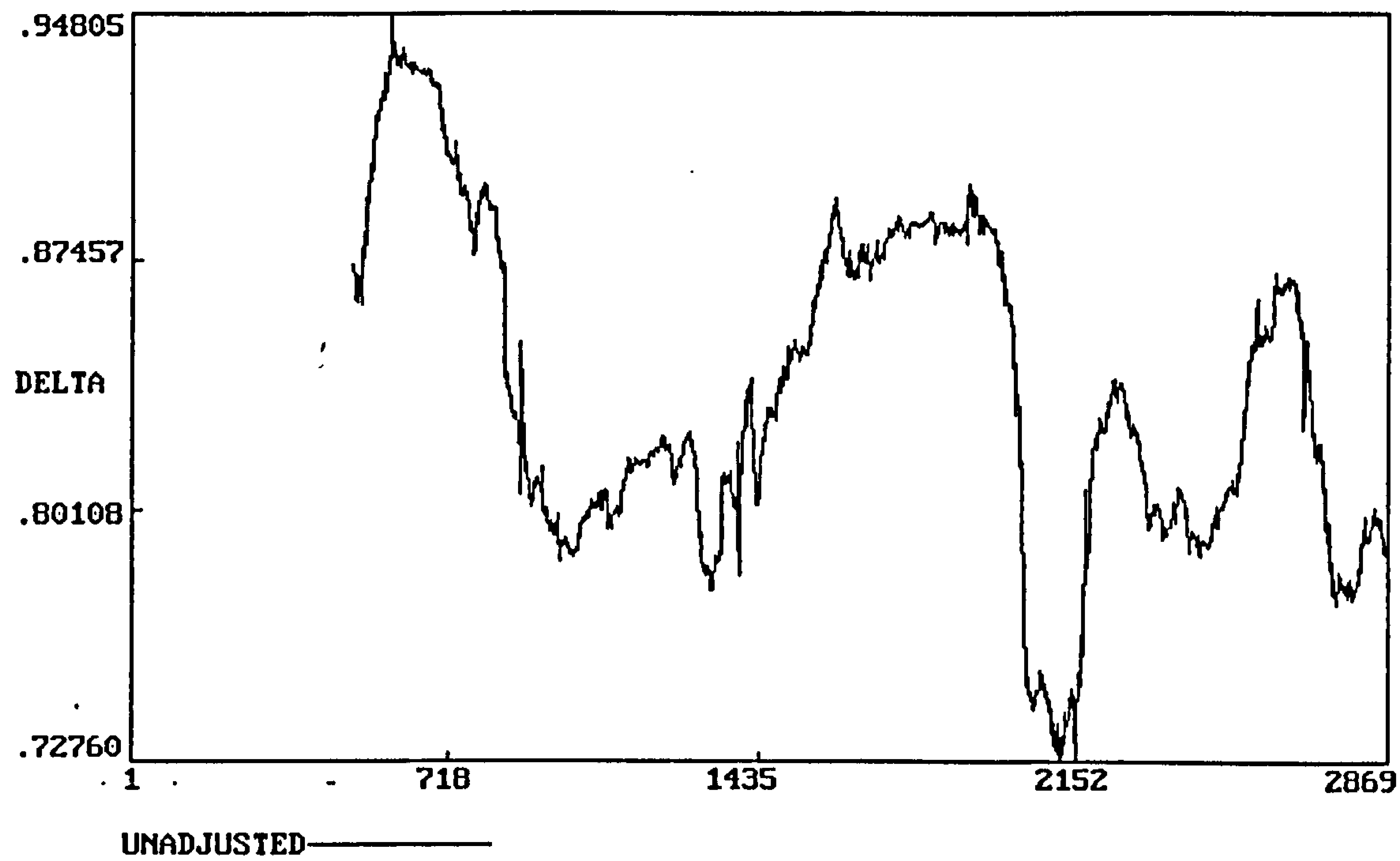


Figure 3.4

Elasticity of supply of arbitrage, δ, with rolling regression estimation of the GDM when the spot index is adjusted for non-synchronicity (sample: 2869 observations)

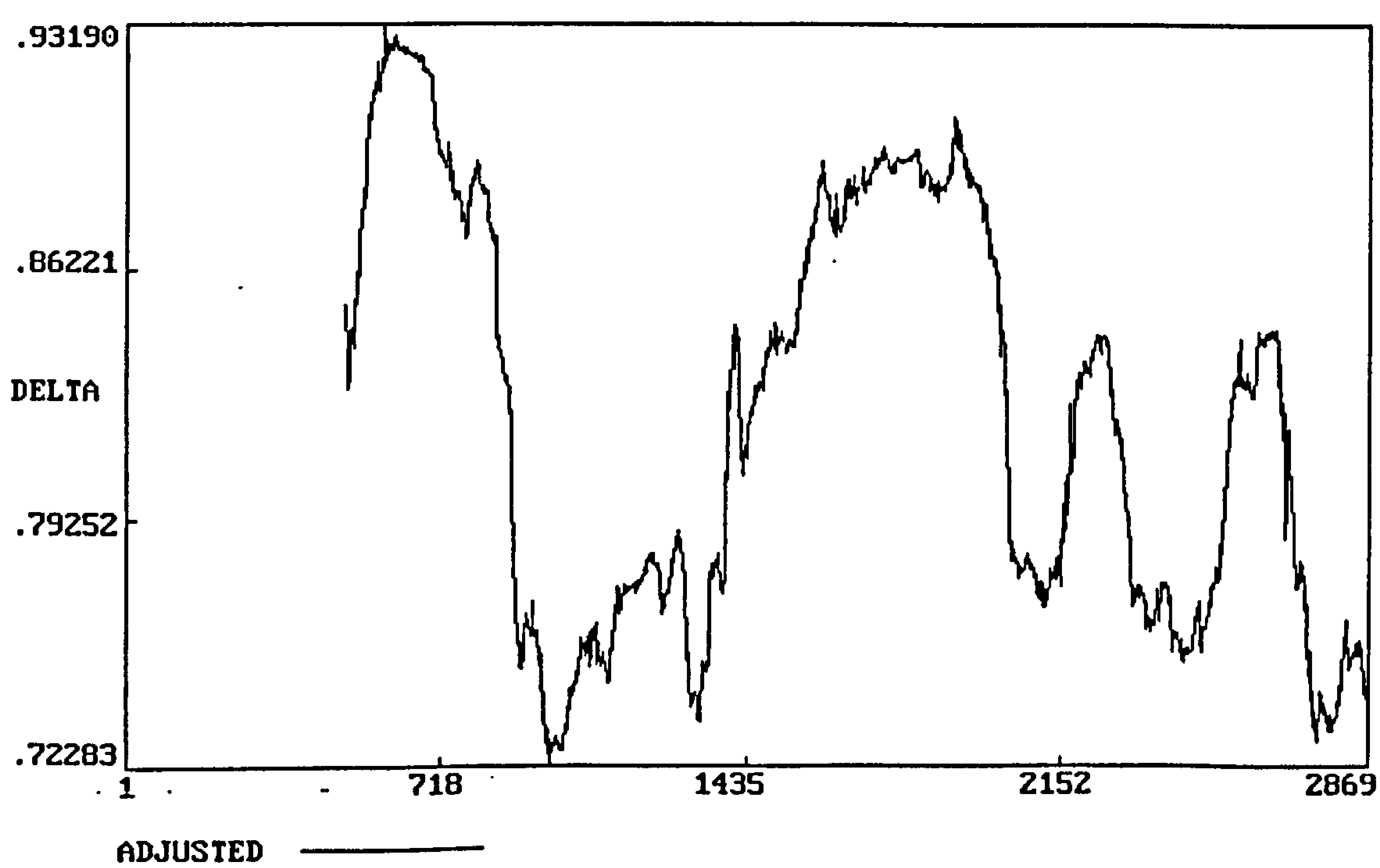


Figure 3.5
Elasticity of supply of arbitrage, δ, with rolling regression estimation of GDM when the spot index is not adjusted for non-synchronicity (sample: 839 observations)

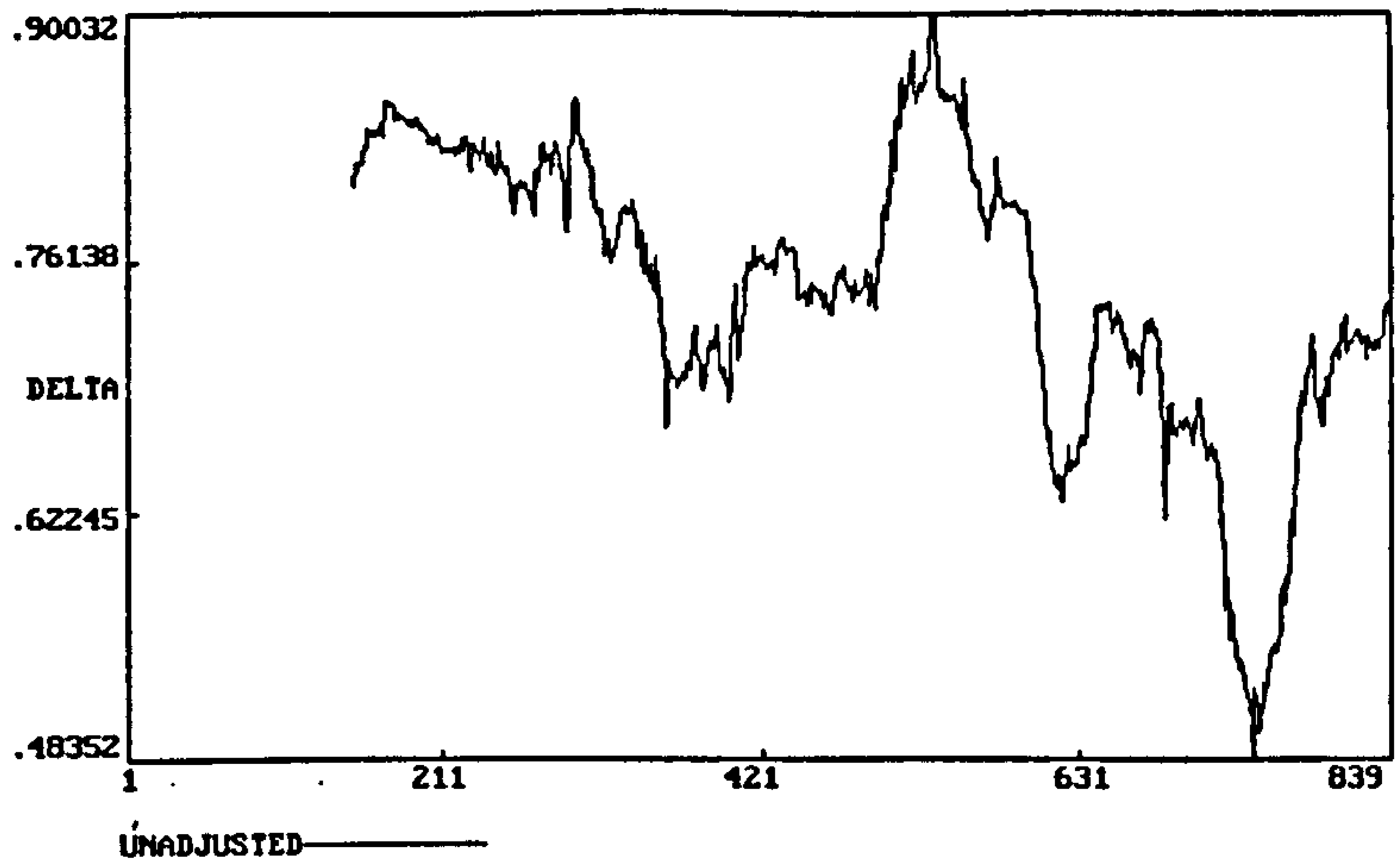


Figure 3.6
Elasticity of supply of arbitrage, δ, with rolling regression estimation of GDM when the spot index is adjusted for non-synchronicity (sample: 839 observations)

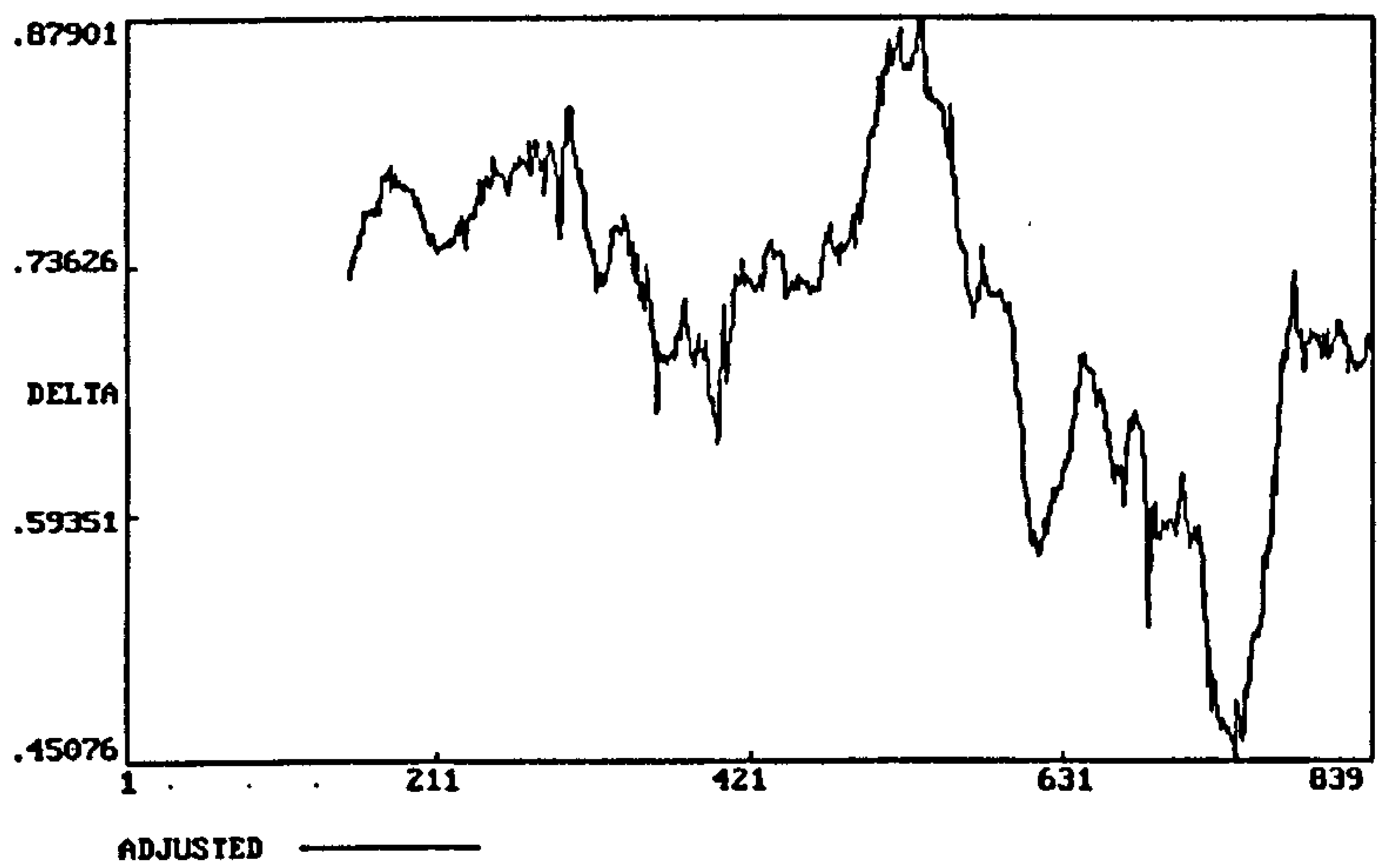
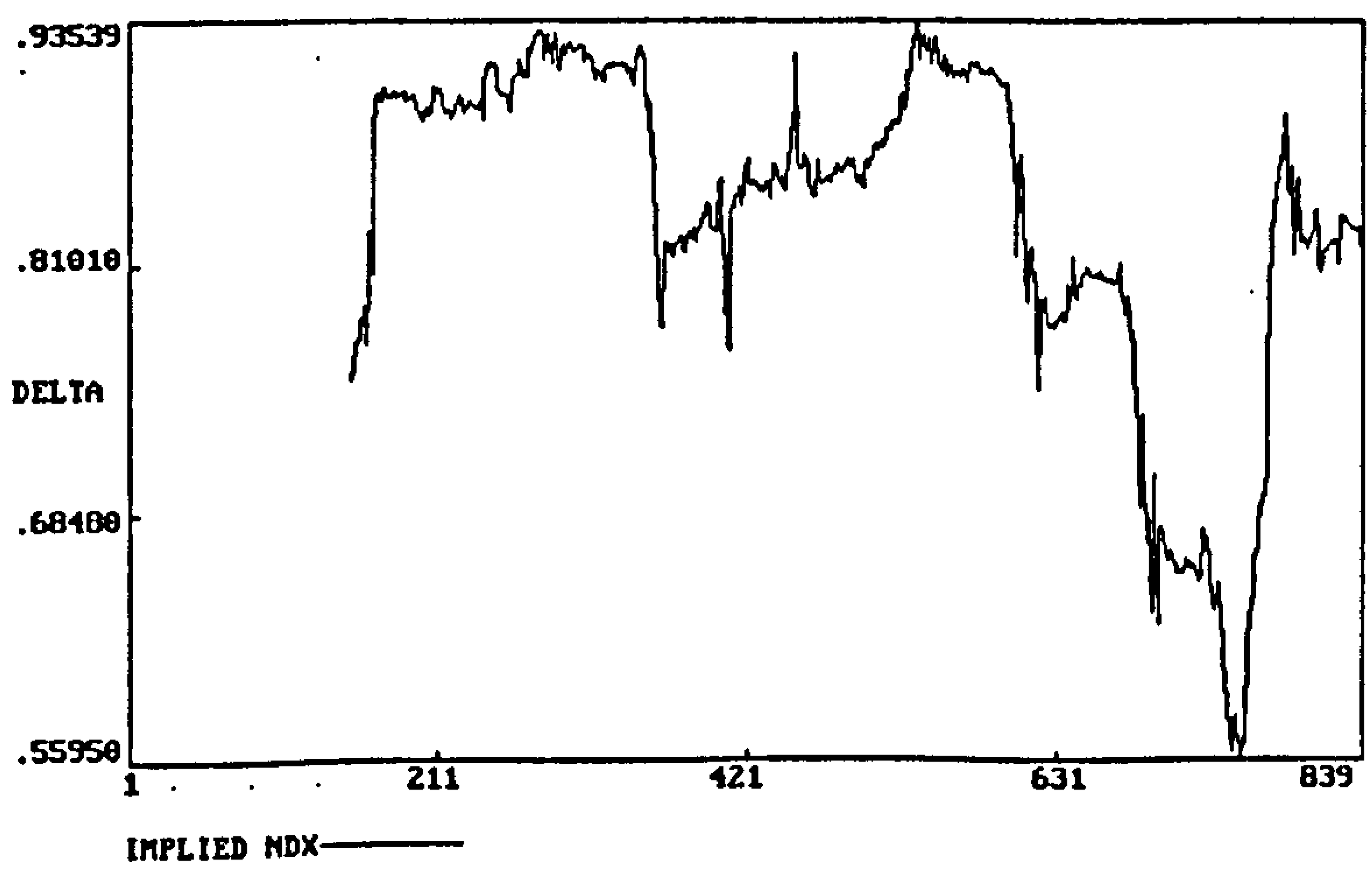


Figure 3.7
Elasticity of supply of arbitrage, δ, with rolling regression estimation of GDM using the implied index (sample:839 observations)



THE COEFFICIENT OF DOMINANCE

Figures 3.8, 3.9, 3.10, 3.11 and 3.12 graphically illustrate the value of the coefficient of dominance, Γ after the rolling regression estimation of the GDM. The figures again confirm the point estimate results that the futures market tends to dominate the spot market. Among the three cases examined we observe the unadjusted and adjusted series to produce similar results. However, the implied index case suggests, in line with the point estimate results, weaker dominance relationship. After examining the trading volume of the spot, and the futures FTSE 100 index we observe that periods with high futures dominance also exhibit a higher increase of the futures trading volume against the spot volume and vise versa. For example, for the period of futures dominance between observations 253 and 308 there is a 7.7% increase in the futures volume and only a 3% increase in the spot volume. However, for the period between observations 384 and 579 the implied index, unlike the other two cases, suggests spot dominance. For this period there is a higher increase in the futures trading than the spot trading. This observation cannot explain the result of the implied index.

The figures can also be used to observe the effects of specific news events on price dominance patterns. While there are numerous changes to the level of dominance, it would be difficult to describe all such changes. However, it is interesting to analyse news events around some of the more striking dominance changes. For example, figures 3.8 and 3.9, observation 882 corresponds to the October 1987 crash and experienced an abrupt change from spot market dominance to futures market dominance. An explanation for this is that with rapidly falling stock prices, volumes in the futures market increased considerably and the futures contracts themselves became the focus of the market's attention. The number of people trying to trade index futures, together with the ease and speed of trading such instruments meant that many traders could participate in the price changes. These actions would have meant a great deal of information was being discovered in the futures market. While volumes in the spot market were also high, the relative share of trading in the futures market was much higher, thus explaining the dominance of the futures market.

For recent years, Figures 3.10 to 3.12 also exhibit striking dominance changes. For example, observation 807 reflecting the events of April 13, 1995, corresponds to a strong dominance of the spot market which could be associated to the decrease in the stock prices on fears that inflation would rise. Higher rates encourage people to get out of equities and turn to fixed income. Price dominance by the spot market could have been due to increased volumes in the spot market as people began to sell, certain key shares in the FTSE 100 fell, leading a 13.5 point fall in the index (spot dominance).

Another example is observation 261 reflecting the events of March 12, 1993 and exhibiting strong futures dominance. Stocks fell dramatically (FTSE down by 38 points) ahead of Norman Lamont's budget on Tuesday 16th. Shareholders locked into gains, deciding not to trade stocks in case they lost money. The trading volume on the stock market traded 52 million fewer shares than the previous day. This would have diminished the amount of information flow on the spot market.

A further example is observation 314 for both Figures 3.10 and 3.11 which corresponds to May 26, 1993 and shows strong spot dominance. The stocks rose strongly due to strong US stock prices. The volume on the stock exchange was very strong - 26 million more shares were traded the previous day, and even that was high. One argument for dominance is that a liquid (high volume) market will use information more quickly because it is more active. The relatively large volumes on the spot market may account for the shift in dominance.

Finally, Figure 3.12 of the implied index case appears to capture events that the other two cases do not respond to. For example, observation 501 exhibits strong spot dominance for the options case which corresponds to February 11, 1994. That day the stocks fell substantially after the fears over rising US base interest rates. The FTSE fell 28 points, and had fallen 97 points over the three days 9 to 11. Trading on the spot market was very active - 997 million shares were traded.

The results of the rolling regression estimation confirm the point estimate results in that there is weak price dominance by the futures market of the spot market. However, the rolling regression is able to exhibit that the price dominance relationship is not at all stable and can even reverse during different time periods. Such findings could not be reached with the point estimates. Finally, the futures market seems to have experienced a relative growth in dominance over its spot market, which appears to have stabilised over recent years. This could be explained by the fact that as the futures market has matured, more traders have become better informed and aware of the market's functions. As a result, the trading volume in the futures market increases, as shown in Figure 4.10 allowing the market to perform its role of price discovery more efficiently, which results to its increasing dominance over the spot market.

Such findings clearly cannot be captured by the point estimation tests. These results are supported by existing literature which recognises the time-vary element in price discovery by investigating either stock indices (Schwarz and Laatsch (1991)) or commodities (some of them are Koontz *et al.* (1990) and Oellermann *et al.* (1989)). The approach of the existing studies to the issue of temporal nature of dominance involves the analysis of different sub-periods of the sample. However, our research improves their research by adopting an even better technique of the rolling regression. In addition, the existing literature covers mainly the U.S. market, therefore our research contributes even further with the analysis of the U.K. market.

Figure 3.8

GDM Dominance Ratio estimated with rolling regression when the spot index is not adjusted for non-synchronicity (sample: 2869 observations).

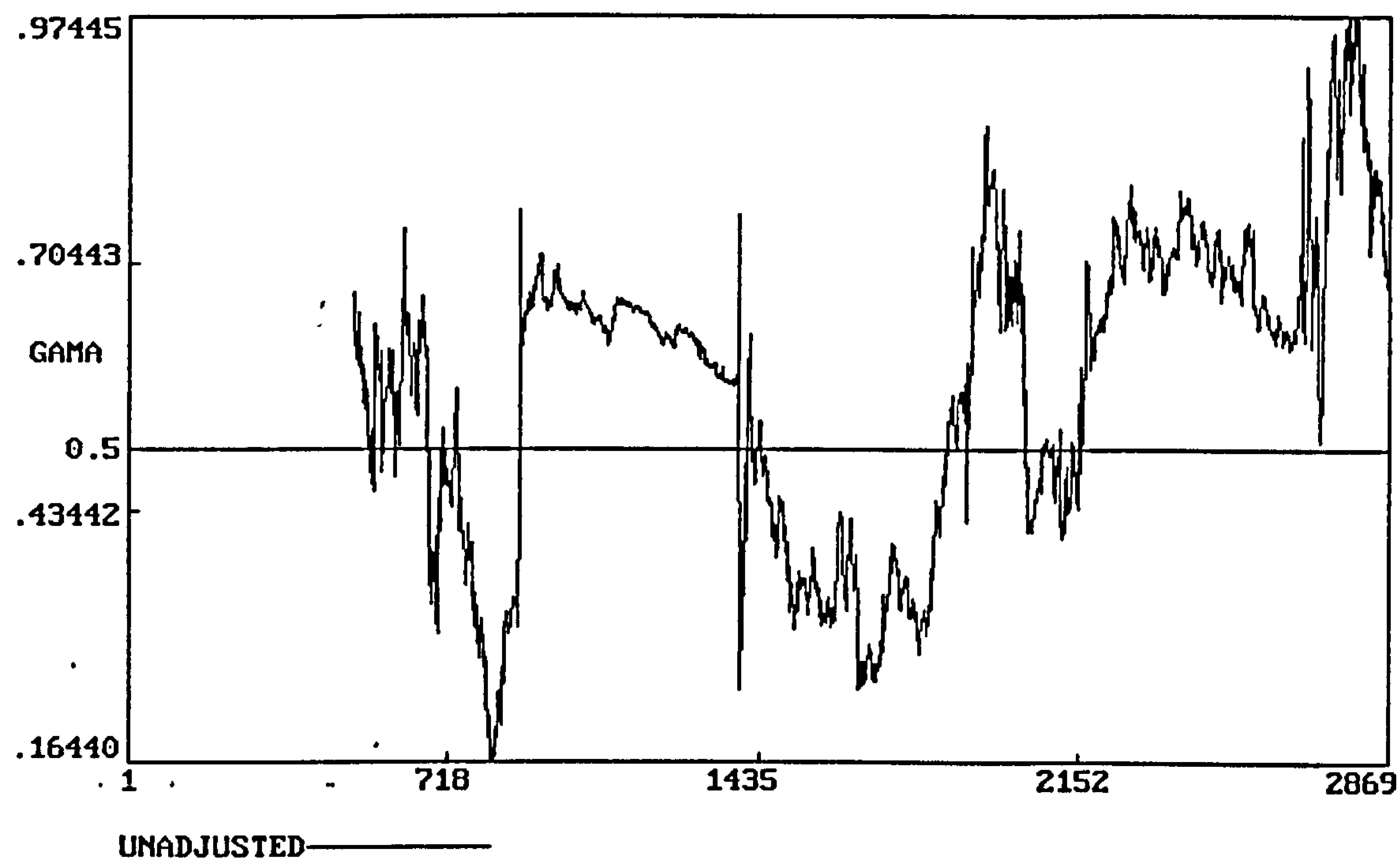


Figure 3.9

GDM Dominance Ratio estimated with rolling regression when the spot index is adjusted for non-synchronicity (sample: 2,869 observations).

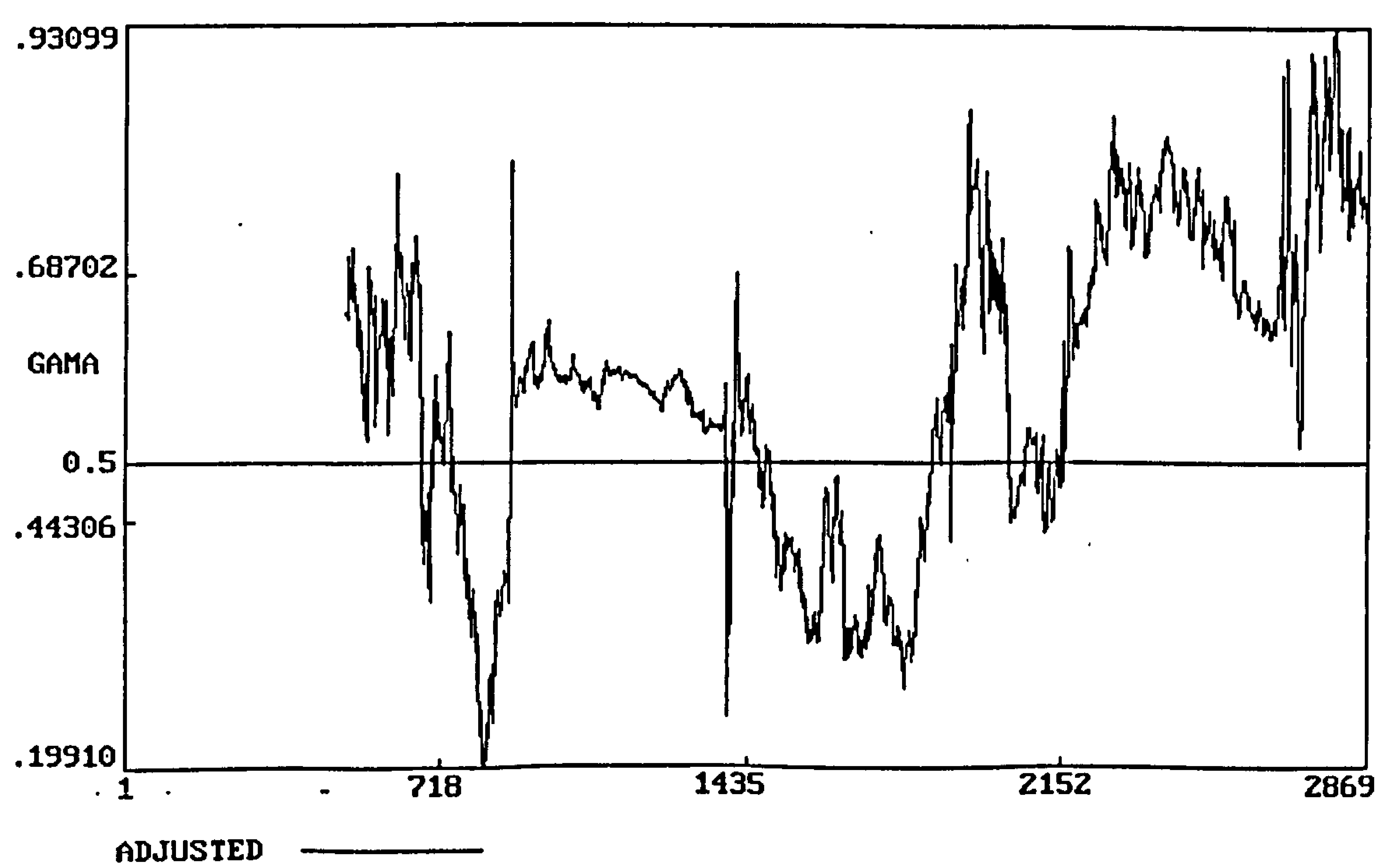


Figure 3.10
GDM Dominance Ratio estimated with rolling regression when the spot index is not adjusted for non-synchronicity (sample: 839 observations).

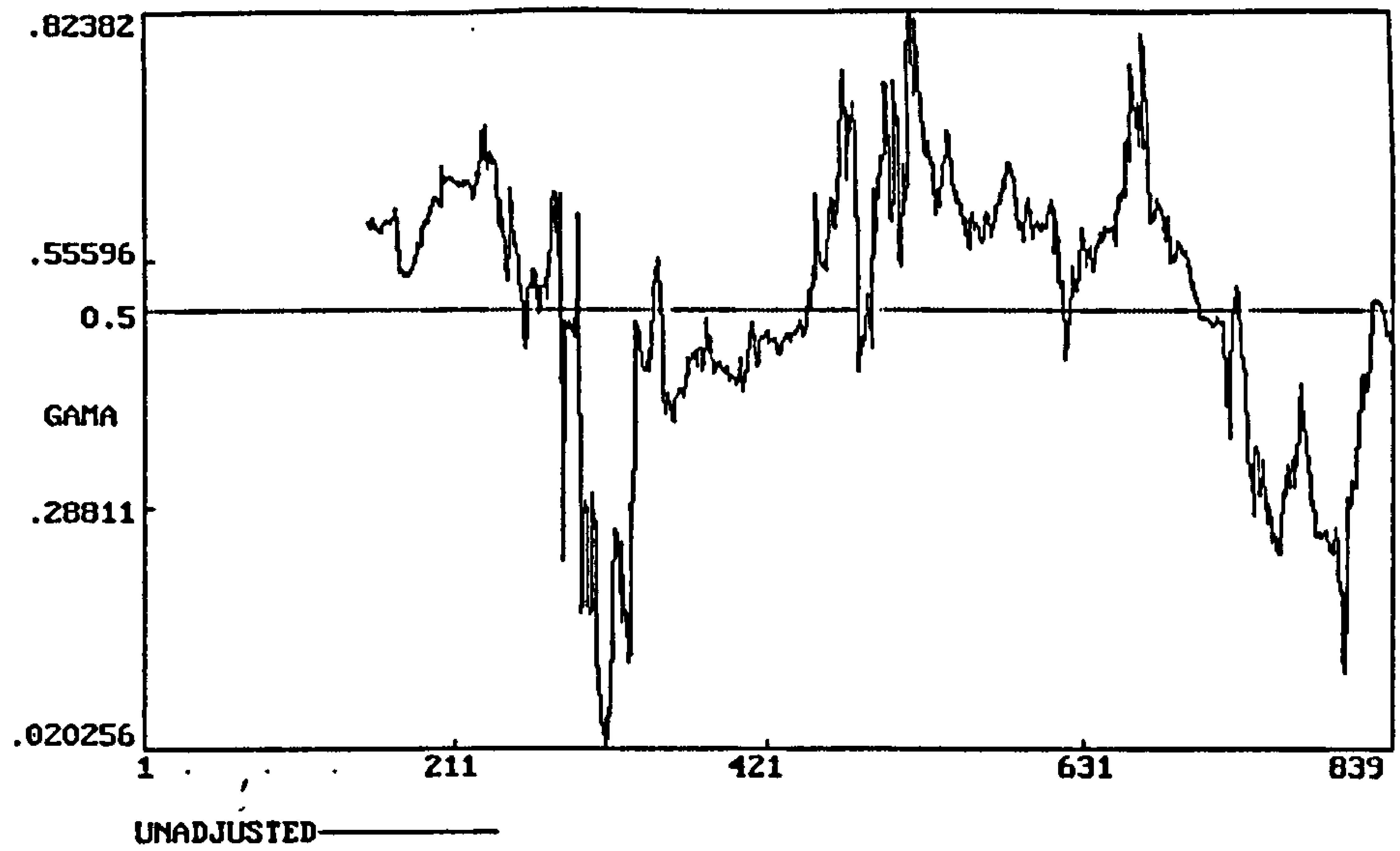


Figure 3.11
GDM Dominance Ratio estimated with rolling regression when the spot index is adjusted for non-synchronicity (sample: 839 observations).

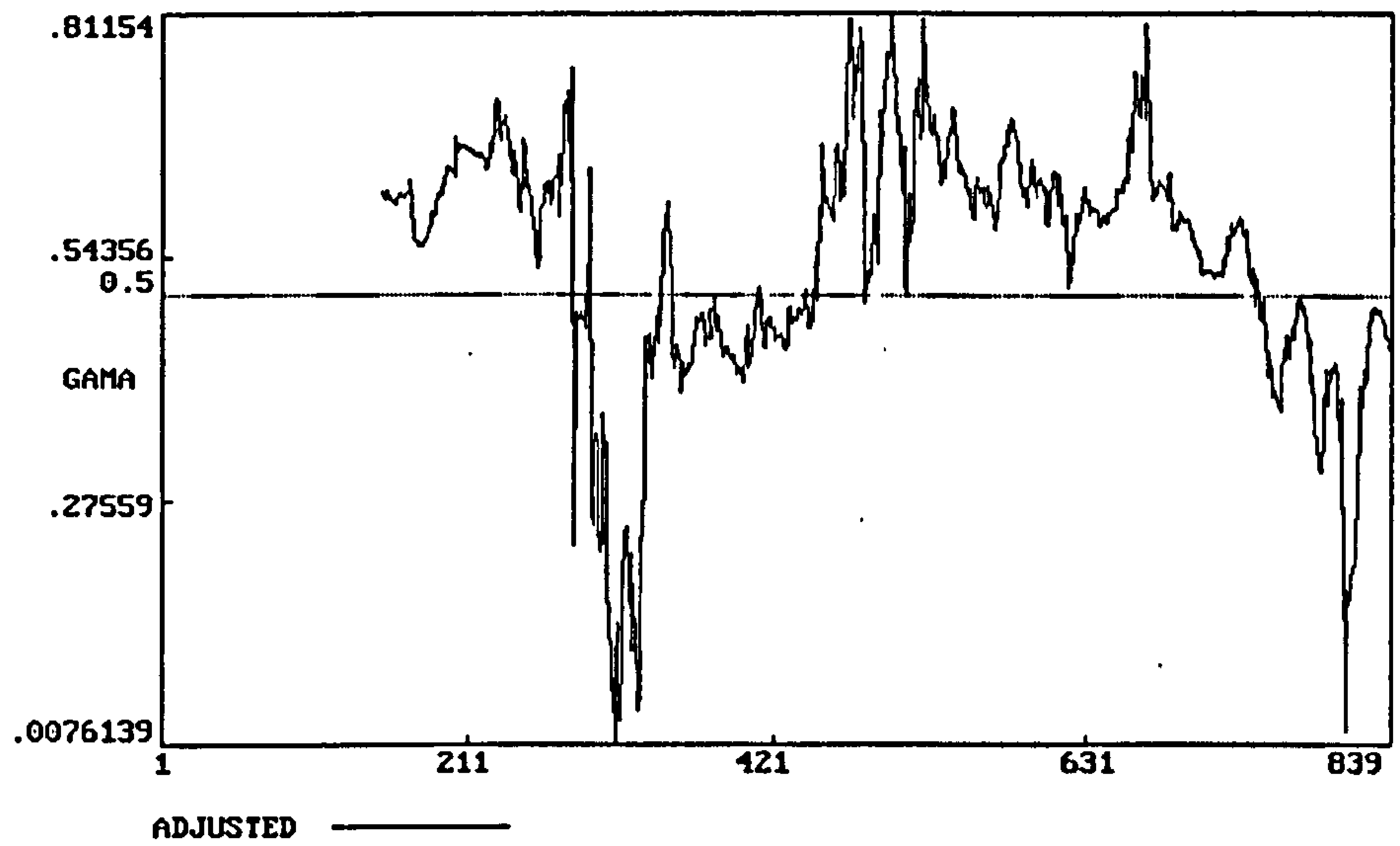
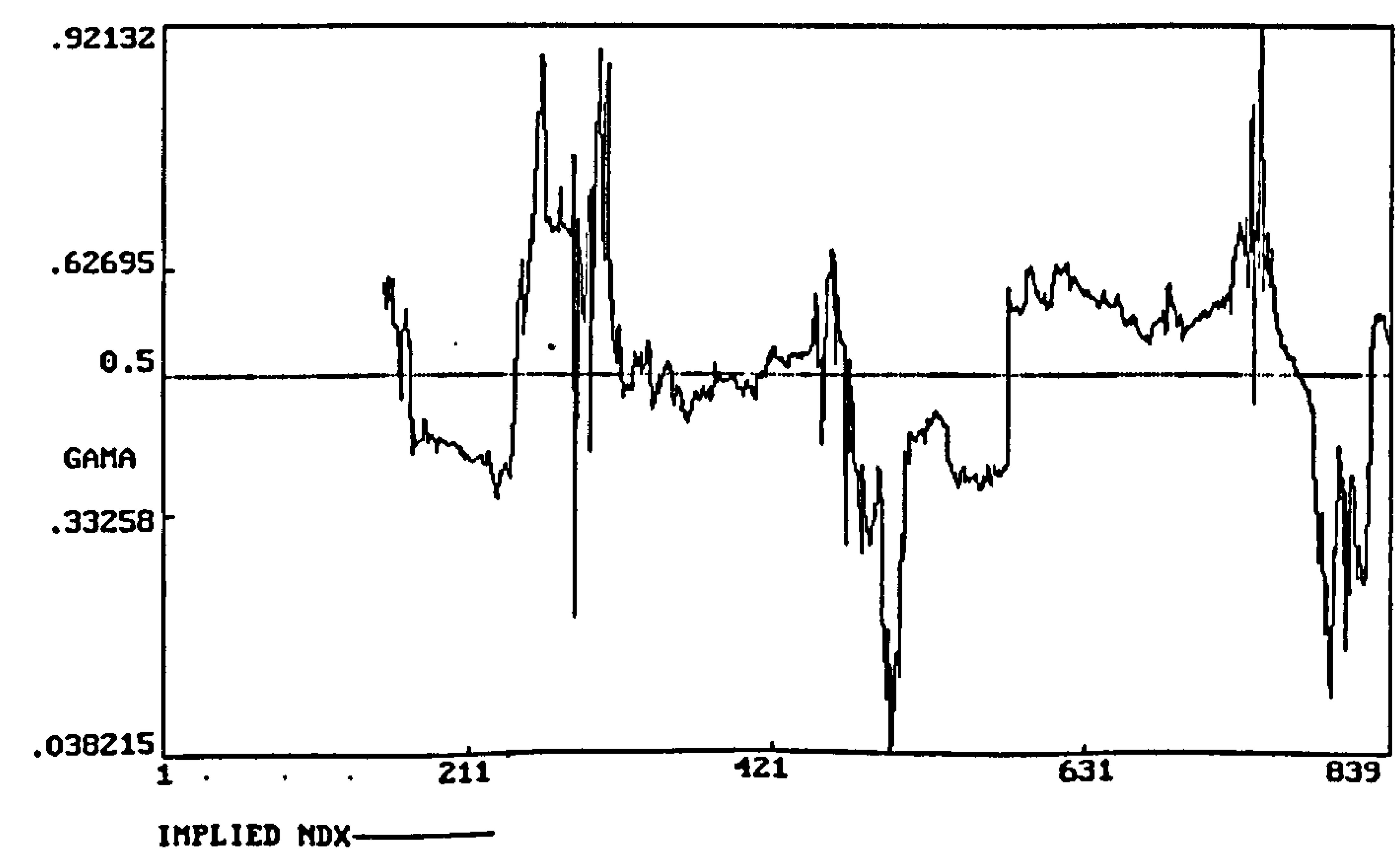


Figure 3.12
GDM Dominance Ratio estimated with rolling regression when using the implied index series (sample: 839 observations).



3.4.4. SUPPLY OF ARBITRAGE AND PRICE DOMINANCE IN RELATION TO TIME TO MATURITY

Our findings so far, based upon the use of rolling regression analysis, imply that the pricing relationship between the spot and the futures market changes over time, leading to variation in their price dominance relationship and the supply of arbitrage between the markets. It is of interest to see how both these measures behave in relation to the time remaining to maturity for a futures contract. This is so as to examine whether the time-to-maturity element can affect and explain the supply of arbitrage and the price dominance relationship. To investigate this, we analyse the spot-futures price relationship over a seven-month lifetime for each futures contract including the expiration month.[1] In addition to this, the calculation of both δ and Γ[2] for the contracts shown is based on the use of the unadjusted for non-synchronicity spot index. However, similar conclusions were reached for the other two cases of spot index.

---

[1]Due to the large number of results produced and the high similarity across the results, an indicative set of findings are presented.

[2]The value provided for each "day" is actually derived from a rolling regression, and is therefore an average value up to that day. The coefficient values are not intended to imply a specific daily value. Indeed, inferences are based on the pattern of dominance/supply of arbitrage over the seven month period as a whole.

Figures 3.13a and 3.13b provide the indicative plots of the elasticity of the supply of arbitrage and the price dominance measure for four futures contracts. The analysis of other contracts gave broadly similar results. Figures 3.14a and 3.14b display the average level of δ and Γ respectively across all contracts for the sample period June 84 to May 95. As expected, both the level of the elasticity of supply of arbitrage and the level and direction of the price dominance seem to vary over time. The graphs of the elasticity of supply of arbitrage, δ show that when a futures contract enters its expiration month, the level of δ tends to grow. This suggests that during the expiration month, the supply of arbitrage declines. Such a result is not surprising. As we discussed in section 3.3 and supported by existing literature (see Yadav and Pope (1990)), when a futures contract enters its expiration month the trading volume decreases as trading interest shifts to the next nearest futures contract as hedgers roll over their positions and as speculators move to the increasingly liquid new nearby contract. This can also justify the observed behaviour of the dominance ratio around expiration, where it is seen to suggest lack of futures dominance over the spot.

Figure 3.13a

The elasticity of supply of arbitrage financial index market plotted for some futures contracts which cover approximately seven months of their life and include the expiration month.

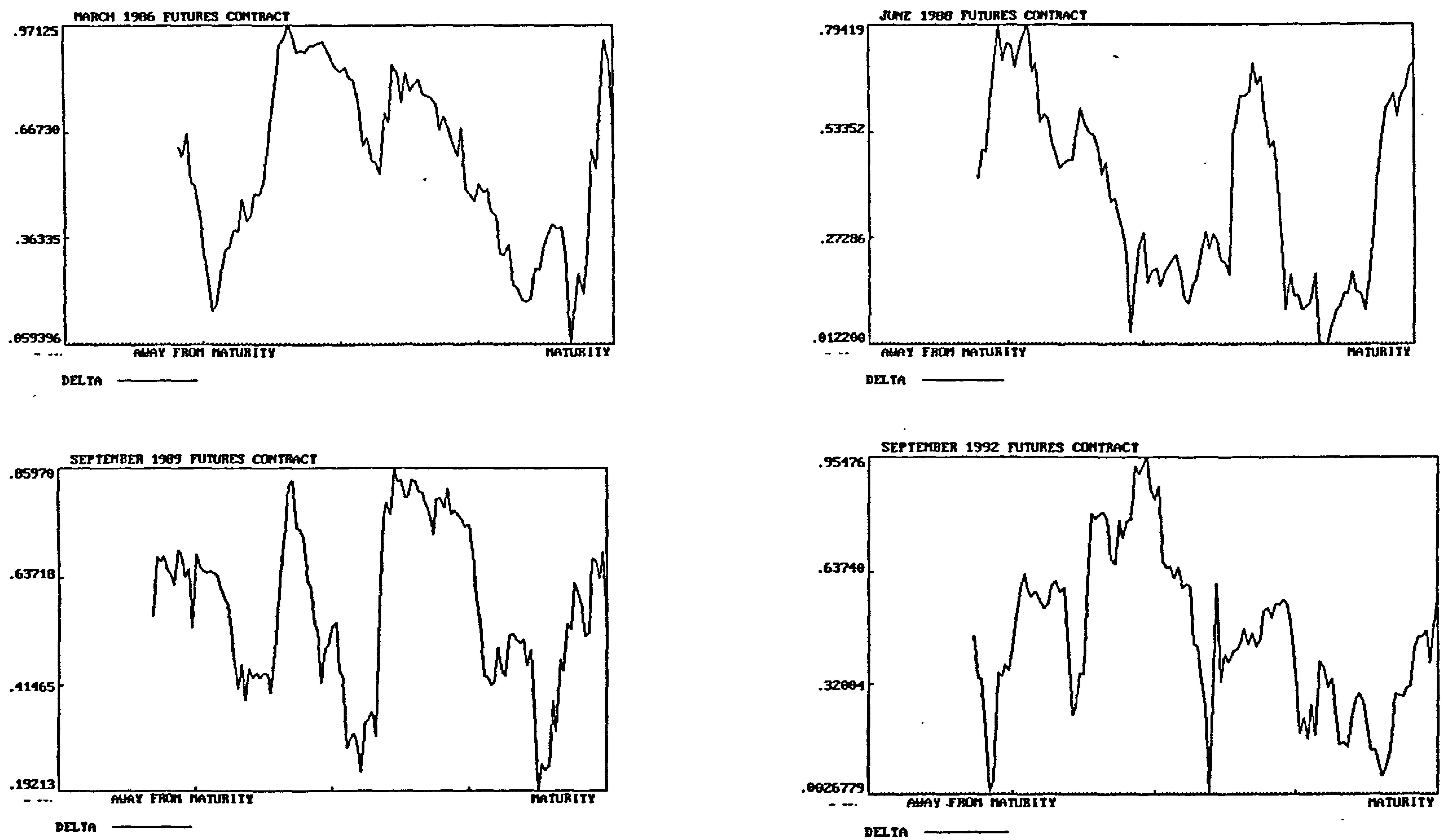


Figure 3.13b

The GDM Dominance Ratio plotted for some futures contracts which cover approximately seven months of their life and include the expiration month.

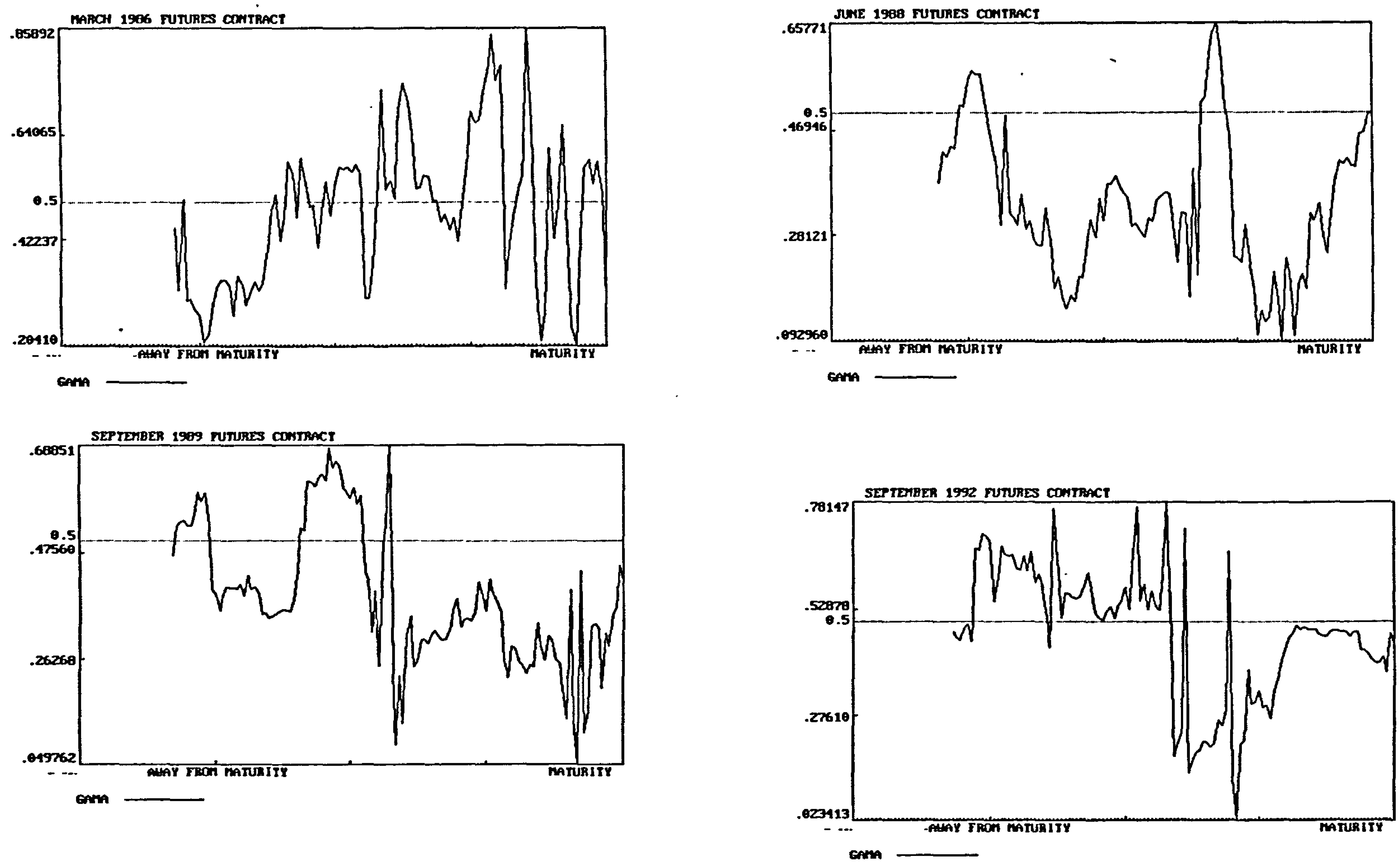


Figure 3.14a
The average elasticity of supply of arbitrage across all contracts including their expiration month for the sample period of June 84 to May 95.

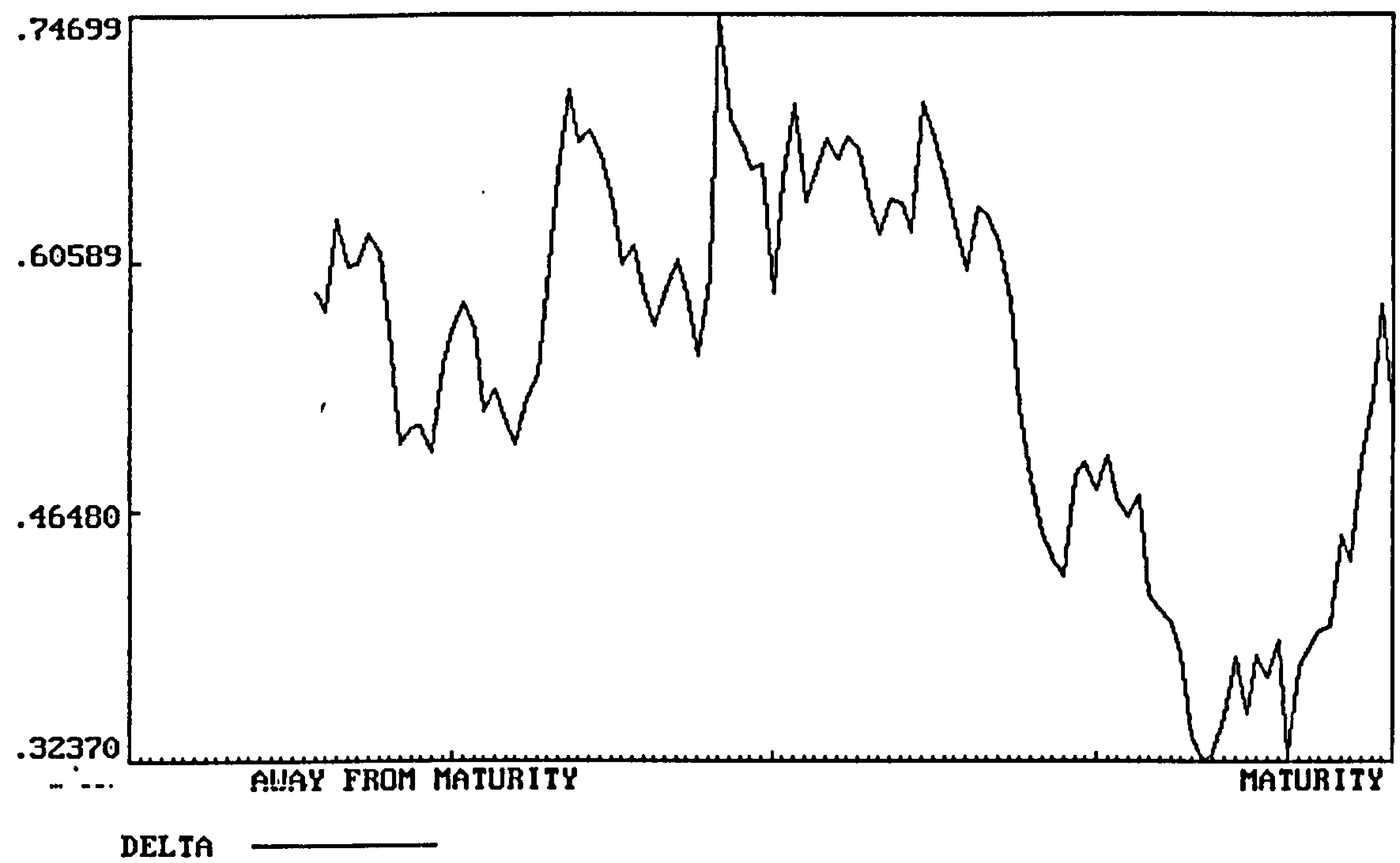
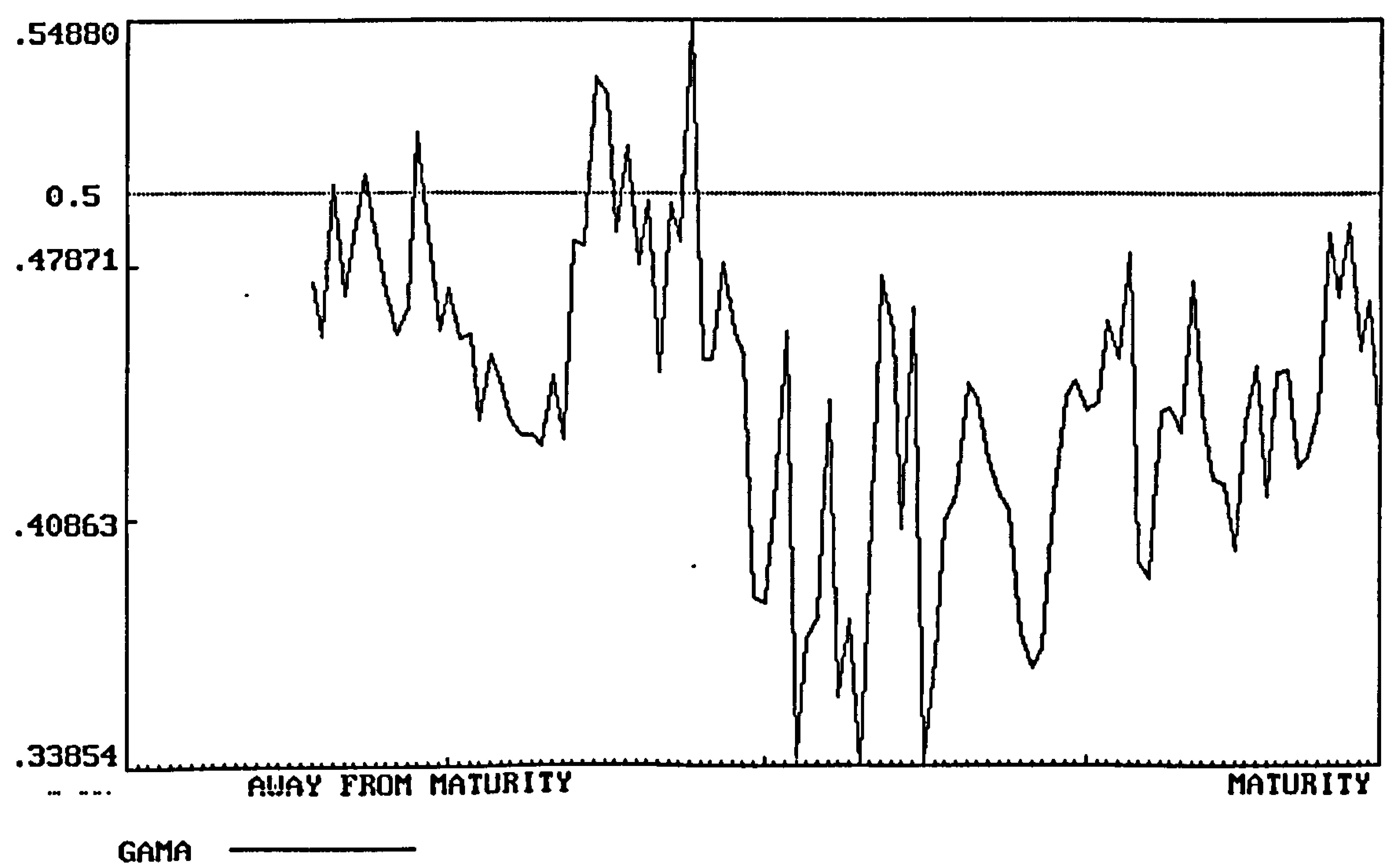


Figure 3.14b

The average GDM Dominance Ratio across all contracts including their expiration month for the sample period of June 84 to May 95.



3.4.5 SUPPLY OF ARBITRAGE AND PRICE DOMINANCE IN RELATION TO THE NATURE OF NEWS

In this section we are interested in the effect of the arrival on the market of both bad and good news to both the elasticity of supply of arbitrage, δ and price dominance, Γ. The results of such an investigation could further our understanding of the determinants of both the elasticity of supply of arbitrage and price dominance. Previous research such as Glosten *et al.* (1989), has suggested that bad news tends to have a larger effect on price changes than good news.

We therefore investigate whether the relative reaction of the spot and the futures markets to the direction of price changes is different by concentrating on the elasticity of supply of arbitrage and the price dominance relationship following good and bad news. In order to do so, the spot index returns are grouped into positive and negative observations along with their corresponding values of δ and Γ. The assumption is that good news corresponds to an increase in price (a positive return), while bad news is the reverse. Results are presented for the unadjusted for non-synchronicity spot index, but similar results are found for the other two cases of spot index. The results are reported in Table 3.9.

Table 3.9

FTSE 100 Spot and Futures Returns, under the effect of good (positive spot returns) vs. bad news (negative spot returns). SD: standard deviation, μ: mean, t-stats: t statistics for the H_0 : $\mu_1=\mu_2$ which is rejected at 5% level of significance if t-value > $|1.960|$.

SERIES	GROUP OF POSITIVE SPOT RETURNS 1276 OBSERVATIONS		GROUP OF NEGATIVE SPOT RETURNS 1092 OBSERVATIONS		t-stats
	μ_1	SD	μ_2	SD	H_0: $\mu_1=\mu_2$
SPOT RETURNS	0.0065	0.0059	-0.0070	0.0078	46.861*
FUTURES RETURNS	0.0071	0.0076	-0.0077	-0.0098	40.549*
BASIS	0.0109	0.0089	0.0091	0.0095	4.731*

* The H_0 is rejected, therefore, $\mu_1 \neq \mu_2$.

Table 3.9 confirms the results of previous studies (such as Glosten et al. (1989)), that bad news affects price changes more than good news. This can be seen in both the spot and the futures returns series which, on average, tend to decrease more at bad news (μ_S=-0.0070, μ_F=-0.0077) than they increase at good news (μ_S=0.0065, μ_F=0.0071). In addition to this the t-stats show that, on average, the spot returns under good news and the spot returns under bad news are statistically different. The result of all these findings prove that the type of news affects the size of price returns. The same result is reached for the futures returns.

Price dominance and the elasticity of supply of arbitrage however, are found not to be affected by the nature of news. This is shown graphically in Figures 3.15, 3.16, 3.17 and 3.18. Based on these, as well as the previous findings, we can conclude that both the spot and the futures markets respond the same way to the arrival of different type of news (both overreact to bad news). Chan (1992) who investigated the MMI and the S&P 500 stock indices on an intraday basis also finds that the tendency of the futures to lead the spot index under bad news is not different under good news.

The nature of news does not only affect the change in the spot and futures prices but also their pricing relationship described by the basis and calculated based on equation (3.15). Table 3.9 shows that the basis is, on average, statistically different under different type of news. Despite the fact that both the spot and the futures prices tend to decrease more with bad news than they increase at good news, they appear to decrease/increase at relatively different rates between them. As a result, the basis is found to be wider when the news is good. However, since the elasticity of supply of arbitrage does not seem to be affected by the nature of news, we can explain our findings by assuming that the increase in the width of the basis is not big enough to overcome the level of transaction costs. As a consequence, arbitrageurs do not seem to exploit the extra opportunities arising under good news since mispricings still appear to be unattractive possibly due to unfavourable transaction costs.

Figure 3.15

The elasticity of supply of arbitrage δ, at the arrival of good news (unadjusted case).

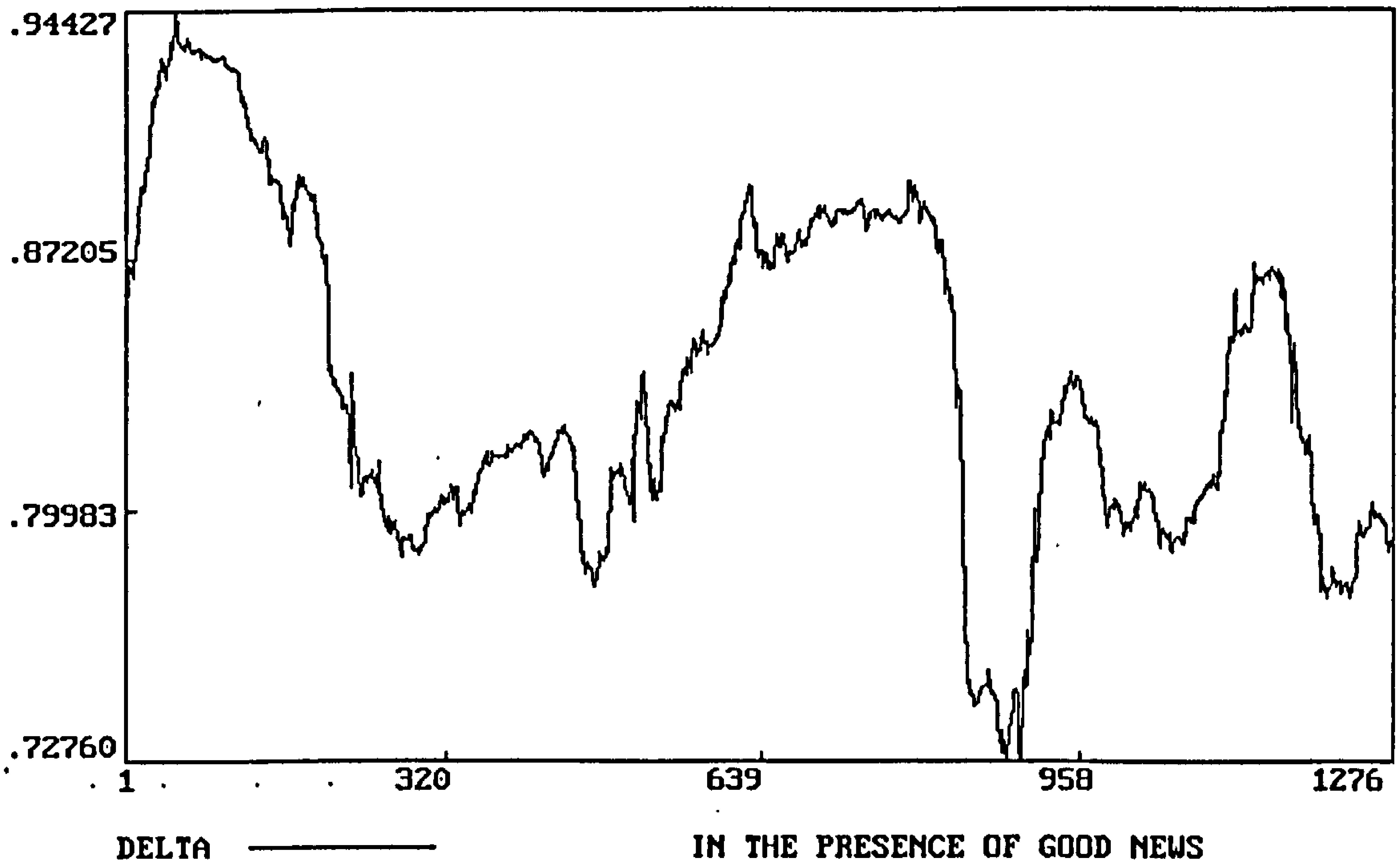


Figure 3.16

The elasticity of supply of arbitrage δ, at the arrival of bad news (unadjusted case).

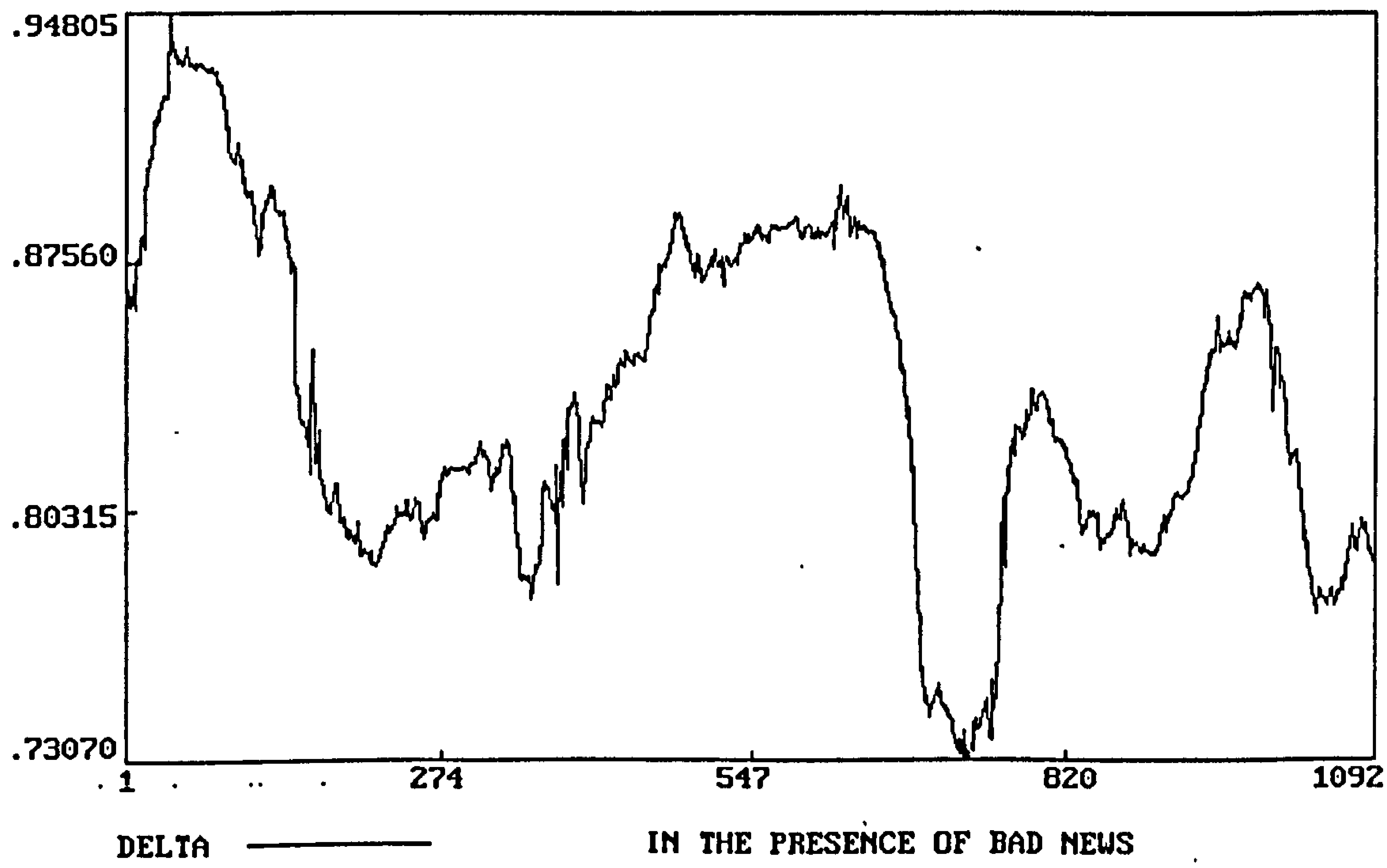


Figure 3.17

The price dominance ratio, Γ, at the arrival of good news (unadjusted case).

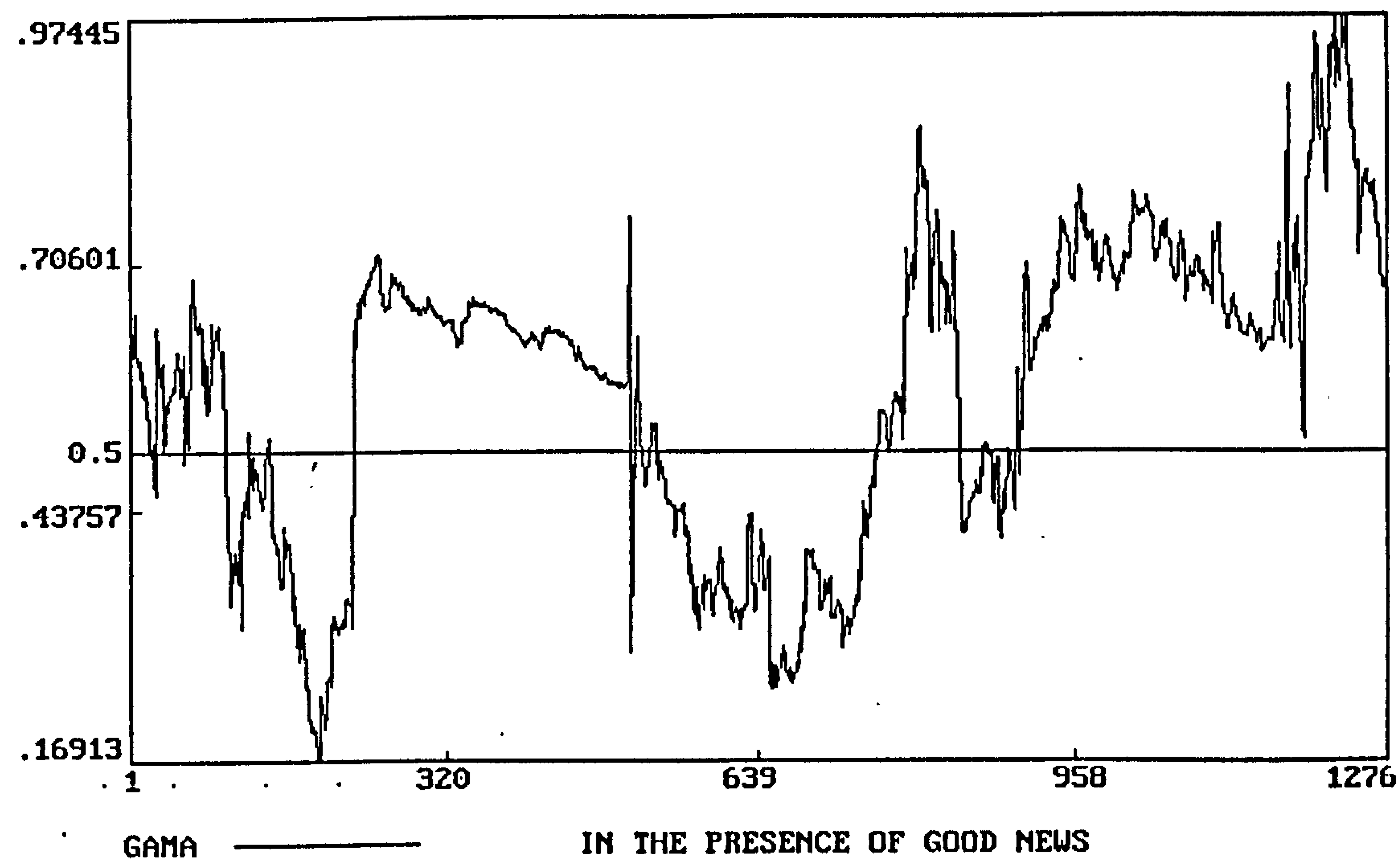
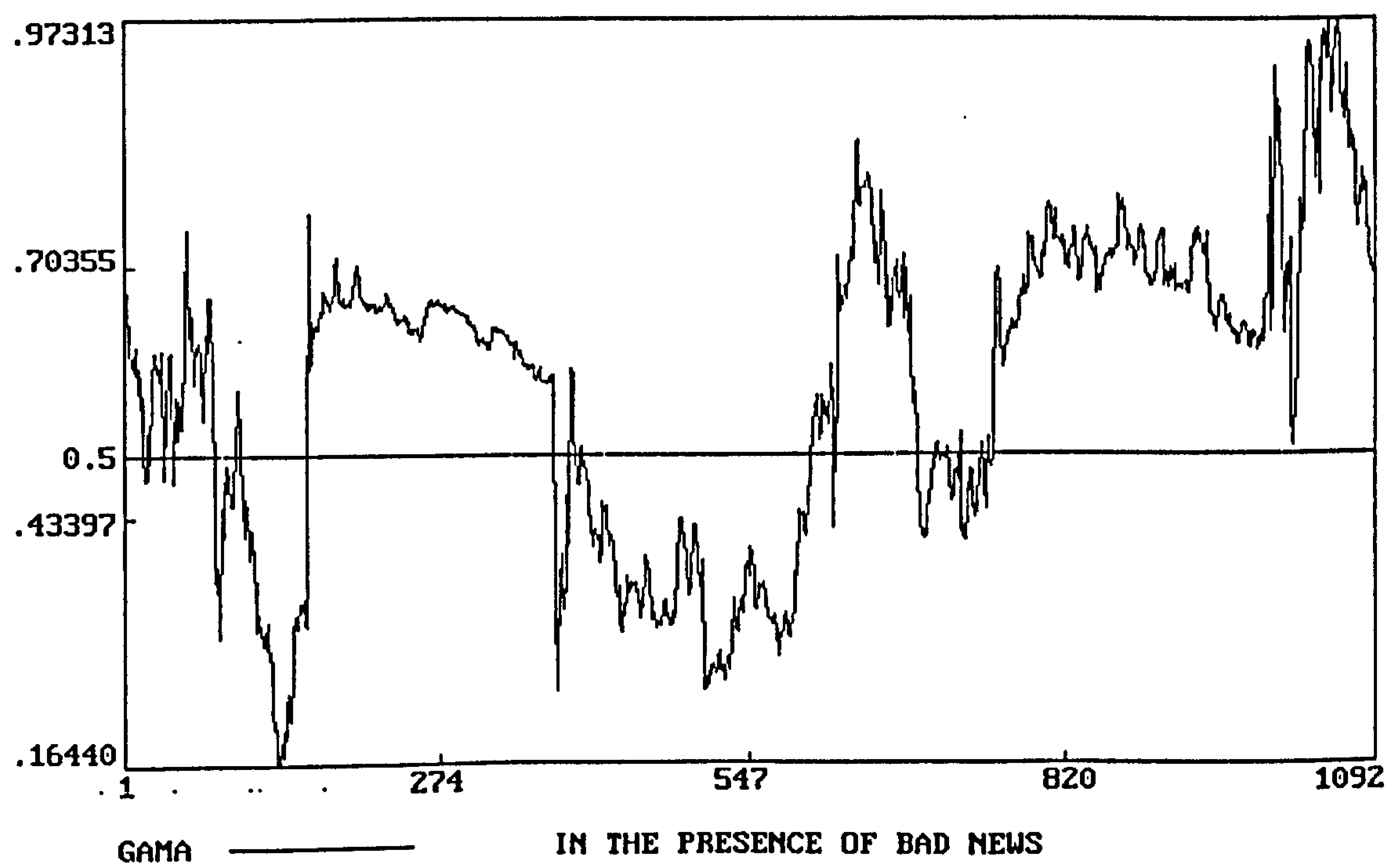


Figure 3.18

The price dominance ratio, Γ, at the arrival of bad news (unadjusted case).



3.5 Summary And Conclusions

The purpose of this chapter is to analyse both the short-run and long-run pricing relationship between the spot and the futures markets in terms of both the elasticity of supply of arbitrage and price dominance. This was achieved with the application of the Generalised Dominance Model in the context of cointegration and error-correction models. The contribution of this chapter lies with the fact that this model has never been applied before on an index series of the U.K. market and is an improved methodology of the existing techniques. This model provides a different, improved way of examining the issue of arbitrage in the futures market, but also allows us to consider the important issue of price dominance between the FTSE 100 spot and futures markets in a more complete way. The value of this model lies at the fact that, unlike previous methodologies, it accounts for all possible routes by which information can be transmitted between the spot and futures markets. This chapter, for the first time in the literature, provides this different way of examining and analysing the FTSE 100 spot index and futures contract.

The empirical work relied upon two aspects. At first, the empirical results were produced based on the use of point estimates. However, the pricing relationship between the spot and the futures markets can be expected to vary over time as the result of the rate of information flows to the markets, the impact that different types of news can have on the two markets, changing levels of trading volume and the maturity effect of the futures market. As a consequence, point estimates will not capture the time-variation involved, and could lead to misleading interpretations being made. Therefore, we analyse the time-varying nature of price dominance and supply of arbitrage by applying a rolling regression estimation. The results show that the use of time-varying estimates better explain the nature of the price relationship in question and illustrate its changing patterns in a more reliable manner. These results imply that although for many reasons the futures market may be expected to reveal information before the spot market (due to lower transaction costs, greater liquidity etc) the spot market will occasionally be the first to react to information. The time-varying estimation also provides a much clearer picture of the way in which price discovery changes between the spot and futures markets, and illustrates the dynamic nature of price discovery patterns better than point estimation, even when point estimates are computed over a number of sub-samples. By observing that the price discovery relationship between the markets can vary a great deal (see figure 3.8), it can be appreciated that while information discovery is normally made by futures markets, they not always dominate spot markets to the same degree, and can be dominated by spot markets. This observation is important since it tells us that we cannot always rely upon observed futures prices to be more up to date than existing spot prices. The time varying estimate illustrates the very changeable nature of dominance, and can also be used to identify how the two markets have reacted to particular news events. This is explored in section 3.4.3.

Overall, the findings of this chapter can be summarised as follows; After using all three cases of spot index, which involve the unadjusted and the adjusted for non-synchronicity spot index and the implied index, the results suggest that non-synchronous trading is not responsible for and cannot fully explain the results. In the long-run, the cointegration tests show that the spot and the futures prices are kept close and do not drift apart without bound. It can be assumed that the market mechanism which acts as the link and allows the two markets to move together is arbitrage trading.

The point estimation results indicate that on the whole, the futures market tends to dominate the spot market, but that this observation is not due to measurement problems caused by non-synchronous trading. Approximately, 76% of new information is incorporated first in the futures prices and is then transmitted to the spot prices. In addition, it is found that the supply of arbitrage is highly inelastic implying that it would take substantial price discrepancies to initiate arbitrage strategies. This shows that mispricing tends to persist, and seems to suggest that the two markets are not kept closely in the shorter-term. This observation is consistent with the finding of a cointegrating relationship between the markets, since cointegration suggests that the two markets will have a common long run relationship, in this case, that the basis will not become infinitely large or that the spot and futures prices will drift apart without bound. In the shorter-term, however, it is possible for the size of the basis to vary as spot and futures prices do not follow each other closely. This is commonly termed the basis risk.

However, the results could be overestimating the persistence of mispricing as they do not distinguish between profitable and non-profitable mispricing. This means that the observed mispricing may fall within the transaction cost bounds where no profits can be made. The apparent lack of arbitrage activity suggested could still be consistent with a well functioning market, since an arbitrage strategy for exploiting the mispricings would not be profitable. The profitability of arbitrage opportunities is the subject of the following chapters.

On the other hand, the time-varying results show that both price dominance and elasticity of supply of arbitrage do not remain stable, something that is not captured by the point estimates reliably. This finding is not surprising since the nature and the speed of information flows vary, and this in turn affects the importance of arbitrageurs and hedger/speculators in transmitting information across the markets through their trading activity. Existing research (see Yadav and Pope (1990)) supports that when a futures contract enters its expiration month, the trading volume decreases because the interest is shifted to the next nearest futures contract, which has more arbitrage opportunities to offer. Consistent with this, during the expiration-month-period, the futures market does not appear to be the source of price discovery, while the measure of the elasticity of supply of arbitrage is found to grow as the result of the decline in the supply of arbitrage trading.

The futures market seems to have experienced a relative growth in dominance over its spot market, which appears to have stabilised over recent years. This is explained by the fact that as the futures market has matured, its participants are better informed, which is reflected in an increase of the trading volume. This shows that the market performs its role of price discovery more efficiently.

Among the three cases of spot index applied in the empirical work of this chapter, the implied index seems to suggest a larger persistence of mispricing and lack of arbitrage trading. In addition, it appears to imply a weaker price dominance relationship of the futures market over the spot market with a nearly simultaneous response to new information from both markets. We do believe the results of the implied index to be more reliable because of the advantages this index exhibits over the unadjusted and the adjusted for non-synchronicity spot series. This can be attributed to the fact that it is derived based on the options contracts. As a result, unlike the reported index, it is not exposed to the effects of non-synchronous trading or becomes the subject of adjusting methods the way the adjusted series did. It additionally, overcomes the a-synchronicity in the closing times between the spot and the futures index markets.

Finally, consistent with previous reports, we observe the nature of news to affect the change in the spot prices with the tendency to react more when the news is bad. In a similar manner, changes in the futures prices also seem to respond asymmetrically to news with the tendency to react more to bad news. However, in line with previous studies, both the elasticity of supply of arbitrage and the price dominance are not affected by the nature of the news arriving at the market. This means that it will still take high levels of mispricing in order to attract arbitrageurs despite the nature of news. It also means that the nature of news does not affect the tendency for one market to become more or less dominant over the other.

In a financial market which performs well, the spot and the futures markets should be related and not function independently. This could be guaranteed by the actions of arbitrageurs. Overall, the results show that in the long-run, arbitrage trading is found to be effective maintaining the close price relationship between the spot and futures markets. On the other hand, in the short-run arbitrage trading appears to be missing or not being enough to remove the observed mispricings. However, since the model does not distinguish between profitable and non-profitable arbitrage opportunities (the subject of the following chapters), we could expect that a significant part of the mispricing persisting falls within the transaction cost bounds. As a result, the two markets could still treated as if they are closely related. Furthermore, since both markets represent prices for the same asset and at maturity the prices are equal, while any time before they are linked through arbitrage the spot and the futures markets should be affected in a similar manner at the arrival of news.

However, the futures prices seem to react first before the spot prices. This could be attributed to the nature of the futures market, which involves among other the ease by which the index can be updated unlike the spot index and the lower transaction costs required.

This chapter provided an initial investigation of the arbitrage relationship between the spot and the futures index markets through the use of the GDM. The chapters to follow analyse the issue of mispricing and arbitrage more explicitly by following a different approach which encounters for transaction costs.

CHAPTER 4

EMPIRICAL EXAMINATION OF THE MISPRICING OF THE FTSE 100 STOCK INDEX FUTURES CONTRACT.

4.1 INTRODUCTION

The chapters presented so far managed to provide us with some insights of the price relationship between the spot and the futures markets. This analysis continues with the detailed investigation of the issue of mispricing of the FTSE 100 stock index futures contract for the U.K. market. That is because the systematic existence of mispriced futures contracts could lead to the occurrence of arbitrage opportunities, raising questions about the ability of the futures market to correctly price its contracts[1]. The issue of correctly pricing futures contracts is also important because it has a direct effect on the role that the futures market plays in the processes of hedging and price discovery.

There is a wide range of studies in the existing literature examining mispricing in the futures market, with the US market attracting more analysis than any other country, and approximately half of all studies such as those by Figlewski (1984a, 1984b), Modest and Sundaresan (1983), Cornell and French (1983a, 1983b), Arditti *et al.* (1986),

[1]It should also be noted that a failure in the spot market could also generate arbitrage opportunities.

Cornell (1985), MacKinlay and Ramaswamy (1988), Merrick (1987, 1989), Bhatt and Cakici (1990), Chung (1991), Klemkosky and Lee (1991) and Saunders and Mahajan (1988). A smaller number of studies investigate the issue in the U.K. like Yadav and Pope (1990, 1991), in Japan, Lim (1992), Brenner *et al.* (1989b, 1990b), in Germany like Buhler and Kempf (1995), in Switzerland like Stulz *et al.* (1990) and in Finland like Puttonen and Martikainen (1991) and Puttonen (1993). All studies find the actual futures price to deviate from its theoretical value based on the cost-of-carry model. However, there is no clear consensus as to whether futures contracts are undervalued or overvalued. In his book, Sutcliffe (1997) reviewed a large number of studies on this subject and found that the majority detect overpriced futures. The significant mispricing observed in particular in the U.S. market was attributed mainly to the fact that the futures market is new and there is lack of knowledge about its workings, therefore, as the market matures the mispricing decreases[1]. Other reasons reported include the restrictions on short sales, which do not allow traders to fully use the proceeds of their short sales[2]. In addition to this, mispricing has been attributed to the tax-timing option which is available to stock owners and is believed to affect the relation between spot and futures prices[3]. However, later reports

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[1]Some of these studies are those by Cornell and French (1983a, 1983b), Figlewski (1984a), Merrick (1987, 1989), and Saunders and Mahajan (1988).

[2]Modest and Sundaresan (1983), Bhatt and Cakici (1990).

[3]Cornell and French (1983a, 1983b).

suggest that the tax-timing option is an insignificant factor on the pricing of futures contracts[12]. Finally, some studies examined the relationship between mispricing and time-to-maturity[3] and found mispricing to be larger the longer the maturity of the futures contract. This finding was attributed to the effect of unanticipated changes involving dividends and interest earning.

This chapter contributes to the existent literature in many ways. At first, since little research has taken place in the U.K. in contrast to the American market, it is of interest to see whether the conclusions reached in the U.S. market are applicable to a different but important economic environment such as the U.K. financial market. Our contribution here to the literature includes the use of a much larger and more updated data set. The importance of using this improved data set lies with the fact that the presence of mispricing has been attributed mainly to the *unfamiliarity* with the new futures market.

Furthermore, the existing studies have relied on the use of either dividend yields or actual dividends when applying

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[1]Cornell (1985), Yadav and Pope (1990), Buhler and Kempf (1995).

[2]Other possible explanations are stale prices/non-synchronous trading, price limits, a-synchronicity in the closing of the spot and futures markets, regulatory restrictions, time lags in trading, inadequate allowance for transactions costs and an incorrect model for the no-arbitrage price.

[3]MacKinlay and Ramaswamy (1988), Buhler and Kempf (1995) and Yadav and Pope (1990).

the cost-of-carry model. If the use of either dividend yield or actual dividends can have an effect on the results of an empirical investigation then the conclusions of such investigations will not be clear due to such dependence. We therefore, investigate both approaches in an attempt to find out whether the results can be significantly different. This represents the second main contribution to this investigation. Moreover, in the calculation of the theoretical futures price based on the cost-of-carry model, we apply three spot series; the observed one, the spot series adjusted for non-synchronicity and the implied index derived in chapter two. As explained in chapter two, the presence of non-synchronous trading in the spot market could affect the relationship between the spot and the futures markets. Therefore, since the existing research in the U.K. is limited to Yadav and Pope (1990,94) and Strickland and Xu (1993), who do not make any adjustments for non-synchronous trading in their tests, our findings are expected to contribute significantly with more reliable and comprehensive results representing our third contribution.

Briefly, the main results of our research are as follows; The futures contracts are found to be significantly undervalued. The absolute value of the mispricing seems to increase with time-to-maturity. The level of mispricing, despite being relatively small, is statistically significant and appears to have decreased in the recent years. In addition, the tax-timing option does not seem to be a significant factor in explaining the observed mispricing. Finally, the implied index suggests higher level and more persistence in mispricing.

The rest of the chapter is organised as follows; Section two presents the methodology used. Section three describes and explains the data used. The empirical findings are in section four, while the chapter finishes with section five, which provides a summary and conclusions.

4.2 METHODOLOGY

4.2.1 THE PRICING RELATION BETWEEN STOCK INDEX AND FUTURES DESCRIBED BY THE COST-OF-CARRY PRICING MODEL

Futures prices are related to expected spot prices according to the *expectations hypothesis*:

$$F'_{t,T} = \exp(S_T) \tag{4.1}$$

where:

$F'_{t,T}$	:	the current price of a futures contract issued at time t and maturing at time T
S_T	:	the spot price at the delivery date of the futures contract
$\exp(S_T)$	:	the curreht expectation of S_T

At equilibrium, the actual futures price equals the theoretical futures price. The cost-of-carry model tries to define the currently expected future spot price. Assuming that the capital market is perfect[1], the cost-of-carry model states that a futures contract will sell not at the spot price, but at a *premium* above it, which represents the cost of carrying the asset until maturity. According

[1]For example, there are no transaction costs, taxes, information asymmetries, or short sale restrictions and investors can get full use of the short selling proceeds and can borrow or lend money at the same, constant and continuously compounded risk-free interest rate.

to Cornell and French (1983b) and Modest and Sundaresan (1983), this relationship is expressed as follows;

$$F'_{t,T} = S_t e^{r(T-t)} - \sum_{k}^{T} D_k e^{r(T-k)} \quad k = t+1,\ldots,T \tag{4.2}$$

where:

t : the time today

T : the time at which the futures contract expires

S_t : the value of the spot index underlying the futures contract at time t

$F'_{t,T}$: the theoretical (or fair value) price at time t of a futures contract maturing at time T

r : the risk-free rate of interest at time t assumed to be constant and continuous. It is assumed to be non-stochastic so that futures can be treated as forward contracts.

$\sum_{k}^{T} D_k e^{r(T-k)}$ the total value of dividends, D, that a stock owner earns, which have accumulated between t and T and being reinvested continuously in risk-free bonds until time T, at the interest rate r.

The first term of the equation arises because payment in a futures transaction is deferred until the contract matures. The second term arises because the futures traders, in contrast to the traders buying directly from the spot market, do not receive dividends paid on the underlying security. Consequently, the futures price equals the deferred value of the current stock price, minus the deferred total value of the reinvested dividends that are paid over the contract period. All of the variables that affect the futures price are directly observable. In fact, if the stock's dividend yield (d) is defined as the dividend flow per unit of currency invested in the stock at time t, $d = D/S_t$, the futures price can be expressed as a function of only the stock price, the dividend yield, the interest rate and the time to maturity (Cornell and French 1983a).

$$F'_{t,T} = S_t e^{(r-d)(T-t)} \tag{4.3}$$

where :

r-d : is the cost of carry which incorporates the cost of financing the investment less the dividends that derive from holding stocks.

If the dividend yield, d, is larger than the interest rate, r, then, the futures price will be below the spot price.[1] However, over the years it has been recorded that, in the U.K., interest rates tend to exceed the dividend rates, therefore the difference between the futures prices and the

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[1] Equations (4.2) and (4.3) should have the time divided by 365. This is supported by Klemkosky and Lee (1991) as follows:

> "Since r is an annualised interest rate, the pricing models should have the terms (T-t)/365 and (T-k)/365. However, for simplicity of presentation, the terms (T-t) and (T-k) are used instead."
> (Klemkosky and Lee 1991, p 293)

spot prices (basis) is positive. This has also been documented about the U.S. as remarked by Kawaller, Koch and Koch (1987):

> "Because market interest rates have historically exceeded the dividend rate on common stocks, the stock index futures price normally exceeds the stock index value, and the basis (futures-to-cash price differential) is positive."
> (Kawaller, Koch and Koch 1987, p 1311)

Despite the fact that equation (4.2) has been widely used, equation (4.3) has also been applied by a number of studies some of which are those by Stoll and Whaley (1990), Bhatt and Cakici (1990), MacKinlay and Ramaswamy (1988), Bailey (1989), Gould (1988) and Klemkosky and Lee (1991).

The forward cost-of-carry model discussed applies to futures if interest rates are non-stochastic. If not, then the futures price will reflect the unanticipated interest earnings or cost from financing the marking to market cash flow in the futures position. However, our research does not consider the effect of the daily settlement on the futures prices, a restriction supported by Cornell (1985) and Cornell and French (1983b). The latter state that:

> "Cox, Ingersoll and Ross (1981), Jarrow and Oldfield (1981), Richard and Sundaresan (1981) and French (1982) examine the theoretical difference between forward and futures prices in a variety of contexts. Though daily settlement

can theoretically affect futures prices, simulations and empirical studies by Rendleman and Carabini (1979), Cornell and Reinganum (1981), and Elton, Gruber and Rentzler (1982) indicate that the difference is economically insignificant... forward and futures prices are used interchangeably."
(Cornell and French 1983b, p 676)

The relationship described by the cost-of-carry model should hold, otherwise, the actual futures price will deviate from the theoretical one. If that is the case then, the observed mispricing could lead to the existence of arbitrage opportunities. However, these arbitrage opportunities may not necessarily be profitable because the market is not perfect, as we have assumed. On the contrary, there are transaction costs, which can be large enough to deter traders from engaging in trading strategies in their attempt to exploit what at first seems to be profitable. Nevertheless, the part of research that deals with the investigation of whether the observed mispricing leads to profitable arbitrage opportunities is presented in the next chapter of this thesis.

In this chapter we apply the cost-of-carry model in order to price the stock index futures contract. We estimate the theoretical futures price using both dividend yield and the value of dividends, which a stockholder would receive over the life of the futures contract (based on equations (4.2) and (4.3) respectively). We then test the results so as to find whether they differ. Our workings assume that D_k is the non-stochastic dividend inflow (measured in index units) of the underlying spot market stock portfolio on date k, (k=t+1,...,T). All the future dividend payments, resulting from stock positions until time T when the futures contract matures, are assumed to be known at time t. The dividend yield is also assumed to be a known, constant and continuous rate. However, there is a lot of evidence to suggest that dividends are seasonal leading to marked changes in dividend yield during the year. The effect of this however, very small. Yadav and Pope (1990) support this as follows;

> "Dividend uncertainty has the effect of increasing the size of the effective arbitrage window. However, in the U.K., dividends are paid semi-annually and the ex-dividend data is fairly predictable. Thus, major problems are not expected, particularly if the analysis is restricted to the near contract, which generally is the most actively traded stock index futures contract on LIFFE. Since dividend declarations occur several weeks before a stock goes ex dividend, making them *certain* for many companies during the period of the near contract, misspecification of dividend expectation is unlikely to be a major factor in explaining any observed mispricing."
>
> (Yadav and Pope 1990, p 575)

The process adopted for the calculation of the daily dividend flow, adjusted for the FTSE 100 index is described as follows; we first identify the original constituent companies that were in the index as well as the changes in it that have occurred over the years examined. We collect the dividends paid and the ex-dividend dates (which are used as a proxy for dividend payment dates)[1] for all the relevant constituents of the index for each day needed. Finally, we gather the market values and unadjusted prices for every day that a company was in the index over the period studied, as well as the total market capitalisation of all the index constituents on those days.

After identifying the data required, the following calculations were made; for each company, the number of shares outstanding on the day that they went ex-dividend is given by dividing the closing market capitalisation of the company by its closing unadjusted price on that day. The number of shares for each company outstanding at the end of each day is then multiplied by the announced dividend of the company going ex-dividend on that day. By summing these figures we obtain the market value of the total dividend each day, which is then divided by the total market capitalisation of all the constituents on that day. The last calculation generates the daily dividend entitlement associated with the index, which is in the form of index units. It is this series denoted by D which is

[1]Generally, dividend payment dates occur within one or two months of the ex-dividend date. Despite this time difference, the ex-dividend date is a reasonable proxy for the dividend payment date, although some additional error is likely. The ex-dividend date is more easily acquired than payment dates.

then used in the cost-of-carry formula described in equation (4.2).

4.2.2 PRODUCING THE MISPRICING SERIES

There are a number of reasons for having violations of the pricing relationship of futures contracts. Among those suggested is the fact that there are delays when executing transactions. Entering transaction data from the market place (a trading pit on LIFFE, and a telephone based market on LSE) into information systems allows the new information to be sent for the updating and dissemination of the index level by the index calculator i.e. FTSE International. Delays could take place when entering the data in the computer, or in the process of computing and transmitting the adjusted index level, as well as in recording the stock index value at the futures exchange. However, price changes in the futures markets are recorded immediately, therefore, when new information arrives in the spot and the futures market simultaneously, the futures market returns will seem to lead the returns in the spot market.

Another explanation proposed for the observed deviations is the differential tax treatment of spot and futures and the existence of a tax-timing option, (as defined by Constantinides (1983)), in a spot position but not in a futures position. Cornell and French (1983a, 1983b) argue that the actual futures prices diverge from their predicted ones because we ignore the different way the stock and futures returns are taxed. Futures traders must pay taxes on all gains in the year they arise, while stockholders pay taxes only on realised gains or losses. As a result, the stockholders have the advantage of the timing option. In the case where there is a decrease in the value of the stock, the stock can be sold and part of the loss can be transferred to the trader's tax liability. On the other hand, if the value of the stock appreciates, the tax payment can be delayed by not realising gains. In contrast to the stockholder's tax timing option, the futures trader lacks this option. The reason why is that capital gains or losses have to be realised either at the end of the year or at the maturity of the contract depending on which comes first.

However, Cornell (1985) finds that the tax-timing option does not have a significant impact on the pricing of futures contracts. Moreover, Yadav and Pope (1990) argue that the tax timing option is more important in the U.S. because the tax law dictates that the tax liability on open futures contracts should be assessed by realising them at the end of the tax year. In the U.K., though, the tax liability arises daily as the futures position is marked-to-market.

After calculating the theoretical stock index futures price we then compare it to its actual price. Any deviations observed will generate a mispricing series which is then tested for size and direction. The mispricing series is defined by Brennan and Schwartz (1990) as the difference between the observed futures price and its theoretical value. Other studies, like those by Merrick (1989), Yadav and Pope (1990) and MacKinlay and Ramaswamy (1988), use the relative mispricing series which is the present value of the difference between actual and theoretical futures price in relation to the index value. In our research we also estimate the relative mispricing series because as MacKinlay and Ramaswamy (1988) state:

> "We work with the mispricing in relative terms because the major components of the determinant of the (arbitrage) bounds should be proportional to the level of the index."
> (MacKinlay and Ramaswamy 1988, p 141)

In order to calculate the mispricing series we adopt the formula used by Yadav and Pope (1990) according to which the percentage mispricing, $X_{t,T}$, is given as follows:

$$X_{t,T} = \frac{F_{t,T} - F'_{t,T}}{S_t} \tag{4.4}$$

Equation (4.4) shows that mispricing is produced when, the theoretical futures price, $F'_{t,T}$, is taken away from the observed index futures price, $F_{t,T}$, and then divided by the spot index price, S_t. A positive mispricing is called an overvaluation and a negative mispricing an undervaluation of the futures contract.

4.3 Data Description And Sources

In order to examine the efficiency of futures pricing relative to the spot index with respect to violations of non-arbitrage pricing conditions, the empirical tests that follow utilise, the data sets applied in previous chapters, which analyse the daily relationship between the FTSE 100 index and the FTSE 100 stock index futures contract of the U.K. Briefly these involve the three spot price series of the unadjusted, the adjusted for non-synchronicity and the implied index, the three-month Treasury Bill, which matures on the day that is closest to the last trading day of the futures contract and the dividend yield on the index. While the first two spot series cover the period between June 1, 1984 to May 31, 1995 (2,869 observations), due to unavailability of data the implied index can only give results for the period March 13, 1992 to May 31, 1995 (839 observations).

The information required on the constituent of the FTSE 100 index and the changes, which took place over the period examined, were kindly provided by the LSE. It also includes all the data needed for the calculation of the daily dividend adjusted on the index. To be more specific, this data involves the dividends and ex-dividend dates of the constituents of the index, along with the market values, unadjusted prices of the index constituents and the total market capitalisation of all the index constituents. However, due to the unavailability of data, the daily dividend series for the index calculated and used in the cost-of-carry model described by equation (4.2), covers the period from April 10, 1990 to May 31, 1995. The number of observations in this period is 1342 and is considered to be sufficient for the empirical investigation of whether the use of dividend yields or the actual dividends paid can produce statistically different results when calculating the theoretical futures price.

Finally, in the same way as in the previous chapters, the data set constructed is based on the near contract shifting to the next contract just before the expiration month begins. This effectively leaves the whole period of the delivery month out of the data series for each contract analysed.

4.4 Empirical Results

4.4.1 Comparing The Use Of Dividend Yield To Actual Dividend Inflow

We apply the cost-of-carry model twice, as described in equations (4.2) and (4.3), using actual dividend inflow and dividend yields respectively. As mentioned before, due to unavailability of data the two series derived represent the theoretical futures price for the period April 10, 1990 to May 31, 1995. In order to investigate whether the use of dividends or dividend yields produces different results, we plot the series as an initial stage in the analysis. This allows us to visually inspect whether the two series are similar. This can be seen in Figures 4.1 and 4.2, for price levels and Figures 4.3 and 4.4 for returns. In both cases it is observed that, the two series appear not to differ to a great degree.

Figure 4.1
The theoretical Futures Price calculated
using dividend yields for the period 10/04/90 - 31/05/95.

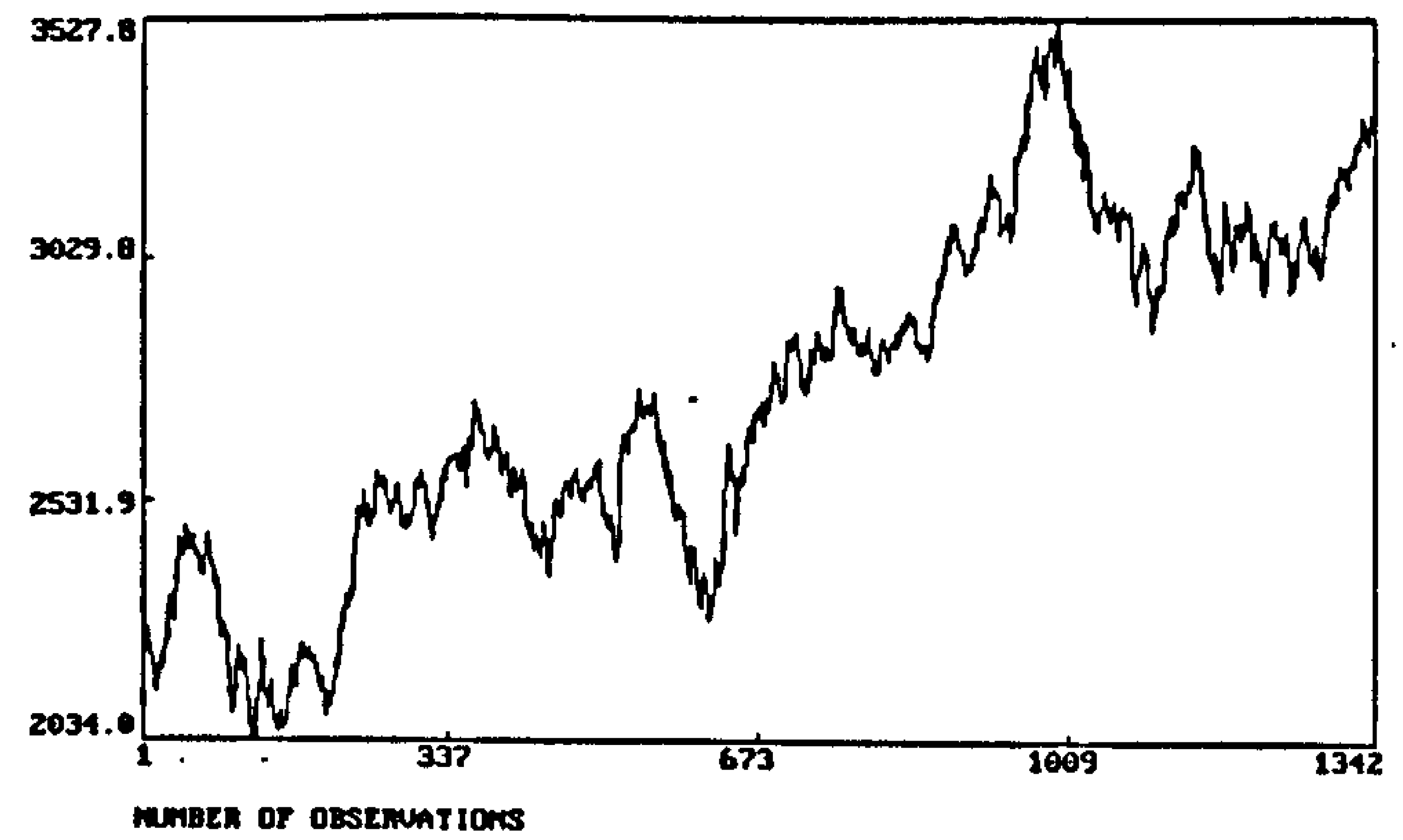


Figure 4.2
The theoretical Futures Price calculated
using dividend inflow for the period 10/04/90 - 31/05/95.

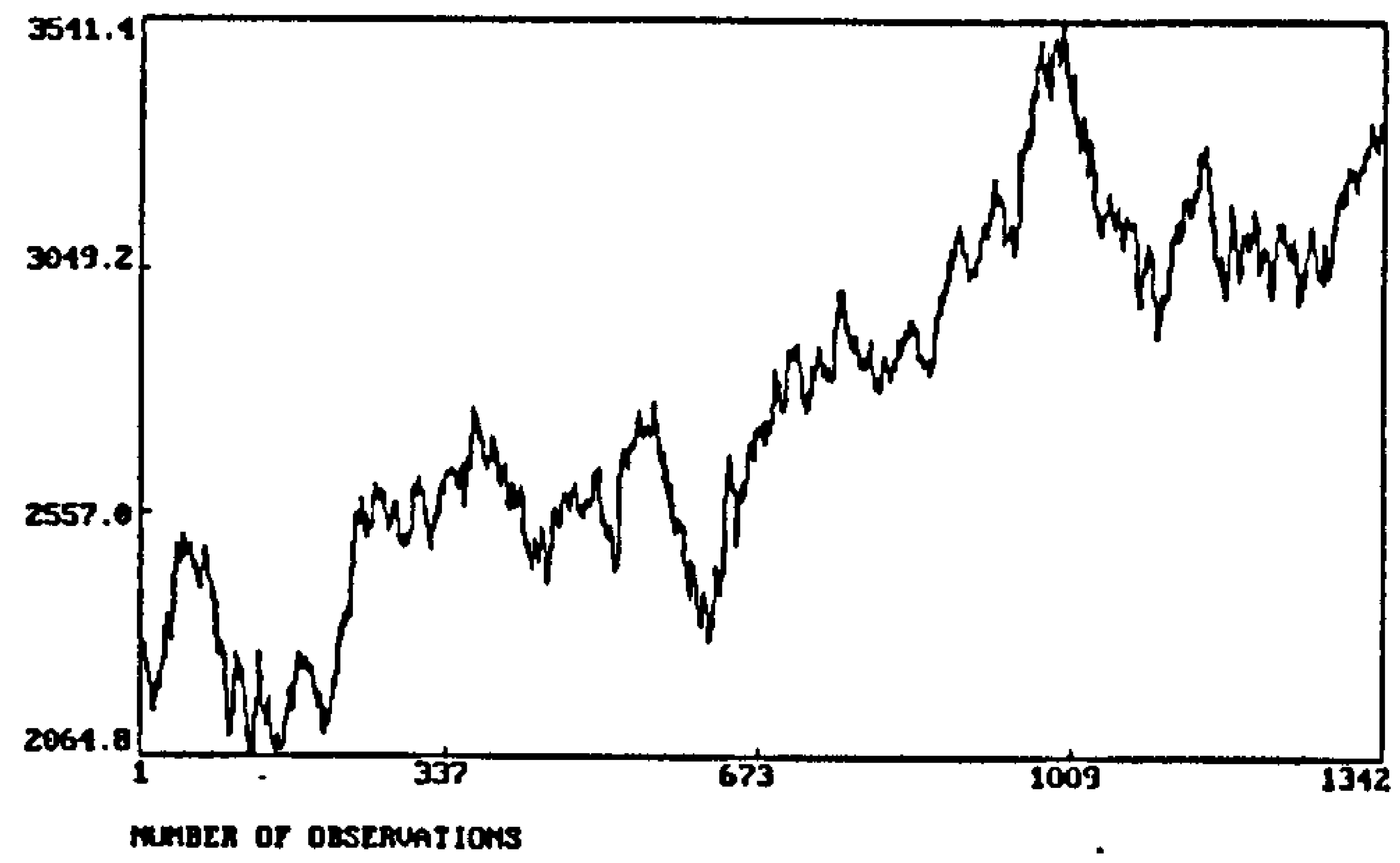


Figure 4.3
Returns on the theoretical Futures Price calculated
using dividend yields for the period 10/04/90 - 31/05/95.

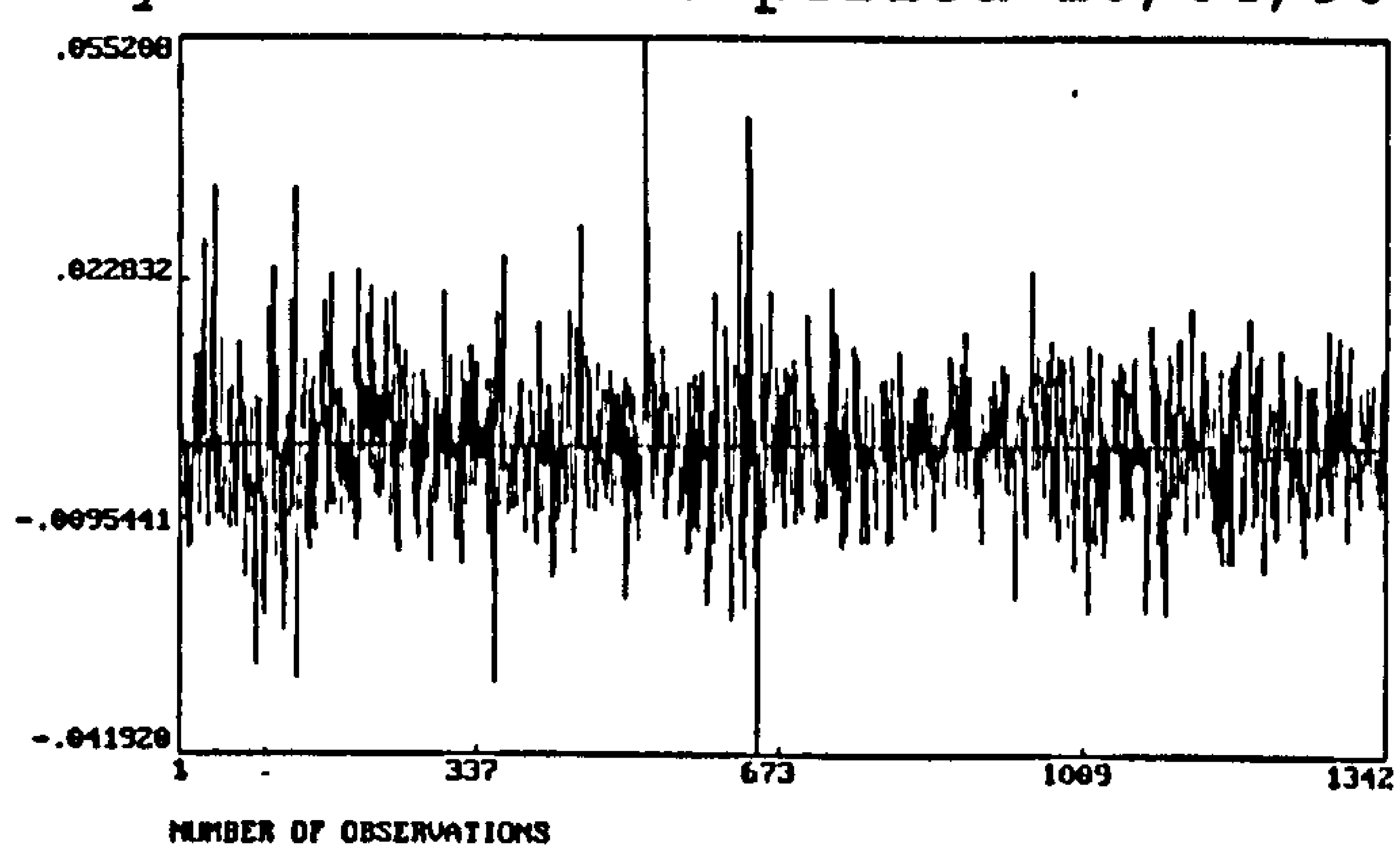
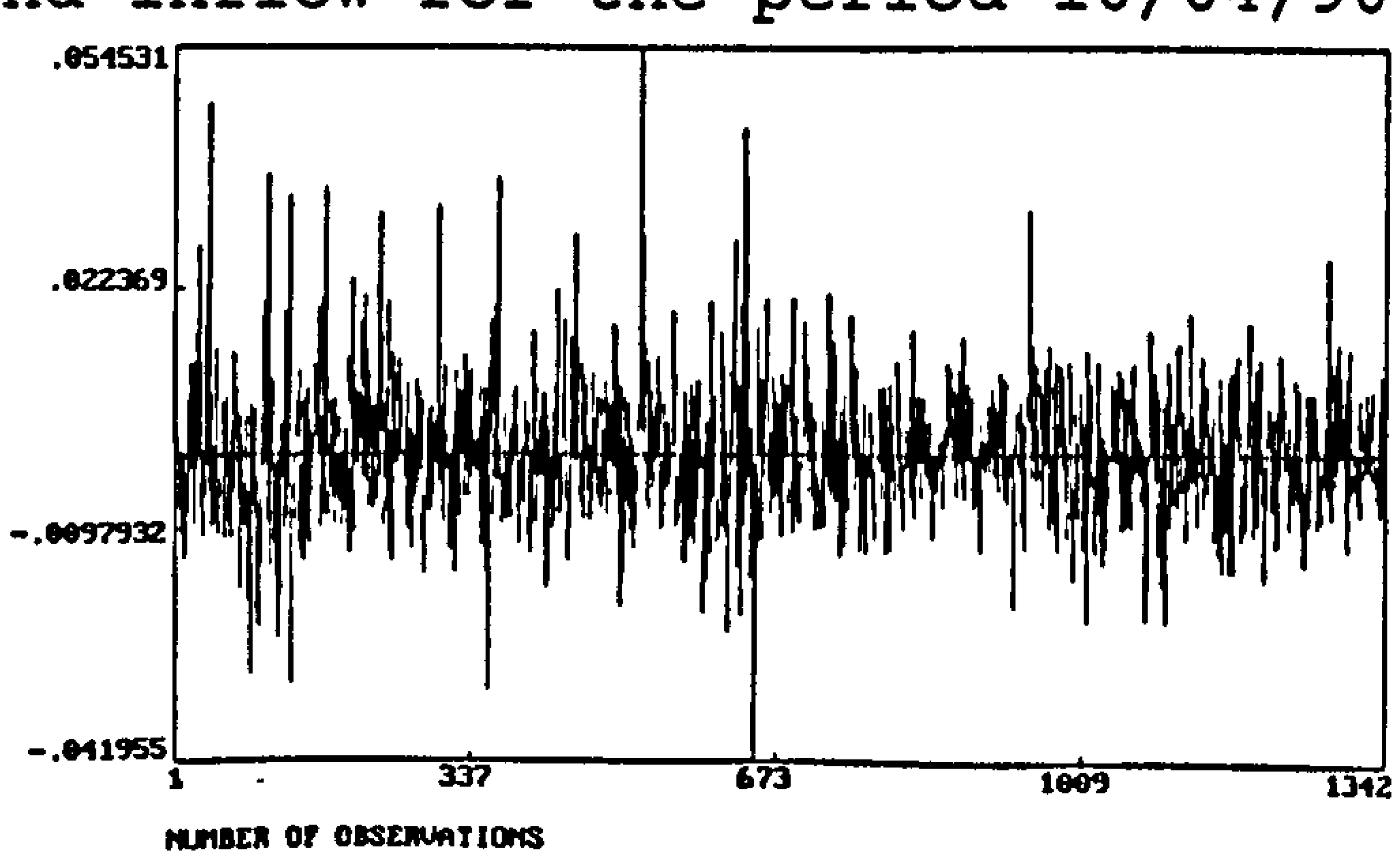


Figure 4.4
Returns on the theoretical Futures Price calculated
using dividend inflow for the period 10/04/90 - 31/05/95.



The two return series, hereafter known as dividend yield series and dividend series, are found to be highly correlated with a correlation coefficient being equal to 0.99. The means of the series are 0.285E-3 and 0.278E-3 for the dividend yield series and the dividend series respectively, and we use a t-statistic to test whether they are statistically different. The two series, A_1 and A_2, are of the same size, n, being equal to 1,342 and are distributed as follows:

$$A_1 \sim N(\mu_1, \sigma_1^2)$$
$$A_2 \sim N(\mu_2, \sigma_2^2)$$

Then, $$\bar{A}_1 - \bar{A}_2 \sim N(\mu_1 - \mu_2, \sigma_1^2/n + \sigma_2^2/n)$$

This distribution is known as the sampling distribution of the difference between means. The test statistic to be used is described by the following formula:

$$Z = \frac{\bar{A}_1 - \bar{A}_2 - (\mu_1 - \mu_2)}{\sqrt{\frac{\sigma_1^2}{n} + \frac{\sigma_2^2}{n}}} \tag{4.5}$$

which is distributed as N(0,1).

We then test whether there is significant difference in the means of the two series. The null hypothesis, H_o, assumes that there is no difference between the means while the alternative hypothesis assumes that the two means are statistically different. We use a two-tailed test, at the

5% level and reject H_0 if $|z| > 1.96$. The test gives $|z| = 0.02$ which is less than 1.96. We therefore, accept H_0 and can say that, at 5% level, the two means are not statistically different.

Even by analysing the sample period on a yearly basis we find that the annual means of the two series are statistically equal and highly correlated. This is shown in Table 4.1.

Table 4.1

Summary statistics of the returns on the theoretical futures price calculated using both dividend yields and dividend inflow, on a yearly basis for the period 10/04/90-31/05/95; n: number of days, STD.DEV:standard deviation,

YEAR	n	USING DIVIDENDS		USING DIV.YIELDS		CORRELATION COEFFICIENT	t-stat Ho: $\mu_1=\mu_2$ Reject Ho at 5% if z>1.96
		MEAN	STD.DEV.	MEAN	STD.DEV.		
1990	190	-0.0001854	0.010865	-0.0001974	0.010303	0.99	0.011*
1991	261	0.0005532	0.009008	0.0005552	0.0085427	0.99	0.003*
1992	262	0.0004629	0.0099044	0.0004752	0.0097566	0.99	0.015*
1993	261	0.0006884	0.0065441	0.0006968	0.006267	0.98	0.014*
1994	260	-0.0004095	0.0081772	-0.0004147	0.0083105	0.99	0.007*
1995	108	0.0006411	0.0065257	0.0007035	0.0062288	0.99	0.074*

*Accept Ho

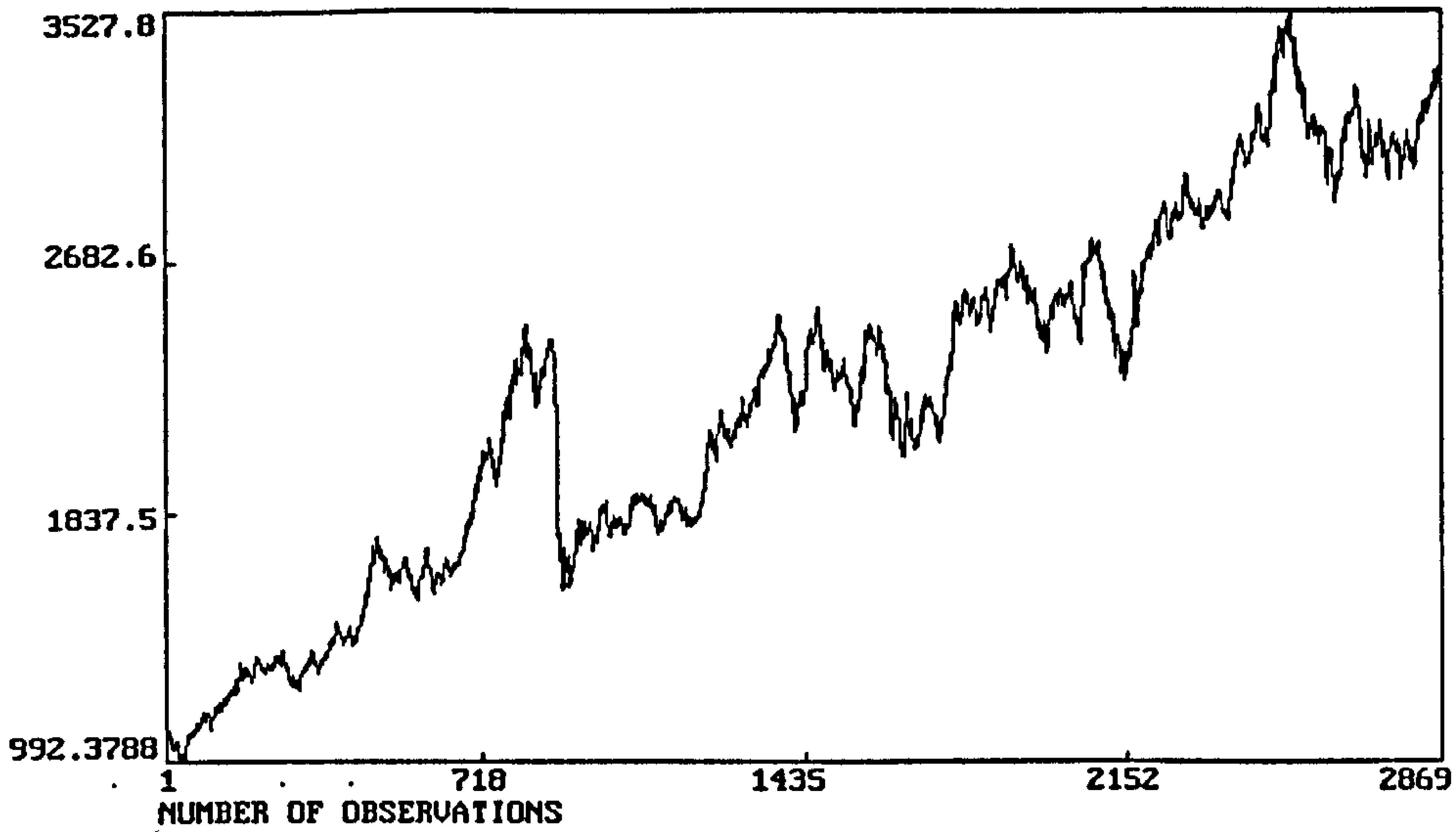
Furthermore, we take the difference between the two return series and find that the residual series has a very small mean, 0.6E-5, i.e. it is very close to zero. To further investigate the closeness of the two series, this residual series is regressed against a constant and is found to have a t-statistic of 0.183, suggesting that it is not significantly different from zero. The above results provide empirical support for our earlier observation, based on casual inspection of price plots, that the two series are very similar. Given these findings the empirical investigations to follow will use the dividend yields for convenience, knowing that any results should be identical to the dividend series.

4.4.2 The Theoretical Futures Price Calculation

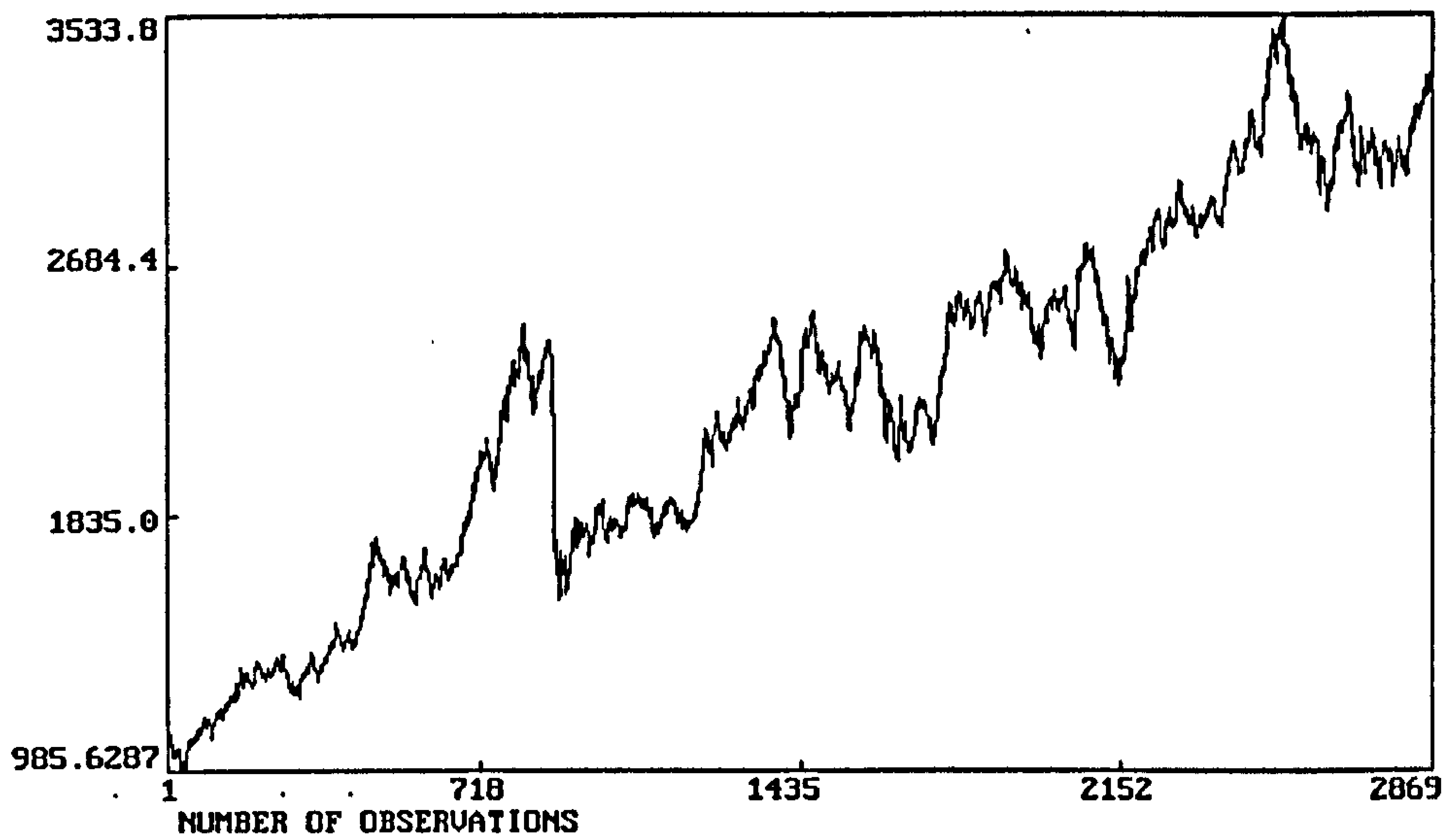
We apply the cost-of-carry model described in equation (4.3) using the three cases of spot series so as to produce the theoretical futures price. Figure 4.5 presents the fair price based on the use of the observed and the adjusted for non-synchronicity spot series for the entire sample of 2,869 observations. We also plot the observed futures price as an initial stage of comparing it to the theoretical one. Figure 4.6 focuses on the smaller sample period of 839 observations and plots the three fair prices calculated based on the three spot series applied, along with the observed futures price.

Figure 4.5

A) The fair futures price using the unadjusted for non-synchronicity spot index for the period 01/06/84-31/05/95.



B) The fair futures price using the adjusted for non-synchronicity spot index for the period 01/06/84 - 31/05/95.



C) The observed futures price for the period 01/06/84 - 31/05/95.

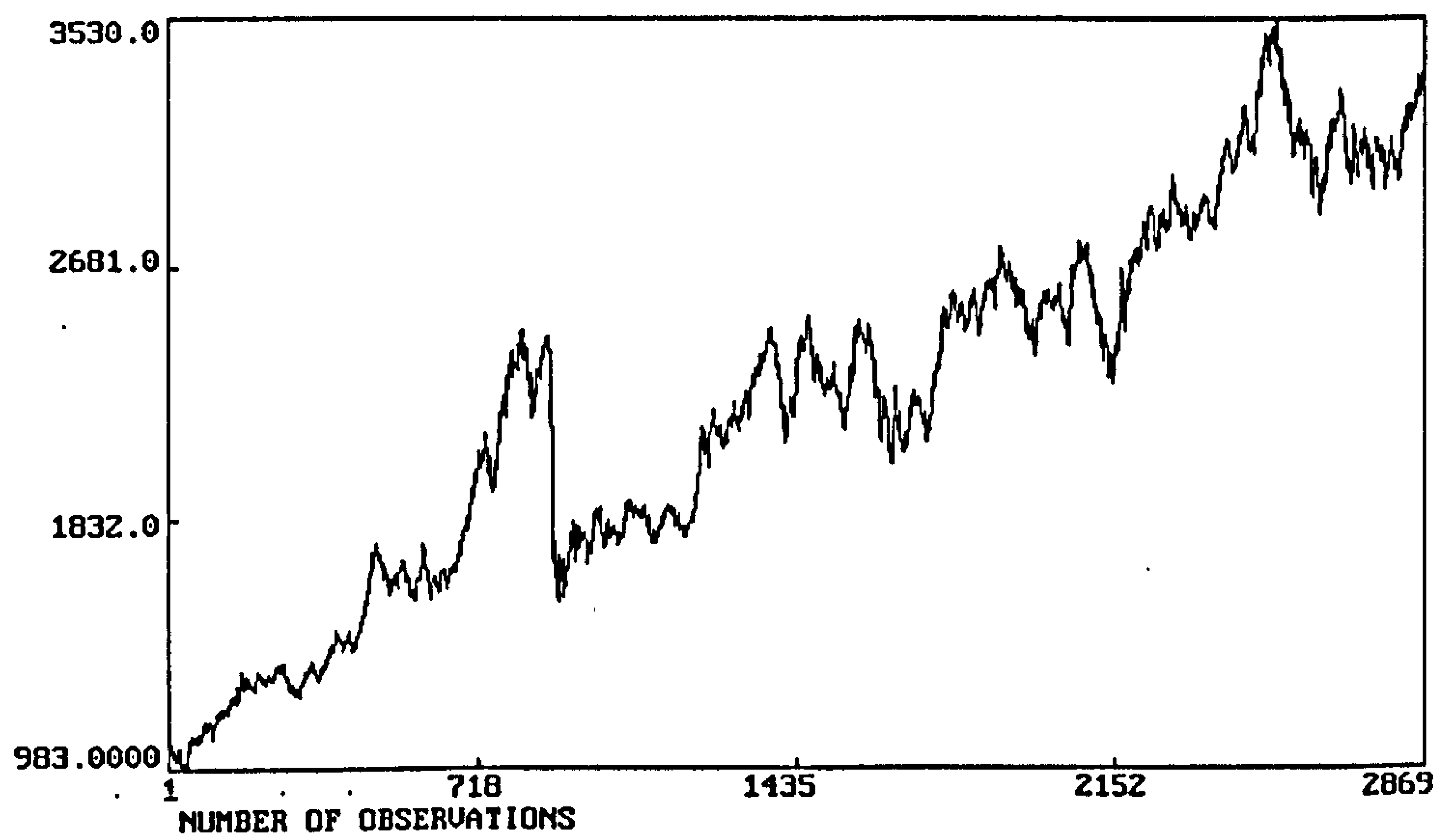
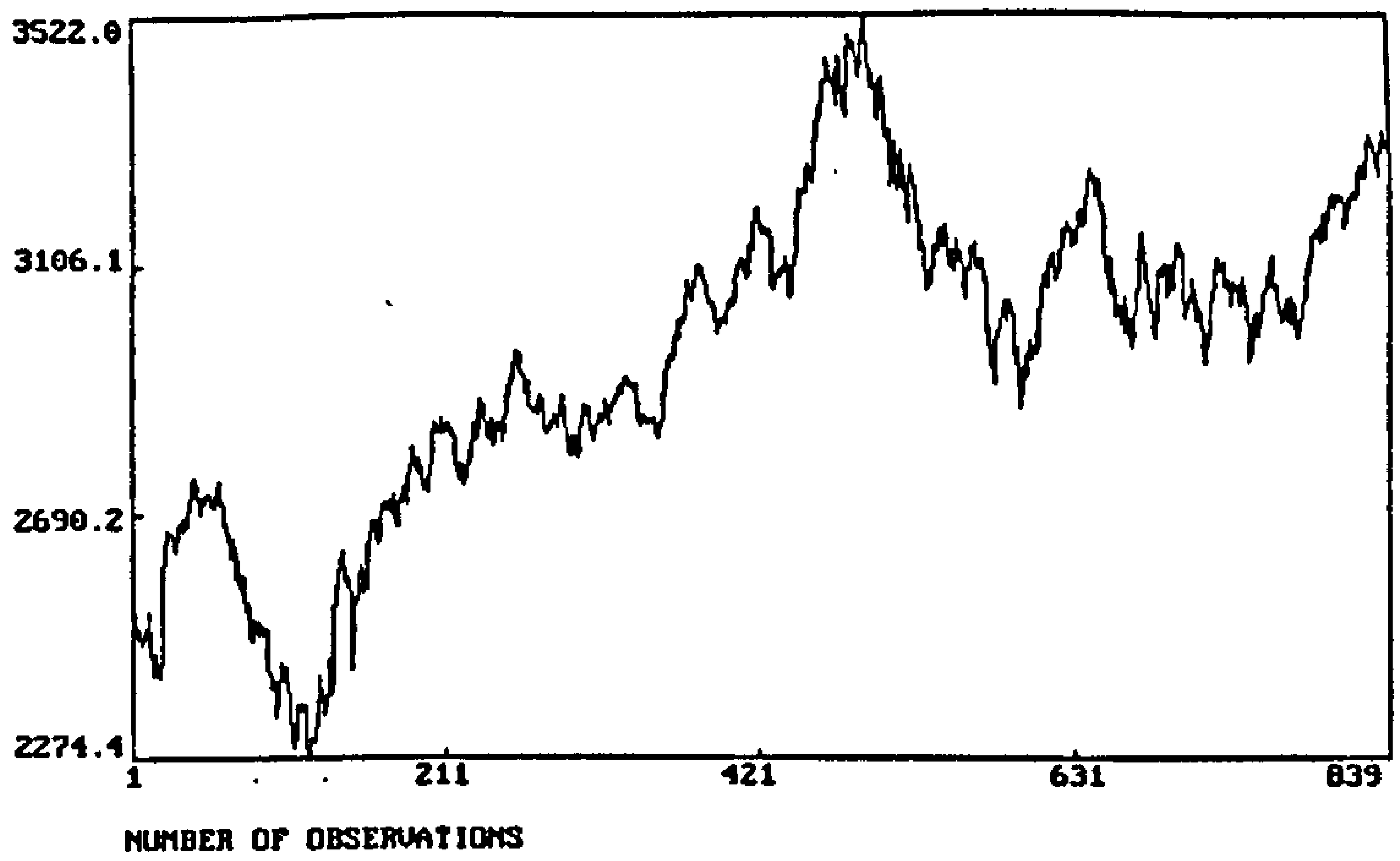
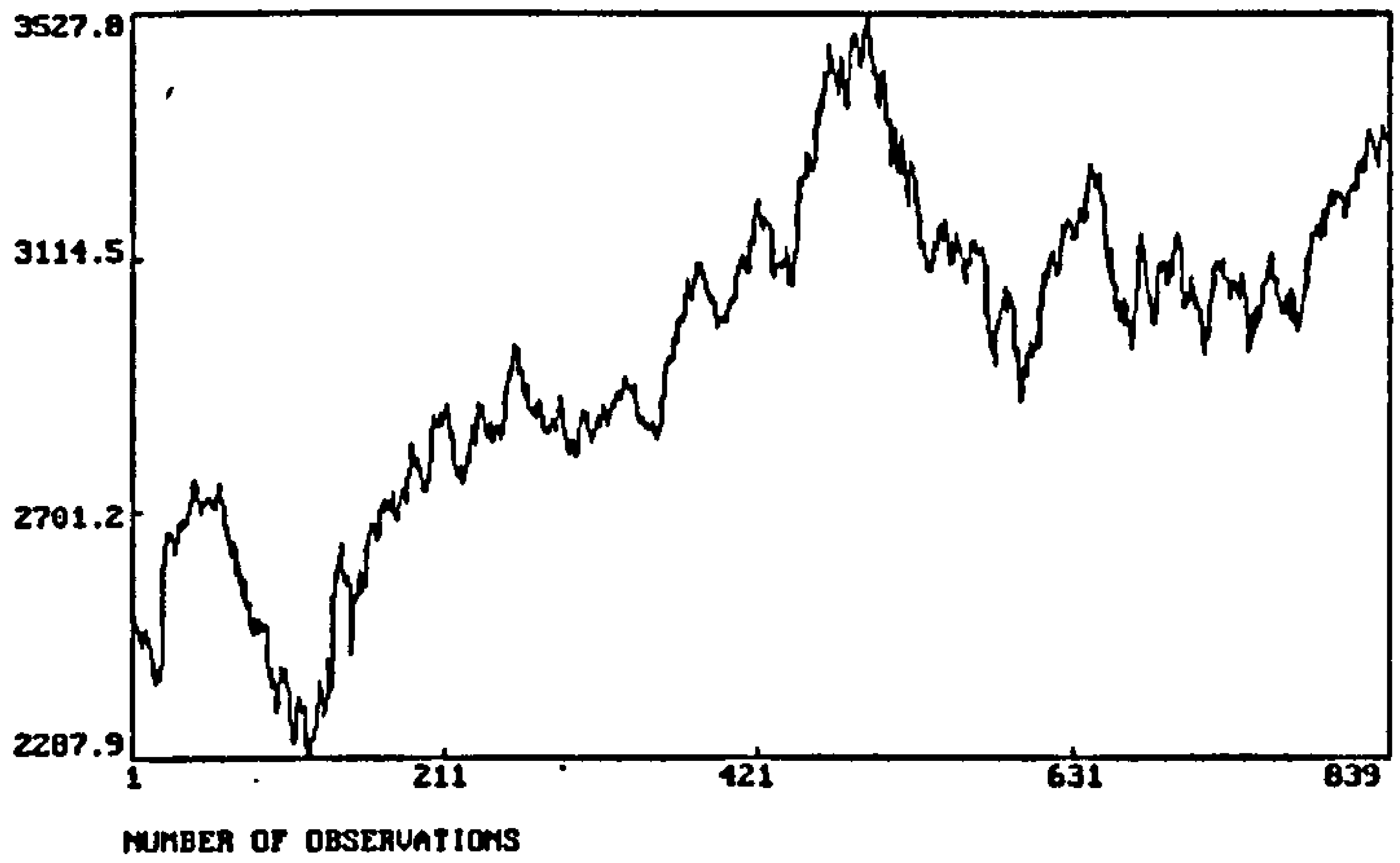


Figure 4.6

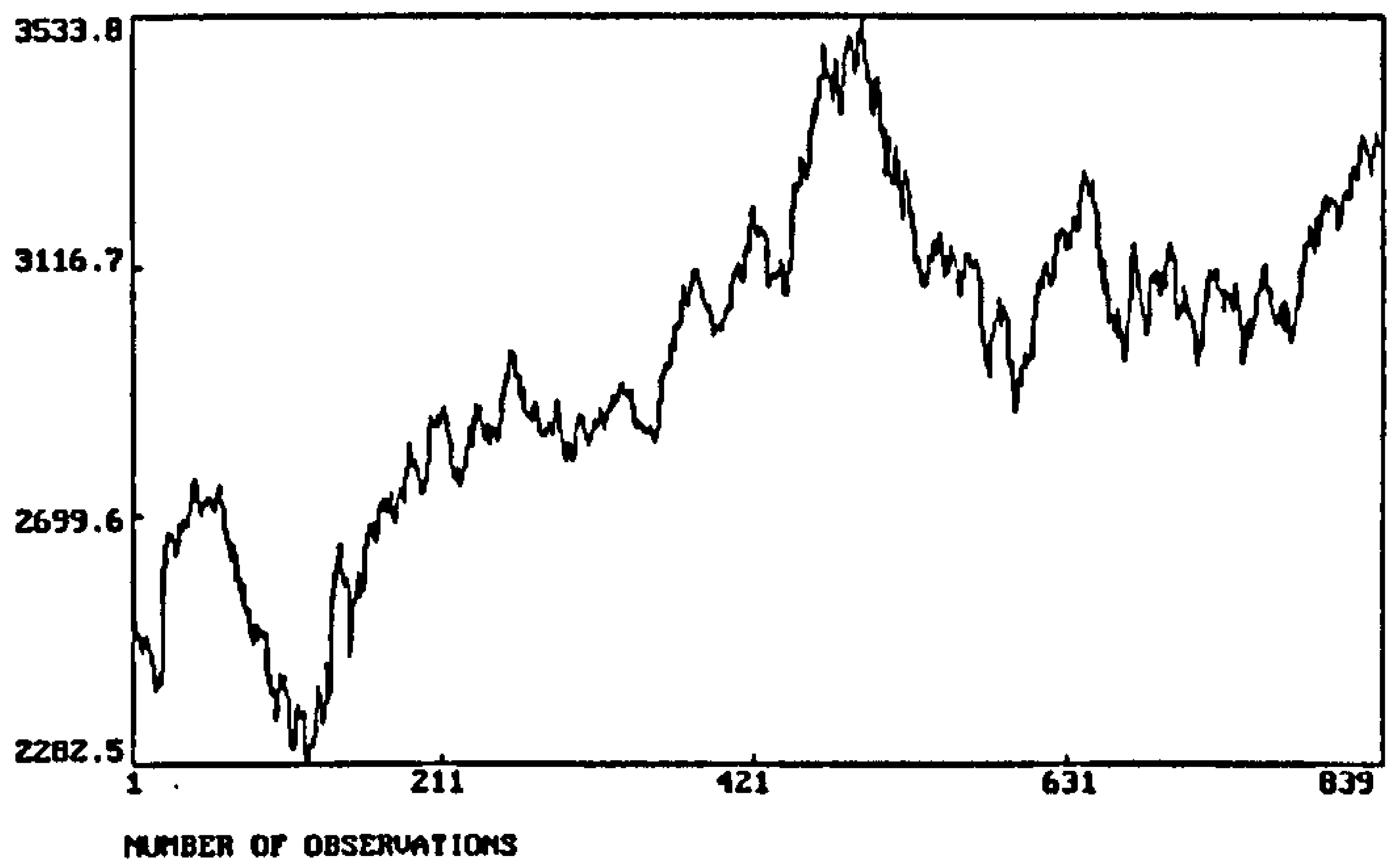
A) The fair futures price using the Implied Index for the period 13/03/92-31/05/95.



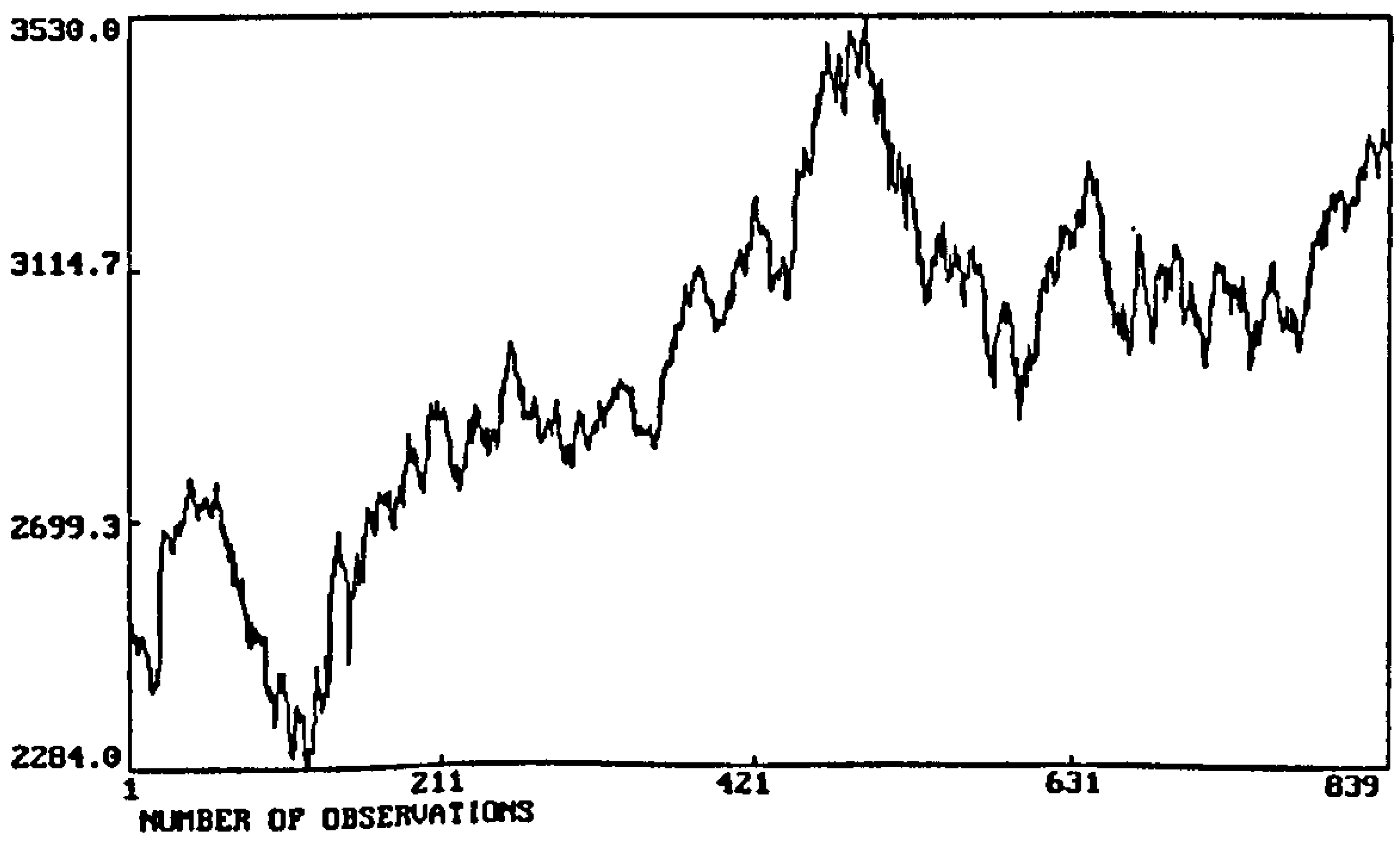
B) The fair futures price using the unadjusted for non-synchronicity spot index for the period 13/03/92 - 31/05/95.



C) The fair futures price using the adjusted for non-synchronicity spot index for the period 13/03/92 - 31/05/95.



D) The observed futures price for the period 13/03/92 - 31/05/95.



An initial observation of Figures 4.5 and 4.6 shows that the price series under investigation are very closely related, which can be confirmed by the statistics about them presented in Tables 4.2 and 4.3. As we can see from the Tables, the series are all highly correlated with a correlation coefficient being 0.999. Furthermore, in order to highlight the similarities between the estimated series, we calculated the t-statistic, which tests the hypothesis that the means, μ, of the series are statistically different. As seen from the Tables, the means of all the series are statistically equal to each other, which confirms the close relationship between the observed futures price and three cases of theoretical futures price on average. However, the absence of a significant difference does not exclude the possibility that sometimes mispricings can occur. In terms of value, although the means of all series are very close, it should be noted that the fair price calculated using the implied index produces the lowest number, 2944.1, (sample 839 observations). For the same sample period, both the unadjusted and the adjusted for non-synchronicity cases give the same average value of fair price being equal to 2951.9.

Table 4.2

Summary statistics of the observed futures price and the unadjusted and adjusted for non-synchronicity fair futures price series. The sample period has 2,869 observations and covers the period 01/06/84 - 31/05/95.

VARIABLES	OBSERVED FUTURES	UNADJUSTED FAIR FUTURES	ADJUSTED FAIR FUTURES
MAXIMUM	3530.0	3527.8	3533.8
MINIMUM	983.0	992.4	985.6
MEAN	2220.8	2223.3	2224.3
STD.DEV.	628.40	622.20	622.51

ESTIMATED CORRELATION COEFFICIENT	
OBSERVED FUTURES vs UNADJUSTED FAIR FUTURES	0.999
OBSERVED FUTURES vs ADJUSTED FAIR FUTURES	0.999
UNADJUSTED FAIR FUTURES vs ADJUSTED FAIR FUTURES	0.999

t-statistics Ho: $\mu_1=\mu_2$ Reject Ho at 5% if z>1.96	
OBSERVED FUTURES vs UNADJUSTED FAIR FUTURES	0.151*
OBSERVED FUTURES vs ADJUSTED FAIR FUTURES	0.121*
UNADJUSTED FAIR FUTURES vs ADJUSTED FAIR FUTURES	0.061*

*Accept Ho

Table 4.3

Summary statistics of the observed futures price as well as the fair futures series based on the Implied index, and the unadjusted and adjusted for non-synchronicity fair futures price series. The sample period has 839 observations and covers the period 13/3/92 - 31/5/95.

VARIABLES	FAIR FUTURES USING IMPLIED INDEX	OBSERVED FUTURES	UNADJUSTED FAIR FUTURES	ADJUSTED FAIR FUTURES
MAXIMUM.	3522.0	3530.0	3527.8	3533.5
MINIMUM	2274.4	2284.0	2287.9	2282.3
MEAN	2944.1	2956.9	2951.9	2951.9
STD.DEV.	266.56	264.48	267.09	268.13

ESTIMATED CORRELATION COEFFICIENTS	
OBSERVED FUTURES vs FAIR FUTURES USING IMPLIED INDEX	0.999
OBSERVED FUTURES vs UNADJUSTED FAIR FUTURES	0.999
OBSERVED FUTURES vs ADJUSTED FAIR FUTURES	0.999
FAIR FUTURES USING IMPLIED INDEX vs UNADJUSTED FAIR FUTURES	0.999
FAIR FUTURES USING IMPLIED INDEX vs ADJUSTED FAIR FUTURES	0.999
UNADJUSTED FAIR FUTURES vs ADJUSTED FAIR FUTURES	0.999

t-statistics Ho: $\mu_1=\mu_2$ Reject Ho at 5% if z>1.96	
OBSERVED FUTURES vs FAIR FUTURES USING IMPLIED INDEX	0.987 accept H_0
OBSERVED FUTURES vs UNADJUSTED FAIR FUTURES	0.385 accept H_0
OBSERVED FUTURES vs ADJUSTED FAIR FUTURES	0.384 accept H_0
FAIR FUTURES USING IMPLIED INDEX vs UNADJUSTED FAIR FUTURES	0.599 accept H_0
FAIR FUTURES USING IMPLIED INDEX vs ADJUSTED FAIR FUTURES	0.597 accept H_0
UNADJUSTED FAIR FUTURES vs ADJUSTED FAIR FUTURES	0.293 accept H_0

We also examine the way the second component of the cost-of-carry formula, which represents the difference between the interest rate and the dividend yield (usually referred to as the cost-of-carry), moves in relation to the time remaining until expiration of a futures contract. The cost-of-carry should be expected to decrease the closer a futures contract is to its maturity, so that at expiration it becomes equal to zero. This allows for the futures price to be equal to the spot price at expiration, otherwise profit could be made by buying the cheaper investment and selling the most expensive.

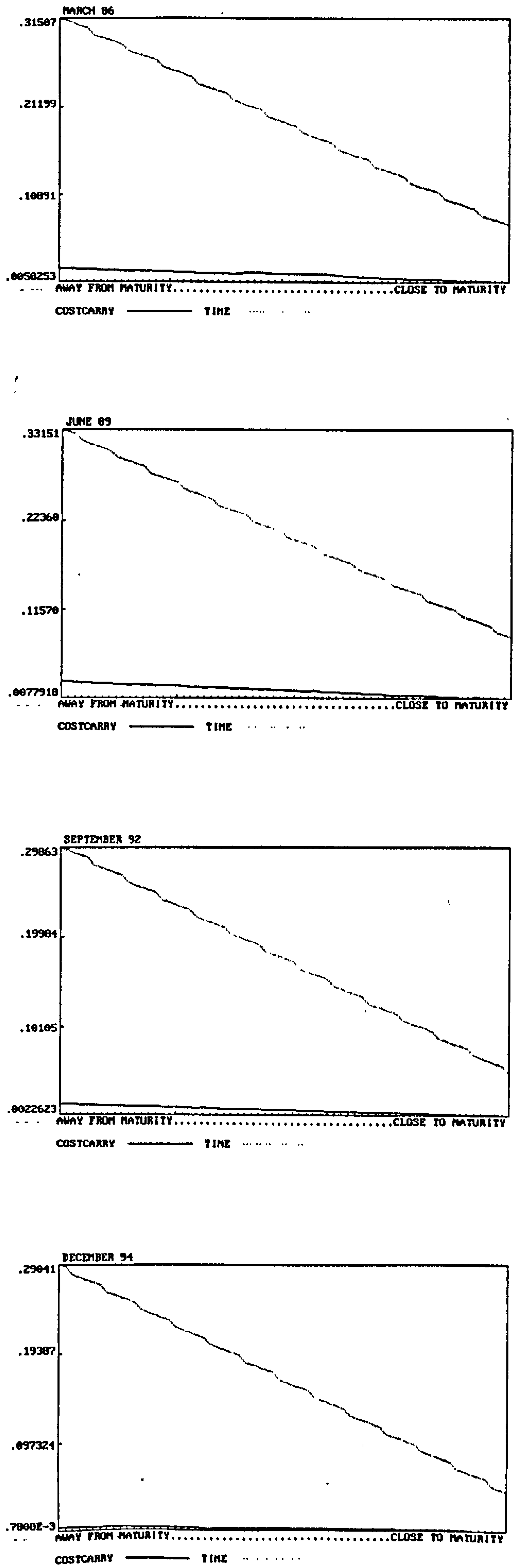
Our findings show that for all contracts examined there is a positive relation between the cost-of-carry and time-to-maturity. However, given the construction of our data series[1] we cannot experience the cost-of-carry becoming zero. Moreover, the cost-of-carry is a linear function of time due to the fact that the dividend yield is assumed to be constant. For illustration purposes we plot the cost-of-carry against time-to-maturity for four contracts[2] in Figure 4.7. A similar behaviour to these four contracts was identified for all contracts consisting the sample period under investigation.

---

[1]As described in section 4.3, we shift from one contract to the next just before the expiration month starts.

[2]Due to the large number of results produced and the high similarity across the results, an indicative set of findings are presented.

Figure 4.7
The cost-of-carry element against time-to-maturity
for four contracts.



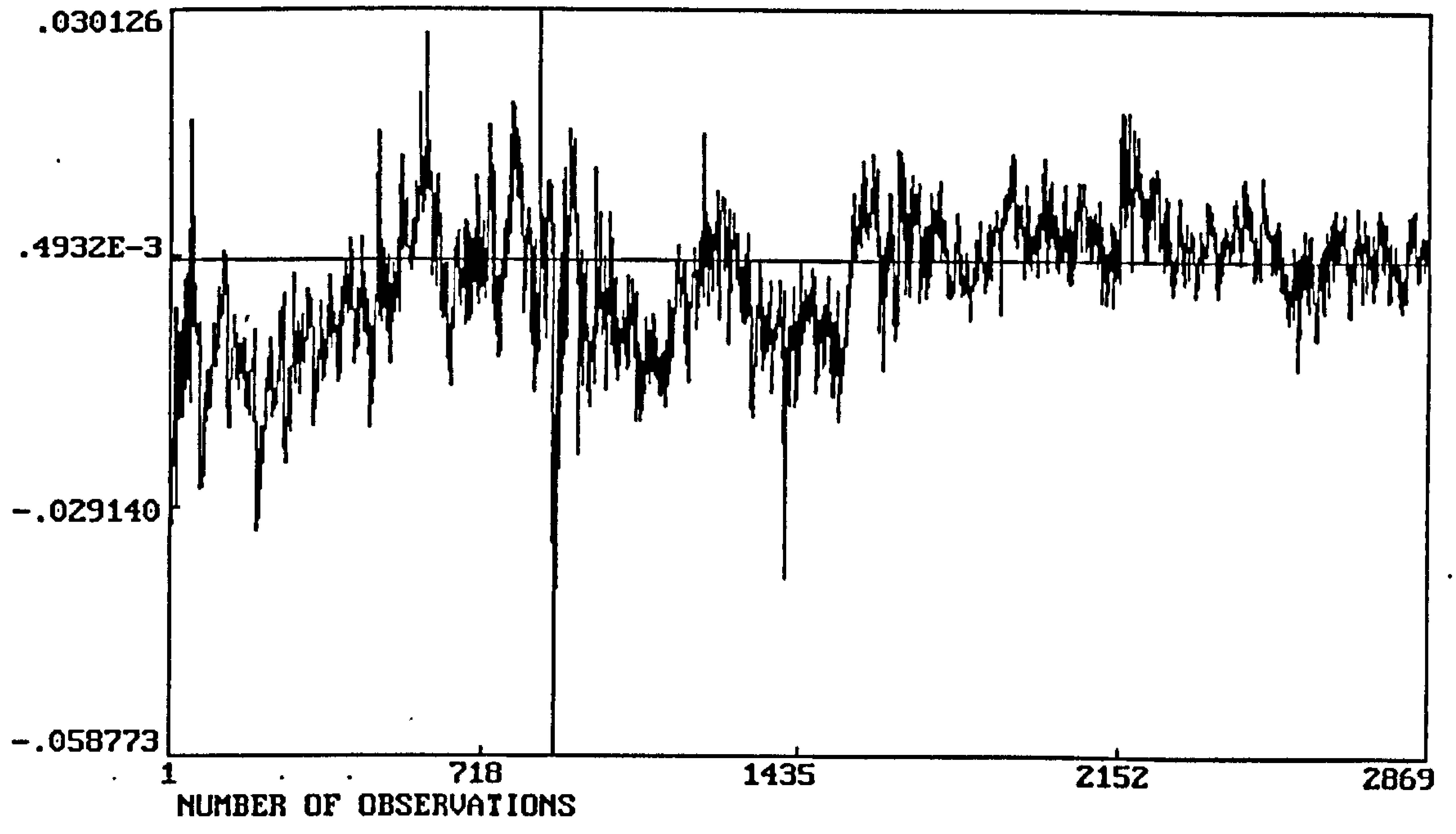
4.4.3 THE PERFORMANCE OF THE MISPRICING SERIES

The next stage involves the calculation of relative mispricing based on the formula described by equation (4.4). If the futures market prices its stock index contracts correctly, then the difference between the actual and the theoretical futures price, $F_{t,T} - F'_{t,T}$, should be zero and the average mispricing should not significantly differ from zero. Given the fact that our research is conducted for the U.K. financial market and only Yadav and Pope (1990,94) and Strickland and Xu (1993) have done similar work in the U.K., our results are directly compared to their results. As a consequence our larger sample period is partitioned in order to acquire a section of the sample period that directly corresponds to the sample period analysed by Yadav and Pope (1990).

Figure 4.8 illustrates the relative mispricing series, computed for the near LIFFE index futures contract over the period June 1, 1984 to May 31, 1995 using both the unadjusted and adjusted for non-synchronicity spot index. In a similar way, Figure 4.9 plots the relative mispricing series for the smaller sample period of 839 observations showing all three cases of spot series considered.

Figure 4.8

A) The mispricing series unadjusted for non-synchronicity for the period 01/06/84 - 31/05/95



B) The mispricing series adjusted for non-synchronicity for the period 01/06/84 - 31/05/95

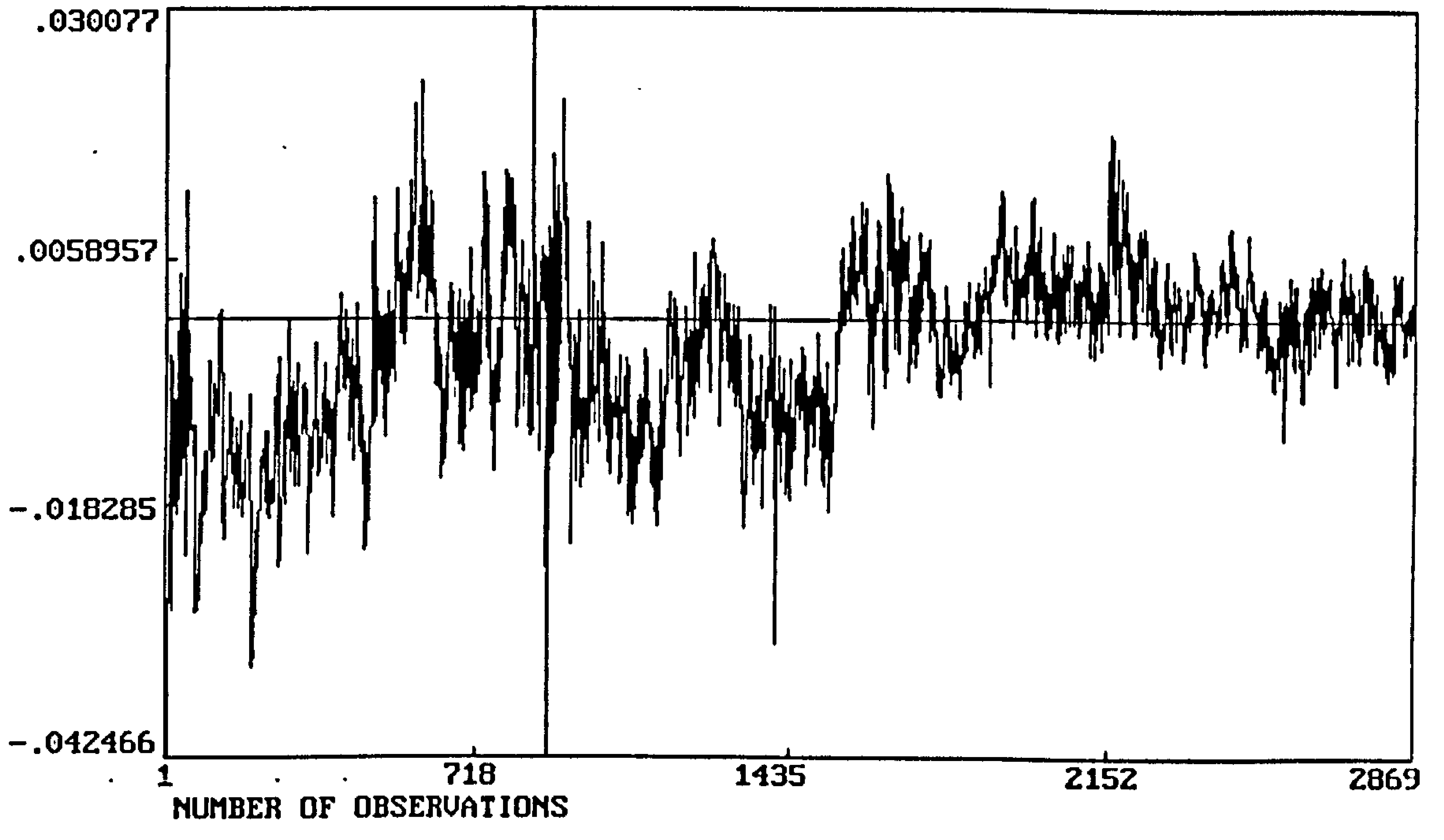
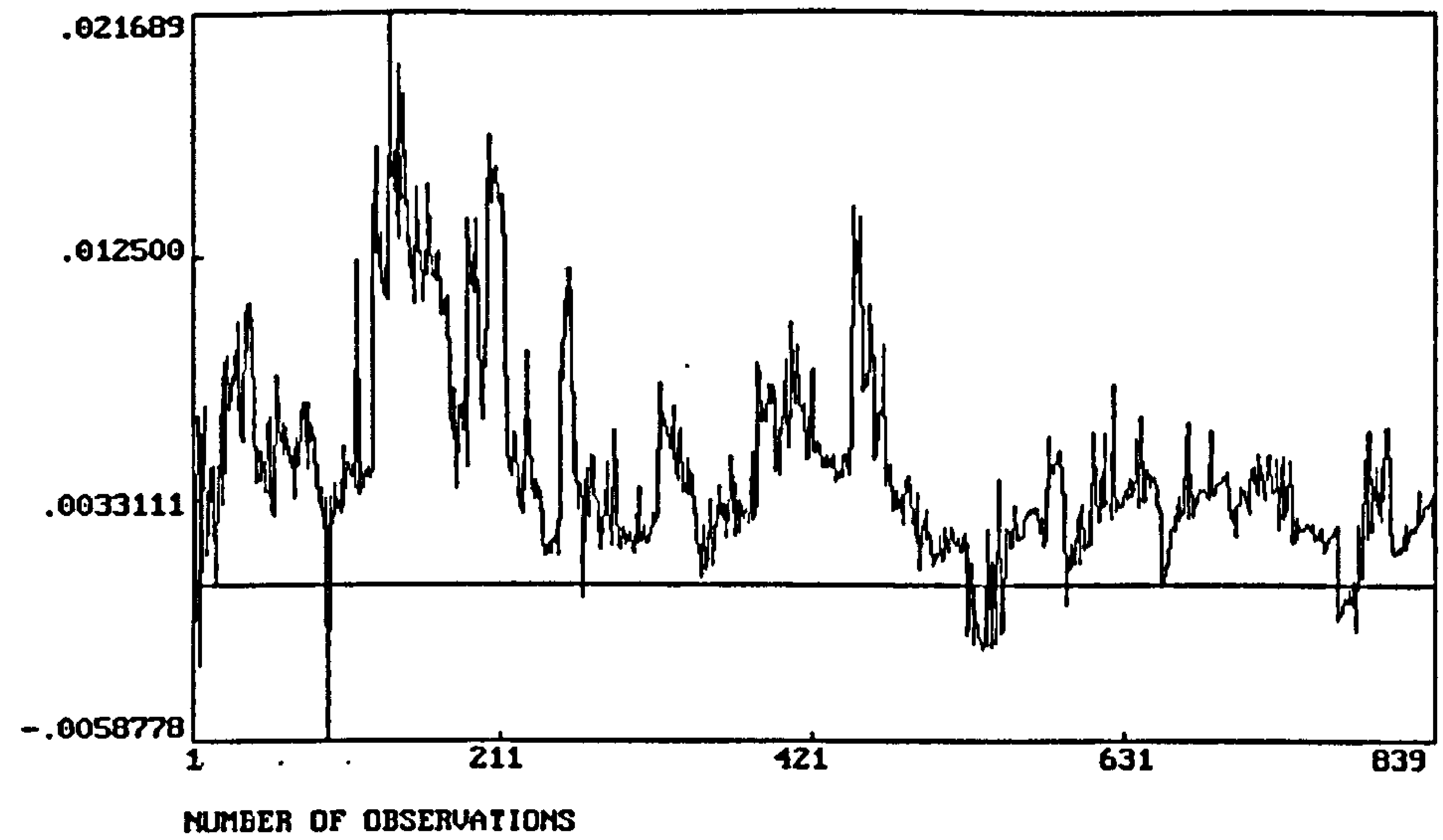
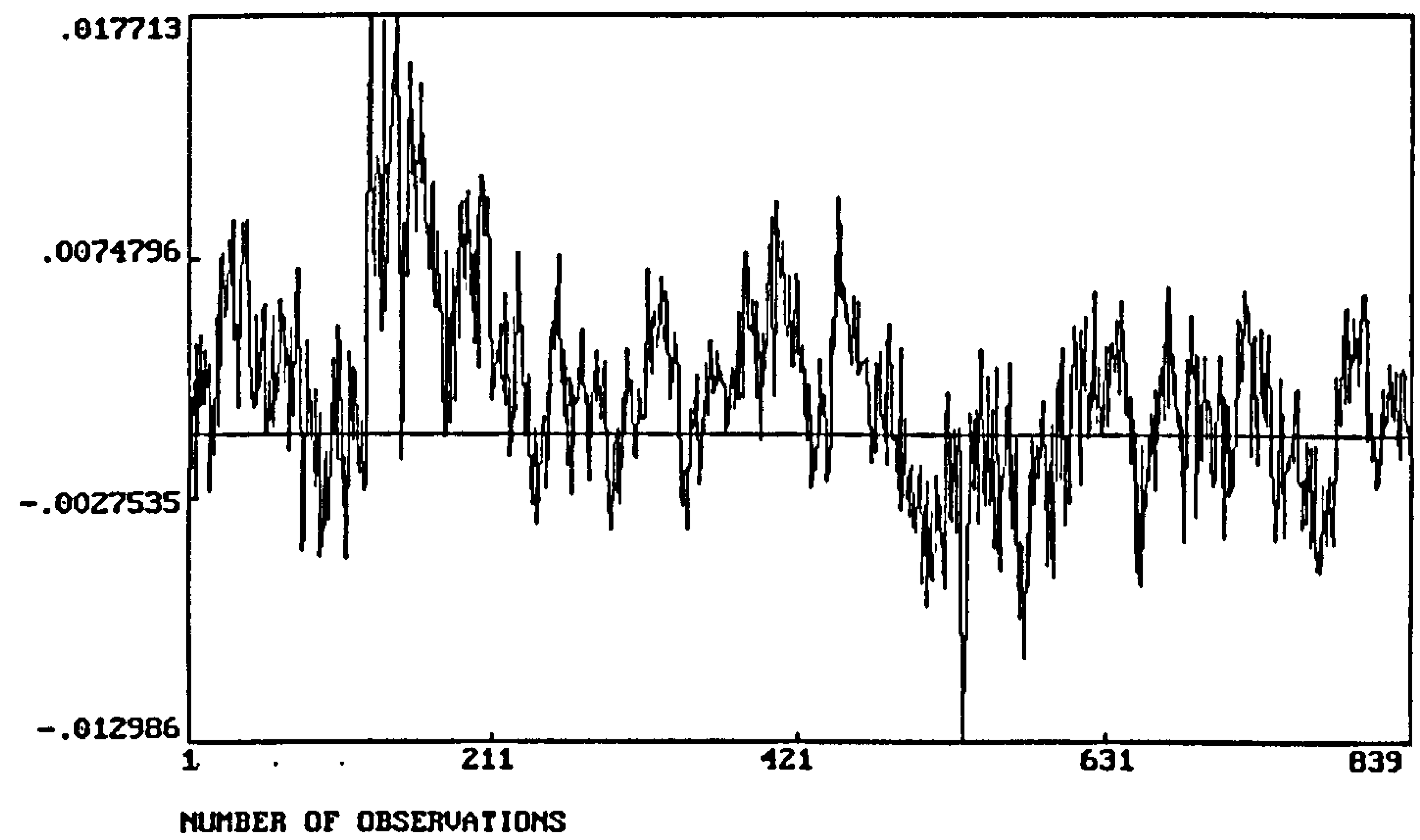


Figure 4.9

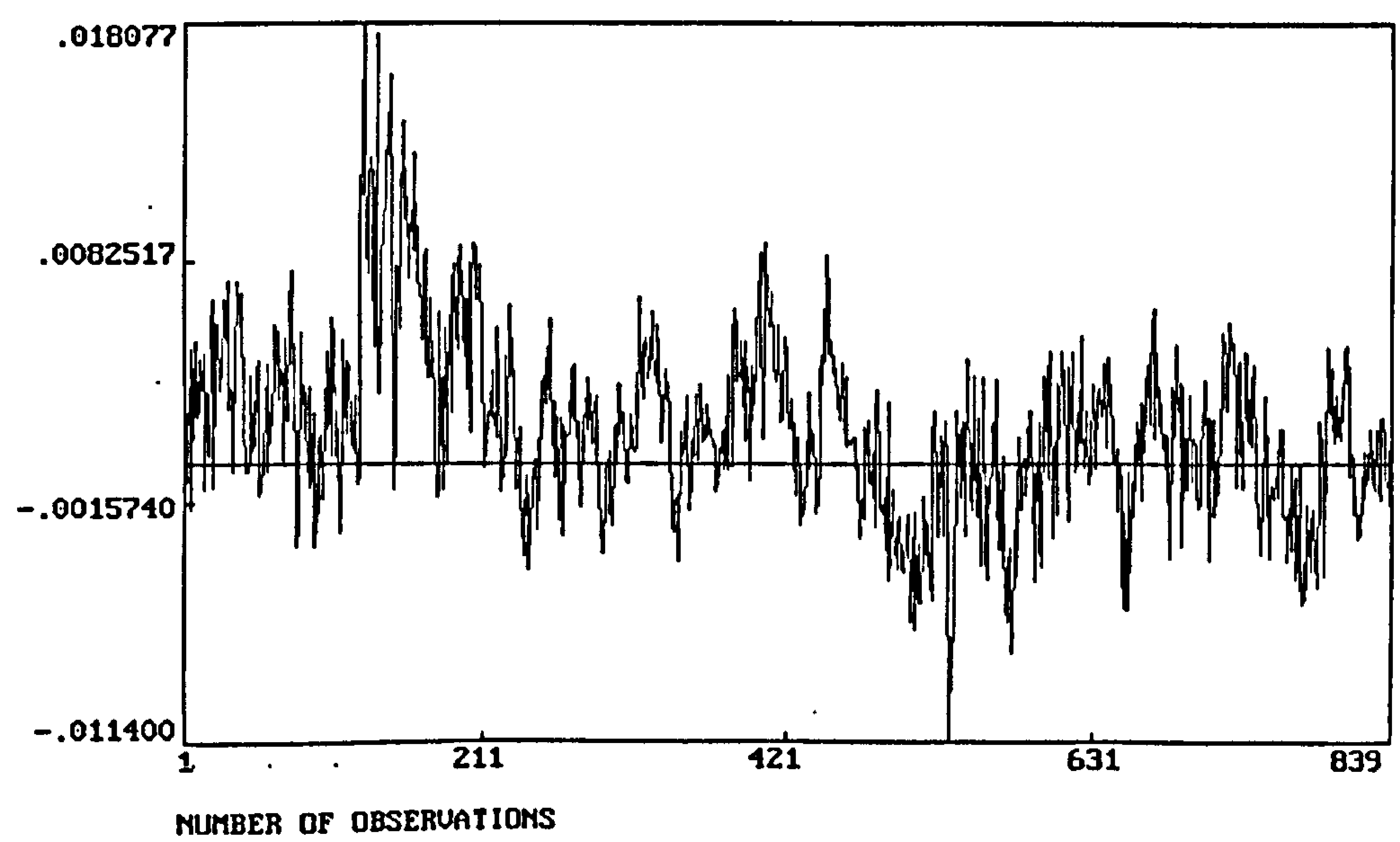
A) The mispricing series based on the Implied Index for the period 13/03/92 - 31/05/95.



B) The mispricing series unadjusted for non-synchronicity for the period 13/03/92 - 31/05/95.



C) The mispricing series adjusted for non-synchronicity for the period 13/03/92 - 31/05/95.



As the figures show, the cost-of-carry pricing relationship is frequently violated in all cases investigated, with a lot of the violations being very large. We can compare the mispricing series produced based on the three spot series used in more detail in Tables 4.4 and 4.5. The correlation coefficients show that there is a relatively high correlation among all series. For the entire sample analysed of 2,869 observations the unadjusted and the adjusted mispricing series are found to be statistically equal on average and very close in value being -0.0023 and -0.0027 respectively.

This relationship is maintained even for the smaller sample period of 839 observations covering recent years where the unadjusted and the adjusted mispricing series are very close on average, being 0.0018 and 0.0015 respectively, as well as statistically equal. On the other hand, the mispricing series calculated using the implied index appears to be statistically different on average to both the unadjusted and the adjusted series. It also suggests the highest average mispricing, 0.0045, with the unadjusted producing the next highest, 0.0018 and the adjusted giving the lowest, 0.0015.

Table 4.4

Summary statistics of the estimated relative mispricing series based on the use of both the unadjusted and adjusted for non-synchronicity spot series. The sample period has 2,869 observations and covers the period 01/06/84 - 31/5/95.

VARIABLES	UNADJUSTED MISPRICING	ADJUSTED MISPRICING
MAXIMUM	0.0301	0.0301
MINIMUM	-0.0588	-0.0425
MEAN	-0.0023	-0.0027
STD.DEV.	0.0081	0.0080

ESTIMATED CORRELATION COEFFICIENTS	
UNADJUSTED MISPRICING vs ADJUSTED MISPRICING	0.954

t-statistics Ho: $\mu_1=\mu_2$ Reject Ho at 5% if z>1.96	
UNADJUSTED MISPRICING vs ADJUSTED MISPRICING	1.870 accept Ho

Table 4.5

Summary statistics of the relative mispricing series based on the Implied index and the unadjusted and adjusted for non-synchronicity mispricing series. The sample period has 839 observations and covers the period 13/3/92 - 31/5/95.

VARIABLES	MISPRICING USING IMPLIED INDEX	UNADJUSTED MISPRICING	ADJUSTED MISPRICING
MAXIMUM	0.0217	0.0177	0.0181
MINIMUM	-0.0059	-0.0129	-0.0114
MEAN	0.0045	0.0018	0.0015
STD.DEV.	0.0037	0.0041	0.0037

ESTIMATED CORRELATION COEFFICIENTS	
MISPRICING USING IMPLIED INDEX vs UNADJUSTED MISPRICING	0.797
MISPRICING USING IMPLIED INDEX vs ADJUSTED MISPRICING	0.760
UNADJUSTED MISPRICING vs ADJUSTED MISPRICING	0.968

t-statistics Ho: $\mu_1=\mu_2$ Reject Ho at 5% if z>1.96	
MISPRICING USING IMPLIED INDEX vs UNADJUSTED MISPRICING	13.840 reject Ho
MISPRICING USING IMPLIED INDEX vs ADJUSTED MISPRICING	16.833 reject Ho
UNADJUSTED MISPRICING vs ADJUSTED MISPRICING	1.590 accept Ho

More information about the mispricing series can be found in the summary statistics presented in Tables 4.6 (for the entire sample of 2,869 observations) and 4.7 (for the sample period of 839 observations), where results are shown for both the entire sample and for individual contracts.

Table 4.6
Summary statistics of the mispricing series, X, in the near FTSE 100 futures contract after both adjusting and not adjusting the spot index for non-synchronicity, sample:01/06/84 to 31/05/95. n: number of days of each contract examined; Figures in parenthesis are t-stat: reject Ho: μ=0 and Ho: ρ=0 at 5% level of significance if t-value > |2.000|.

CONTRACT	n	Adjusting for non-synchronicity			Without adjusting for non-synchronicity		
		<0	>0	MEAN	<0	>0	MEAN
OVERALL SAMPLE 01/06/84 ... 31/05/95	2869	1650	1219	-0.0027 (-17.841)*	1597	1272	-0.0023 (-14.847)*
FIRST PART 01/06/84 ... 31/05/88	1043	781	262	-0.0063 (-20.959)*	765	278	-0.0057 (-18.826)*
SECOND PART 01/06/88 ... 31/05/95	1826	869	957	-0.0006 (-4.476)*	832	994	-0.0003 (-2.011)*
SEP 84	66	60	6	-0.0133 (-10.145)*	61	5	-0.0115 (-10.380)*
DEC 84	65	62	3	-0.0137 (-13.511)*	62	3	-0.0125 (-12.756)*
MAR 85	64	64	0	-0.0142 (-32.510)*	64	0	-0.0130 (-34.666)*
JUN 85	66	66	0	-0.0181 (-19.974)*	66	0	-0.0176 (-20.360)*
SEP 85	65	64	1	-0.0116 (-18.282)*	65	0	-0.0117 (-17.962)*
DEC 85	65	65	0	-0.0118 (-22.792)*	65	0	-0.0105 (-20.271)*
MAR 86	65	58	7	-0.0059 (-11.131)*	59	6	-0.0052 (-11.389)*
JUN 86	65	50	15	-0.0057 (-5.832)*	54	11	-0.0047 (-5.624)*
SEP 86	65	10	55	0.0055 (0.001)	8	57	0.0055 (9.238)*
DEC 86	65	33	32	0.0002 (0.184)	35	30	0.0004 (0.347)
MAR 87	65	49	16	-0.0034 (-6.240)*	36	29	-0.0007 (-0.187)
JUN 87	65	39	26	-0.0007 (-0.835)	33	32	0.0009 (1.253)
SEP 87	66	23	43	0.0030 (2.995)*	26	40	0.0036 (3.240)*
DEC 87	65	31	34	-0.0006 (-0.544)	35	30	-0.0053 (-3.032)*
MAR 88	65	47	18	-0.0035 (-2.971)*	39	26	-0.0026 (-2.124)*
JUN 88	66	60	6	-0.0065 (-11.273)*	57	9	-0.0063 (-10.315)*
SEP 88	66	66	0	-0.0111 (-21.530)*	66	0	-0.0109 (-2.752)*
DEC 88	65	59	6	-0.0088 (-11.792)*	64	1	-0.0088 (-13.429)*
MAR 89	64	53	11	-0.0038 (-8.034)*	40	24	-0.0020 (-3.366)*
JUN 89	66	30	36	0.0006 (1.138)	23	43	0.0014 (2.800)*
SEP 89	66	62	4	-0.0088 (-13.639)*	63	3	-0.0071 (-11.966)*
DEC 89	65	63	2	-0.0095 (-14.606)*	65	0	-0.0105 (-1.917)
MAR 90	64	64	0	-0.0084 (-20.521)*	64	0	-0.0073 (-18.821)*
JUN 90	66	49	17	-0.0056 (-7.024)*	50	16	-0.0061 (-7.223)*
SEP 90	66	10	56	0.0036 (7.110)*	13	53	0.0037 (6.058)*

DEC 90	65	9	56	0.0048 (7.872)*	15	50	0.0038 (0.693)
MAR 91	64	19	45	0.0023 (5.273)*	11	53	0.0030 (6.757)*
JUN 91	66	59	7	-0.0035 (-11.680)*	54	12	-0.0018 (-6.232)*
SEP 91	65	24	41	0.0009 (3.196)*	19	46	0.0016 (4.719)*
DEC 91	65	2	63	0.0052 (14.276)*	5	60	0.005 (1.556)
MAR 92	65	9	56	0.0041 (9.577)*	9	56	0.0040 (9.693)*
JUN 92	65	10	55	0.0030 (9.148)*	7	58	0.0036 (9.460)*
SEP 92	66	14	52	0.0019 (6.135)*	29	37	0.0007 (1.837)
DEC 92	65	4	61	0.0076 (13.276)*	2	63	0.0088 (15.856)*
MAR 93	64	18	46	0.0027 (5.997)*	11	53	0.0038 (7.576)*
JUN 93	66	17	49	0.0011 (4.495)*	16	50	0.0013 (4.809)*
SEP 93	66	15	51	0.0016 (5.723)*	8	58	0.0021 (7.529)*
DEC 93	65	13	52	0.0028 (8.233)*	12	53	0.0036 (9.701)*
MAR 94	64	37	27	-0.0005 (-1.203)	30	34	0.0008 (1.707)
JUN 94	66	46	20	-0.0019 (-4.794)*	50	16	-0.0028 (-6.616)*
SEP 94	66	21	45	-0.0010 (3.541)*	22	44	0.0009 (2.437)*
DEC 94	65	26	39	0.0005 (1.565)	26	39	0.0003 (1.000)
MAR 95	64	34	30	0.0004 (1.093)	35	29	0.0002 (0.571)
JUN 95	66	36	30	-0.0003 (-1.043)	23	43	0.0006 (1.598)

t-statistics H_o: $\mu_1=\mu_2$ Reject at 5% if z>1.96			CORR. COEFF.	
	FIRST PART 01/06/84- 31/5/88	SECOND PART 01/06/88- 31/05/95	FIRST PART	SECOND PART
ADJUSTED MISPRICING vs UNADJUSTED MISPRICING	1.388#	1.701#	0.931	0.973
ADJUSTED MISPR. vs YADAV AND POPE'S MISPR.	7.889##	-	**	-
UNADJUSTED MISPR. vs YADAV AND POPE'S MISPR.	4.395##	-	**	-

* The figures are statistically significant.
** Not possible to have due to unavailability of Yadav and Pope's data
 # Accept Ho
Reject Ho

Table 4.7

Summary statistics of the mispricing series, X, in the near FTSE 100 futures contract using all three cases of spot series, sample:13/03/92 to 31/05/95. Figures in parenthesis are t-stat: reject Ho: μ=0 and Ho: ρ=0 at 5% level of significance if t-value > |2.000|.

CONTRACT	n	Adjusting for non-synchronicity			Without adjusting for non-synchronicity			Using the Implied Index		
		<0	>0	MEAN	<0	>0	MEAN	<0	>0	MEAN
OVERALL SAMPLE 13/03/92 ... 31/05/95	839	291	548	0.0015 (11.825)*	270	569	0.0018 (12.687)*	37	802	0.0045 (35.504)*
JUN 92	56	10	46	0.0028 (8.020)*	6	50	0.0035 (8.350)*	3	53	0.0053 (13.160)*
SEP 92	66	14	52	0.0019 (6.135)*	29	37	0.0007 (1.837)	1	65	0.0045 (17.788)*
DEC 92	65	4	61	0.0076 (13.276)*	2	63	0.0088 (15.856)*	0	65	0.0118 (26.931)*
MAR 93	64	18	46	0.0027 (5.997)*	11	53	0.0038 (7.576)*	0	64	0.0073 (11.724)*
JUN 93	66	17	49	0.0011 (4.495)*	16	50	0.0013 (4.809)*	1	65	0.0036 (10.545)*
SEP 93	66	15	51	0.0016 (5.723)*	8	58	0.0021 (7.529)*	0	66	0.0035 (17.054)*
DEC 93	65	13	52	0.0028 (8.233)*	12	53	0.0036 (9.701)*	0	65	0.0060 (33.091)*
MAR 94	64	37	27	-0.0005 (-1.203)	30	34	0.0008 (1.707)	0	64	0.0046 (10.439)*
JUN 94	66	46	20	-0.0019 (-4.794)*	50	16	-0.0028 (-6.616)*	19	47	0.0009 (4.037)*
SEP 94	66	21	45	-0.0010 (3.541)*	22	44	0.0009 (2.437)*	1	65	0.0033 (16.692)*
DEC 94	65	26	39	0.0005 (1.565)	26	39	0.0003 (1.000)	0	65	0.0032 (22.727)*
MAR 95	64	34	30	0.0004 (1.093)	35	29	0.0002 (0.571)	0	64	0.0029 (21.453)*
JUN 95	66	36	30	-0.0003 (-1.043)	23	43	0.0006 (1.598)	12	54	0.0021 (8.864)*

* The mean figures are statistically significant

We first explain the results for the sample period of 2,869 observations shown in Table 4.6. Apart from investigating the sample as a whole, it is also divided into two parts. The first part consists of sixteen contracts (1043 observations) and covers the time period that the study by Yadav and Pope (1990) analyse. In their study, in line to ours, they use daily closing prices of the FTSE 100 futures contract, basing their data on the near contract. Since Yadav and Pope's study is the only one studying the U.K. market for arbitrage, we compare our results directly to theirs. The average mispricing for this period for the adjusted, the unadjusted and the Yadav and Pope's unadjusted mispricing is found to be -0.006, -0.005 and -0.004 respectively. This shows that mispricing on average is similar in all cases. In addition, we test the hypothesis that these means are statistically different between them. The statistics suggest that both the adjusted and unadjusted series have statistically equal means and are highly correlated (0.931). This again indicates that the non-synchronous trading problem is not as severe in the U.K. as in the U.S.. However, both the adjusted and unadjusted series are found to be statistically different to the mean of the Yadav and Pope's series. This could be explained by the different way the data series was constructed, since Yadav and Pope shift to the next nearest contract at expiration of the futures contract, while we shift just before the expiration month starts. Despite that, it is obvious that the means between the Yadav and Pope's series and our series are very close in value and indicate the presence of relatively small mispricing.

On a contract to contract basis all cases suggest that the majority (approximately 80%) of the contracts are found to be both undervalued[1] and have statistically significant average mispricing. Furthermore absolute mispricing seems to have decreased over the period examined but not dramatically. Specifically, for the adjusted case it has dropped from 0.0133 (Sep 84) to 0.0065 (Jun 88), for the unadjusted case it has declined from 0.0115 (Sep 84) to 0.0063 (Jun 88) and finally, for the Yadav and Pope's unadjusted case it is reduced from 0.0090 to 0.0060.

We continue by comparing the results of adjusted and unadjusted mispricing with those of the second part of our sample period, which starts at the point where Yadav and Pope's period ends. Our results firstly indicate how mispricing has performed in recent years in comparison to the first years that the stock index futures market was introduced. In addition to this we will be able to see whether our results in the first part of the sample period about non-synchronous trading hold for the second part too. Our findings show that, both the adjusted and unadjusted series are highly correlated (0.973) with similar, small but statistically significant means being -0.0006 and -0.0003 respectively, which are also found to be statistically equal. The mean of both series in the second part of the period analysed is smaller than the mean in

[1]In the existing literature, there is no clear consensus as to whether futures contracts tend to be mainly undervalued or overvalued. In his book, Sutcliffe (1997) reviewed a large number of studies on this subject and found that the majority detect overpriced futures.

the first part of the sample period (-0.0063 and -0.0057 for the adjusted and unadjusted series respectively). However, mispricing is still present and is significant.

Furthermore, on a contract to contract basis, both series provide a similar percentage of undervalued contracts (approximately 40%). However, if we compare the number of undervalued contracts in the first part of the sample period (approximately 80%) to that in the second part of the sample period (approximately 40%) we find it to have been reduced by approximately 50%. Moreover, in both cases the majority of the contracts have, on average, statistically significant mispricing. In addition to this, absolute mispricing seems to have decreased over the period examined in both cases. Specifically, for the adjusted case it has dropped from 0.0111 (Sep 88) to 0.0003 (Jun 95), while for the unadjusted case it has declined from 0.0109 (Sep 88) to 0.0006 (Jun 95). As a consequence, we can see that the results imply that the presence of non-synchronous trading does not have severe effects. Additionally, the level of mispricing appears to have declined in the recent years[1]. However, it is still present and significant. Figure 4.10 shows the average annual level of the trading volume of the FTSE 100 futures. As seen the trading volume of the futures contract has increased dramatically over the years. Such an observation can explain the reduction in the level of mispricing. The

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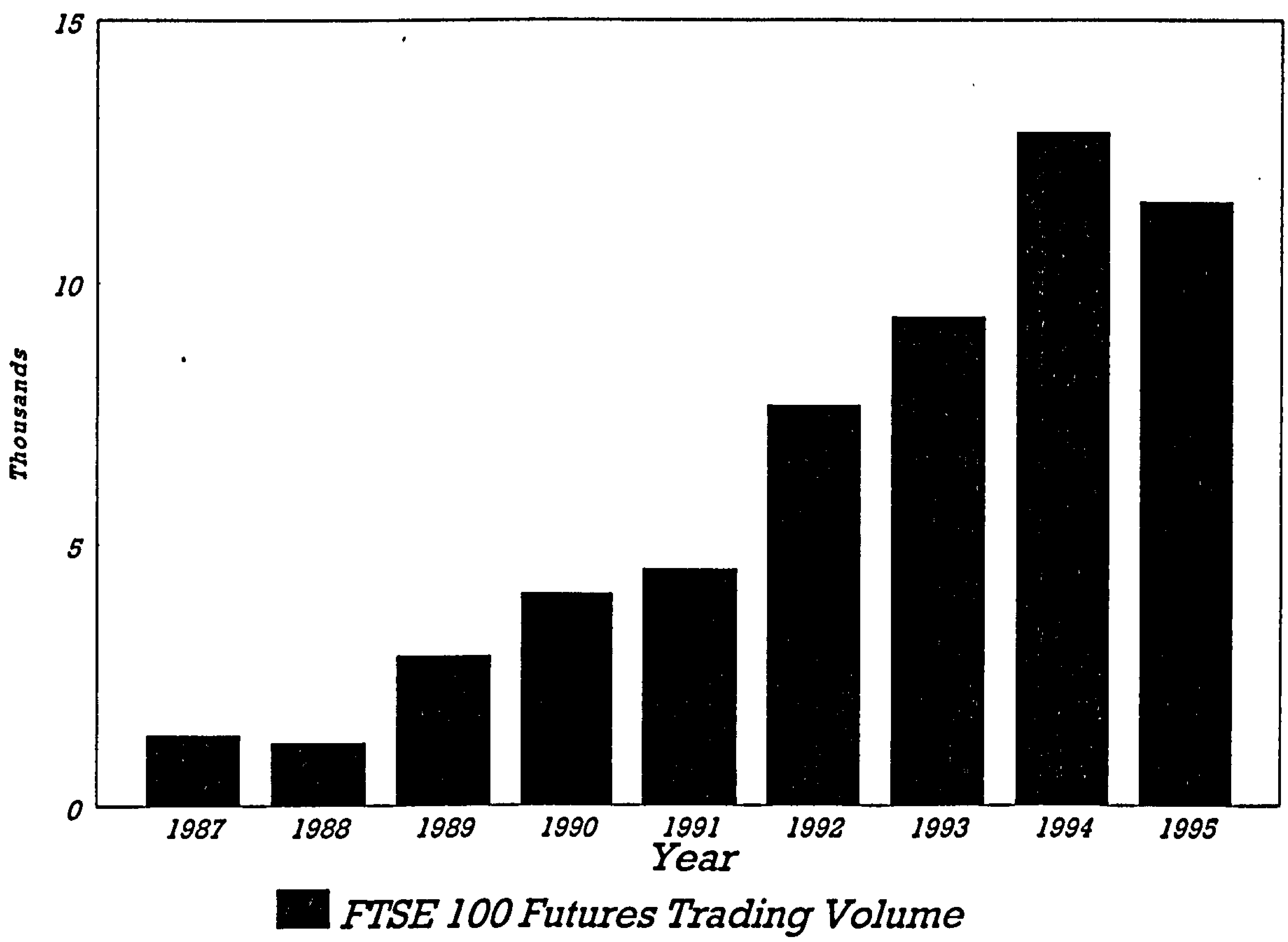
[1]This finding is consistent with various studies such as those by Cornell and French (1983a, 1983b), Cornell (1985), Figlewski (1984a), Merrick (1987, 1989), Arditti *et al.* (1986), Saunders and Mahajan (1988) and Bhatt and Cakici (1990).

traders are better informed about the futures market and trade more often reducing the level of mispriced contracts.

Figure 4.10

Average yearly trading volume of the FTSE 100 futures during the period 01/01/87 and 31/05/95 (due to unavailability of volume data the period 01/06/84 to 31/12/86 is not shown). Year 1995 consists of 108 observations.



Finally, we explain the results about the smaller sample period of 839 observations displayed in Table 4.7. The observed mispricing is on average relatively small for both the unadjusted, the adjusted and the implied index case, but statistically significant. However, the implied index suggests the highest average mispricing 0.0045 as opposed to the adjusted case 0.0018 and the unadjusted case 0.0015. On a contract to contract basis, the mispricing series based on the implied index indicates a statistically significant mispricing for all contracts (13/13), while it is significant for the majority of the contracts for both the unadjusted (8/13) and the adjusted (9/13) case.

Furthermore, all series suggest a decline in mispricing over the period examined. More specifically, the implied index case of mispricing series appears to have declined from 0.0053 (June 92 contract) to 0.0021 (June 95 contract). Finally, the average mispricing during the June 92 contract for the unadjusted and adjusted for non-synchronicity mispricing is 0.0035 and 0.0028 respectively and drops to 0.0006 and -0.0003 respectively (June 95 contract). A possible explanation for this result given by similar studies[1] is that the futures market is still continuing to mature over the period and has is becoming increasingly less prone to mispricing through greater pricing efficiency.

[1]Cornell and French (1983a,b), Figlewski (1984a), Merrick (1987, 1989) and Saunders and Mahajan (1988).

On the whole, we can say that the adjusted mispricing series gives the smallest average mispricing (0.0015) over the whole sample, but on a contract basis the unadjusted mispricing series has the smallest number of significant average mispricing (8/13). The mispricing series suggested by the implied index case identifies the presence of both higher and more significant mispricing than what implied by the unadjusted and the adjusted series. Overall, the results so far suggest that for the time period analysed the pricing of the futures contracts has not always been efficient, although such apparent inefficiencies may be removed once transactions costs are considered. However, over the years the level of mispricing appears to become smaller, with the observed futures price and the theoretical futures price coming closer together.

These findings are consistent with the findings of the previous chapter. In particular, the previous chapter produced a relatively high value for the supply of elasticity of arbitrage, which appears to have declined over the years. Such a finding suggests the presence of mispricing which has decreased over the years, which is also confirmed by the results of this chapter. However, the presence and significance of the mispricing even in the recent years is undisputable. Furthermore, the previous chapter also suggested high similarities in the results of both the unadjusted and the adjusted cases, indicating the small effect of non-synchronous trading in the U.K. market, which is also supported in this chapter. Finally, in line with the findings of this chapter, the previous chapter shows that the options implied index case suggests the highest degree of mispricing among the cases investigated.

We further analyse the mispricing series for auto-correlation and present the results in Tables 4.8 (entire sample of 2,869 observations) and 4.9 (sample of 839 observations). Table 4.8 indicates the presence of positive first-order auto-correlation for both the unadjusted and the adjusted case, with nearly all the auto-correlation coefficients of the contracts (98%) being statistically significant. ARMA modelling of the mispricing series shows it to follow an auto-regressive process of order one.[1] Over the entire sample period, the auto-correlation of the mispricing series is both significant and high, 0.860 for the unadjusted case and 0.855[2] for the adjusted case. Our results suggest that mispricing tends to persist above or below zero and not fluctuate randomly around zero.[3]

If we compare our results to those by Yadav and Pope for the same period that they investigate we find that there are similarities. They too find significant, high positive first-order auto-correlation for the majority of the contracts, which appears to have declined only slightly over the years. For their entire sample the auto-

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[1]This is consistent with Yadav and Pope (1990).

[2]An ADF Unit Root test was carried out on the mispricing series and the series was found not to contain a unit root, thus supporting stationarity.

[3]This is consistent with MacKinlay and Ramaswamy (1988).

correlation coefficient is 0.800, which is very closely related to our findings of 0.834 for the unadjusted case and 0.821 for the adjusted case. Therefore, our findings are similar to those of Yadav and Pope, which imply that there is a strong tendency for mispricing to persist and this persistence has not been reduced significantly as the market has matured. In addition, the remaining period that consists of the updated and recent data that Yadav and Pope do not cover, shows that auto-correlation is still very high and significant. Therefore, despite the fact that the futures market is not any more new, there is still mispricing in the recent years of lower size but of high tendency to persist.

When we analyse the smaller sample of 839 observations in Table 4.9, we find all three cases of spot series applied to suggest the presence of positive first-order auto-correlation, which is both high and statistically significant. This finding again suggests that mispricing tends to persist. Over the whole sample, the lowest auto-correlation coefficient is 0.728 and given by the adjusted for non-synchronicity series. The existence of auto-correlation in the unadjusted series (0.803), can be and was put down to the fact that non-synchronicity was not considered. This seems to be confirmed by the fact that when it is removed the auto-correlation is reduced. However, the adjustment process might have removed more than just the effects of non-synchronicity. In addition, it is possible that some of the observed auto-correlation is genuine and not due to the existence of non-synchronous trading. This is reflected in the results based on the use of implied index which, despite the fact that it is not subject to non-synchronous trading problems, shows high first-order auto-correlation (0.881).

The observed serial correlation in the mispricing series suggests persistence in mispricing. This can mean that mispricing is not removed quickly and suggests that arbitrage trading is not strong, or that the profits from arbitrage trading cannot cover the associated transaction costs. The results about the auto-correlation in the mispricing series are also consistent with the findings of the previous chapter, where the high values of the elasticity of supply of arbitrage clearly suggests that not only mispricing is present, but also has a high tendency to persist. It was also found that this persistence appears to have had a relatively small decline over the years, which confirms the results of this chapter.

Table 4.8

Estimated first-order auto-correlation ($\hat{\rho}$) of both the unadjusted and adjusted for non-synchronicity mispricing series (X), on the FTSE 100 stock index futures contracts, sample period 01/06/84 to 31/05/92. Auto-correlation coefficients are slope coefficients in the regression $y_t = \rho y_{t-1} + e_t$. Heteroscedasticity was detected for some of the sub-samples investigated. In those cases white heteroscedasticity consistent standard errors were used. Reject H_0: $\rho = 0$ at the 5% level of significance if t-value > |2.000|.

CONTRACT	n	Adjusting for non-synchronicity	Not adjusting for non-synchronicity
		ρ(X)	ρ(X)
OVERALL SAMPLE 01/06/84 ... 31/05/95	2869	0.855 (54.472)*	0.860 (28.377)*
FIRST PART 01/06/84 ... 31/05/88	1043	0.821 (31.052)*	0.834 (33.759)*
SECOND PART 01/06/88 ... 31/05/95	1826	0.857 (56.961)*	0.859 (59.653)*
SEP 84	66	0.623 (6.331)*	0.569 (5.526)*
DEC 84	65	0.894 (15.540)*	0.906 (16.734)*
MAR 85	64	0.636 (6.543)*	0.587 (5.965)*
JUN 85	66	0.865 (13.229)*	0.853 (12.528)*
SEP 85	65	0.663 (7.165)*	0.739 (8.958)*
DEC 85	65	0.755 (9.094)*	0.792 (10.005)*
MAR 86	65	0.615 (5.987)*	0.549 (5.152)*
JUN 86	65	0.796 (10.504)*	0.731 (8.500)*
SEP 86	65	0.687 (7.626)*	0.713 (8.143)*
DEC 86	65	0.867 (13.440)*	0.869 (13.954)*
MAR 87	65	0.320 (2.697)*	0.269 (2.254)*
JUN 87	65	0.740 (8.644)*	0.704 (7.743)*
SEP 87	66	0.662 (6.025)*	0.743 (7.731)*
DEC 87	65	0.056 (0.487)	0.590 (6.243)*
MAR 88	65	0.771 (9.526)*	0.762 (9.360)*
JUN 88	66	0.623 (5.408)*	0.642 (6.710)*
SEP 88	66	0.570 (5.384)*	0.583 (5.723)*

DEC 88	65	0.898 (15.006)*	0.894 (14.348)*
MAR 89	64	0.399 (3.444)*	0.594 (5.828)*
JUN 89	66	0.672 (7.175)*	0.661 (6.858)*
SEP 89	66	0.772 (9.746)*	0.720 (8.205)*
DEC 89	65	0.284 (1.970)	0.318 (2.638)*
MAR 90	64	0.464 (4.011)*	0.419 (3.703)*
JUN 90	66	0.846 (11.905)*	0.864 (12.524)*
SEP 90	66	0.603 (6.038)*	0.710 (8.094)*
DEC 90	65	0.512 (4.735)*	0.585 (5.725)*
MAR 91	64	0.507 (4.470)*	0.484 (4.283)*
JUN 91	66	0.657 (6.537)*	0.620 (6.075)*
SEP 91	65	0.455 (3.964)*	0.536 (4.913)*
DEC 91	65	0.675 (7.240)*	0.736 (8.538)*
MAR 92	65	0.542 (5.061)*	0.475 (4.267)*
JUN 92	65	0.336 (2.829)*	0.528 (4.936)*
SEP 92	66	0.353 (3.010)*	0.483 (4.377)*
DEC 92	65	0.592 (5.950)*	0.556 (5.607)*
MAR 93	64	0.741 (8.707)*	0.765 (9.369)*
JUN 93	66	0.559 (5.423)*	0.645 (6.827)*
SEP 93	66	0.643 (6.687)*	0.647 (6.823)*
DEC 93	65	0.689 (7.649)*	0.717 (8.194)*
MAR 94	64	0.768 (9.683)*	0.805 (10.684)*
JUN 94	66	0.429 (3.803)*	0.451 (4.038)*
SEP 94	66	0.255 (2.156)*	0.485 (4.558)*
DEC 94	65	0.457 (4.042)*	0.439 (3.866)*
MAR 95	64	0.576 (5.615)*	0.583 (5.722)*
JUN 95	66	0.697 (7.614)*	0.792 (10.396)*

*The auto-correlation figures are statistically significant

Table 4.9
Estimated first-order auto-correlation ($\hat{\rho}$) of the mispricing series based on the Implied index and the unadjusted and adjusted for non-synchronicity mispricing series, sample period 13/03/92 to 31/05/95. n: number of days of each contract examined; Figures in parenthesis are t-stat: reject H_o: μ=0 and H_o: ρ=0 at 5% level of significance if t-value > |2.000|.

CONTRACT	n	Not adjusting for non-synchronicity	Based on the Implied Index	Adjusting for non-synchronicity
		ρ(X)	ρ(X)	ρ(X)
JUN 92	56	0.528 (4.936)*	0.580 (5.599)*	0.335 (2.643)*
SEP 92	66	0.483 (4.377)*	0.300 (2.521)*	0.353 (3.010)*
DEC 92	65	0.556 (5.607)*	0.689 (7.557)*	0.592 (5.950)*
MAR 93	64	0.765 (9.369)*	0.917 (17.898)*	0.741 (8.707)*
JUN 93	66	0.645 (6.827)*	0.827 (11.749)*	0.559 (5.423)*
SEP 93	66	0.647 (6.823)*	0.710 (8.091)*	0.643 (6.687)*
DEC 93	65	0.717 (8.194)*	0.587 (5.968)*	0.689 (7.649)*
MAR 94	64	0.805 (10.684)*	0.873 (13.703)*	0.768 (9.683)*
JUN 94	66	0.451 (4.038)*	0.597 (5.941)*	0.429 (3.803)*
SEP 94	66	0.485 (4.558)*	0.498 (4.643)*	0.255 (2.156)*
DEC 94	65	0.439 (3.866)*	0.684 (7.427)*	0.457 (4.042)*
MAR 95	64	0.583 (5.722)*	0.680 (7.321)*	0.576 (5.615)*
JUN 95	66	0.792 (10.396)*	0.740 (8.803)*	0.697 (7.614)*

OVERALL SAMPLE 01/06/84 - 31/05/95	Not adjusting for non-synchronicity	Based on the Implied Index	Adjusting for non-synchronicity
N	839	839	839
< 0	270	37	291
> 0	569	802	548
MEAN	0.0018 (12.687)*	0.0045 (35.504)*	0.0015 (11.825)*
ρ(X)	0.803 (35.319)*	0.881 (39.427)*	0.728 (26.519)*

* The figures are statistically significant.

4.4.4 MISPRICING AND TIME-TO-MATURITY

The positive auto-correlation observed in the mispricing series could be the result of a time-dependent trend in mispricing. It has been suggested by Cornell and French (1983a, 1983b) that, due to the presence of the tax-timing option (as already explained in section 4.2.2.) in the spot market but not in the futures market, mispricing should be negative (futures undervalued compared to cost-of-carry prices), with its negative value decreasing as time to maturity increases. We therefore, examine the behaviour of mispricing in relation to time-to-maturity so as to identify the relationship between the magnitude of the mispricing and the contracts' maturity. This is achieved with the estimation of a simple linear regression applied in each contract. The formula used is given as follows:

$$X_{t,T} = a + b(T-t) + \varepsilon_t \tag{4.6}$$

Where, the mispricing, $X_{t,T}$, is regressed against the time remaining to maturity, T-t. The impact of the time to maturity to the mispricing is reflected to the coefficient, b. Therefore, we examine its sign and test its significance by assuming that H_o: b=0. If the tax-timing option is actually important then, the coefficient b should be negative and the constant a zero. The results of the regressions are shown for the adjusted cases in Table 4.10. Similar results were produced for the other two cases of spot index. The R^2 will show how much of the variation in the mispricing is explained by the time to maturity.

The regression produces 34 out of 44 statistically significant coefficients, b, which implies that there is a relation between time-to-expiration and mispricing. However, the explanatory power of the regression (R^2) is fairly low for the majority of the contracts (84%), which means that time-to-maturity is not the only factor affecting the behaviour of the mispricing. Furthermore, the coefficient of expiration time, b, is negative only for sixteen out of forty four contracts (36%). For the remaining contracts it is either insignificant or positive. Moreover, twenty nine out of forty four regressions produce a statistically significant, positive constant. Therefore, we can conclude that the tax-timing option does not seem to be present or valuable.

Yadav and Pope applied the same formula as described in equation (4.6) and found only 6 out of 16 contracts (37%) to have a negative coefficient b, while the remaining ones were either positive or statistically insignificant. As a result, they conclude that the tax-timing option does not seem to be important. In addition to this they find that time-to-expiration is statistically significant when explaining the observed mispricing.[1] For the same sample period as that of Yadav and Pope's we find similar results. Only 7/16 contracts (43%) are producing statistically significant negative b, while there is indication that time-to-maturity is related to the observed mispricing.

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[1]These findings are also consistent with those reported by Cornell (1985), MacKinlay and Ramaswamy (1988).

Table 4.10

Regression of adjusted for non-synchronicity mispricing, $X_{t,T}$, against time to maturity, T-t. $X_{t,T} = a + b(T-t) + e$, sample:2,869 observations. Figures in parentheses are t statistics. Reject Ho:a=0 and Ho:b=0 at 5% level of significance if t-value > |2.000|.

PERIOD	No.of Obs.	a	b	R^2 (%)
SEP 84	66	0.003 (1.000)	-0.082 (-5.560)**	32.6
DEC 84	65	0.007 (5.416)*	-0.102 (-16.612)**	81.4
MAR 85	64	-0.012 (-9.424)*	-0.011 (-1.744)	4.7
JUN 85	66	-0.001 (-0.993)	-0.084 (-12.167)**	69.8
SEP 85	65	-0.005 (-2.756)*	-0.033 (-4.291)**	22.6
DEC 85	65	-0.008 (-5.277)*	-0.018 (-2.643)**	9.9
MAR 86	65	-0.012 (-8.979)*	0.031 (4.803)**	26.8
JUN 86	65	0.007 (2.889)*	-0.062 (-5.527)**	32.6
SEP 86	65	0.011 (6.480)*	-0.027 (-3.488)**	16.2
DEC 86	65	-0.022 (-13.073)*	0.105 (13.937)**	75.5
MAR 87	65	-0.005 (-3.328)*	0.010 (1.354)	2.8
JUN 87	65	-0.005 (-1.831)	0.019 (1.645)	4.1
SEP 87	66	-0.009 (-3.827)*	0.061 (5.300)**	30.5
DEC 87	65	0.0006 (0.177)	-0.006 (-0.373)	0.2
MAR 88	65	-0.021 (-7.234)*	0.083 (6.353)**	39.0
JUN 88	66	-0.012 (-7.676)*	0.027 (3.786)**	18.3
SEP 88	66	-0.009 (-5.859)*	-0.010 (-1.466)	3.2
DEC 88	65	0.004 (2.669)*	-0.062 (-9.077)**	56.7
MAR 89	64	0.001 (1.126)	-0.025 (-4.305)**	23.0
JUN 89	66	-0.005 (-3.762)*	0.027 (4.447)**	23.6
SEP 89	66	-0.013 (-7.361)*	0.022 (2.683)**	10.1

DEC 89	65	-0.011 (-5.786)*	0.008 (0.923)	1.3
MAR 90	64	-0.005 (-4.677)*	-0.014 (-2.508)**	9.2
JUN 90	66	0.008 (5.372)*	-0.068 (-9.641)**	59.2
SEP 90	66	-0.0006 (-0.448)	0.021 (3.271)**	14.3
DEC 90	65	0.007 (3.678)*	-0.009 (-1.137)	2.0
MAR 91	64	0.003 (2.161)*	-0.002 (-0.409)	0.3
JUN 91	66	-0.001 (-1.575)	-0.011 (-2.830)**	11.1
SEP 91	65	0.004 (4.945)*	-0.015 (-3.997)**	20.2
DEC 91	65	0.0004 (0.484)	0.023 (5.401)**	31.6
MAR 92	65	-0.0007 (-0.609)	0.023 (4.394)**	23.4
JUN 92	65	0.002 (2.393)*	0.005 (1.118)	1.9
SEP 92	66	0.0004 (0.518)	0.009 (2.044)**	6.1
DEC 92	65	0.0008 (0.660)	0.039 (6.183)**	37.8
MAR 93	64	-0.004 (-5.281)*	0.039 (9.419)**	58.9
JUN 93	66	-0.0005 (-0.871)	0.009 (2.911)**	11.7
SEP 93	66	-0.001 (-1.939)	0.016 (4.938)**	27.6
DEC 93	65	-0.0005 (-0.692)	0.019 (4.783)**	26.6
MAR 94	64	-0.007 (-12.692)*	0.039 (12.787)**	72.5
JUN 94	66	-0.001 (-1.541)	-0.002 (-0.346)	0.2
SEP 94	66	0.003 (5.532)*	-0.015 (-4.299)**	22.4
DEC 94	65	0.002 (2.689)*	-0.009 (-2.232)**	7.3
MAR 95	64	-0.003 (-3.668)*	0.019 (4.505)**	24.7
JUN 95	66	0.002 (2.113)*	-0.012 (-2.778)**	10.8

* The constant a is significant.

**The coefficient b is significant.

Time-to-maturity could be in relation to mispricing also due to the fact that the future is difficult to predict and there is uncertainty about important factors such as dividends and the effect of interest rates to stock prices. We therefore, investigate the relationship between time-to-maturity and mispricing by regressing the absolute value of mispricing against time to maturity, in order to observe the direction of the size of the mispricing in relation to the time remaining for each contract to mature. The results are presented in Tables 4.11 (for the 2,869-observation-sample) and 4.12 (for the 839-observation-sample).

Table 4.11 shows that the explanatory power of the regression for the majority of the contracts is fairly low for both series, which means that time to maturity does not explain a lot of the observed absolute mispricing. However, in both cases the majority of the contracts show a positive relationship between the size of mispricing and time to maturity. As a consequence, it is suggested that absolute mispricing decreases as time-to-maturity decreases.[1] The reason why mispricing decreases as the contract approaches maturity is that at maturity the spot and futures assets are identical and so must be priced identically. Prior to maturity, while the spot and futures represent the same asset they differ in time and as such their prices will be similar but not the same. As a consequence, mispricing of a futures contract close to

[1]This is also consistent with a number of studies that have looked at this issue; Yadav and Pope (1990), Cornell (1985) MacKinlay and Ramaswamy (1988).

maturity will be very limited due to stronger links with the spot.

When analysing the sample period that Yadav and Pope utilise, our results are similar to those by Yadav and Pope implying positive relationship between time-to-maturity and absolute mispricing.

Table 4.12 presents the results for the unadjusted, the adjusted and the implied index case. It is found that all series exhibit a small but statistically significant positive relation between mispricing and time-to-expiration, for the majority of the contracts. This is also reflected in the explanatory power of the regression which takes relatively low values for the majority of the contracts. On the whole, we can conclude that all cases suggest that the further away from maturity a futures contract is, the largest the mispricing.[1]

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[1]Also supported by MacKinlay and Ramaswamy (1988), Cornell (1985) and Yadav and Pope (1990).

Table 4.11

Regression of absolute magnitude of mispricing, $|X_{t,T}|$, against time to maturity, T-t, after both adjusting and not adjusting the spot index for non-synchronicity. $|X_{t,T}| = a + b(T-t) + \epsilon$, sample:2,869 observations. Figures in parentheses are t statistics. Reject H_0:a=0 and H_0:b=0 at 5% level of significance if t-value > |2.000|.

PERIOD	No.of Obs.	Adjusting for non-synchronicity		Without adjusting for non-synchronicity	
		b	R^2 (%)	b	R^2 (%)
SEP 84	66	0.077 (5.819)*	34.6	0.068 (6.290)*	41.8
DEC 84	65	0.101 (16.756)*	81.7	0.101 (21.181)*	87.7
MAR 85	64	0.011 (1.744)	4.7	0.002 (0.408)	0.3
JUN 85	66	0.084 (12.167)*	69.8	0.084 (14.745)*	77.2
SEP 85	65	0.034 (4.309)*	22.8	0.055 (9.251)*	57.6
DEC 85	65	0.018 (2.643)*	9.9	0.034 (5.882)*	35.4
MAR 86	65	-0.029 (-4.906)*	27.6	-0.005 (-0.985)	1.5
JUN 86	65	0.069 (9.216)*	57.4	0.044 (6.466)*	39.9
SEP 86	65	-0.016 (-2.450)*	8.7	-0.022 (-3.390)*	15.4
DEC 86	65	0.006 (0.776)	0.9	0.013 (-1.023)	3.1
MAR 87	65	-0.008 (-1.495)	3.4	-0.005 (-1.274)	2.5
JUN 87	65	-0.001 (-0.241)	0.09	0.004 (0.710)	0.8
SEP 87	66	0.018 (2.219)*	7.1	0.027 (2.921)*	11.8
DEC 87	65	-0.015 (-1.357)	2.8	-0.033 (-1.729)	4.5
MAR 88	65	0.005 (0.562)	0.5	0.003 (0.336)	0.2
JUN 88	66	-0.023 (-3.990)*	19.9	-0.029 (-5.134)*	29.2
SEP 88	66	0.010 (1.466)	3.2	-0.008 (-1.291)	2.5
DEC 88	65	0.058 (8.985)*	56.1	0.061 (13.044)*	73.0
MAR 89	64	0.015 (3.221)*	14.3	0.024 (4.666)*	26.0
JUN 89	66	0.0004 (0.101)	0.01	0.004 (1.060)	1.7
SEP 89	66	-0.019 (-2.459)*	8.6	-0.011 (-1.501)	3.4

DEC 89	65	-0.008 (-0.888)	1.2	-0.003 (-0.328)	0.2
MAR 90	64	0.014 (2.508)*	9.2	-0.007 (-1.235)	2.4
JUN 90	66	0.043 (7.073)*	43.9	0.043 (7.001)*	43.4
SEP 90	66	0.006 (1.269)	2.4	0.015 (2.982)*	12.2
DEC 90	65	0.0005 (0.078)	0.01	-0.001 (0.235)	0.09
MAR 91	64	0.002 (0.401)	0.2	-0.002 (-0.348)	0.2
JUN 91	66	0.011 (3.618)*	16.9	0.003 (1.192)	2.2
SEP 91	65	-0.010 (-4.433)*	23.8	-0.014 (-5.59)*	33.2
DEC 91	65	0.022 (5.573)*	33.0	0.029 (7.891)*	49.7
MAR 92	65	0.021 (4.236)*	22.2	0.014 (2.769)*	10.8
JUN 92	65	0.005 (1.299)	2.6	-0.002 (-0.461)	0.3
SEP 92	66	0.007 (2.393)*	8.2	0.008 (2.924)*	11.8
DEC 92	65	0.037 (6.259)*	38.3	0.031 (4.684)*	25.8
MAR 93	64	0.025 (6.497)*	40.5	0.034 (8.260)*	52.4
JUN 93	66	0.007 (4.177)*	21.4	0.011 (4.957)*	27.7
SEP 93	66	0.016 (8.389)*	52.4	0.012 (5.207)*	29.8
DEC 93	65	0.013 (4.125)*	21.3	0.016 (4.403)*	23.5
MAR 94	64	-0.002 (-0.787)	0.9	0.009 (2.437)*	8.7
JUN 94	66	0.0002 (0.046)	0.003	-0.0007 (-0.153)	0.004
SEP 94	66	-0.002 (-1.015)	1.6	-0.004 (-1.536)	3.5
DEC 94	65	0.002 (0.691)	0.7	0.003 (0.939)	1.4
MAR 95	64	0.004 (1.476)	3.4	0.004 (1.346)	2.8
JUN 95	66	0.012 (5.602)*	32.9	0.014 (5.311)*	30.6

* The coefficient b is significant.

Table 4.12

Regression of absolute magnitude of mispricing, $|X_{t,T}|$, against time to maturity, T-t, after both adjusting and not adjusting the spot index for non-synchronicity as well as when using the Implied Index, sample:839 observations. $|X_{t,T}| = a + b(T-t) + \epsilon_t$. Figures in parentheses are t statistics. Reject Ho:a=0 and Ho:b=0 at 5% level of significance if t-value > | 2.000|.

SAMPLE PERIOD	No.of Obs.	Using the Implied Index		Adjusting for non-synchronicity		Not adjusting for non-synchronicity	
		b	R^2 (%)	b	R^2 (%)	b	R^2 (%)
JUN 92	56	-0.009 (-1.690)	5	0.003 (0.619)	0.7	-0.007 (-1.159)	2.4
SEP 92	66	0.007 (2.891)*	11.5	0.007 (2.393)*	8.2	0.008 (2.924)*	11.8
DEC 92	65	0.0036 (8.647)*	54.2	0.037 (6.259)*	38.3	0.031 (4.684)*	25.8
MAR 93	64	0.056 (10.596)*	64.4	0.025 (6.497)*	40.5	0.034 (8.260)*	52.4
JUN 93	66	0.025 (7.392)*	46	0.007 (4.177)*	21.4	0.011 (4.957)*	27.7
SEP 93	66	0.013 (5.539)*	32.4	0.016 (8.389)*	52.4	0.012 (5.207)*	29.8
DEC 93	65	0.012 (6.071)*	36.9	0.013 (4.125)*	21.3	0.016 (4.403)*	23.5
MAR 94	64	0.043 (14.091)*	76	-0.002 (-0.787)	0.9	0.009 (2.437)*	8.7
JUN 94	66	-0.004 (-3.977)*	19.8	0.0002 (0.048)	0.003	-0.0007 (-0.153)	0.004
SEP 94	66	-0.004 (-1.534)	3.5	-0.002 (-1.015)*	1.6	-0.004 (-1.536)	3.5
DEC 94	65	-0.003 (-1.654)	4.1	0.002 (0.691)	0.7	0.003 (0.939)	1.4
MAR 95	64	0.011 (9.140)*	57.4	0.004 (1.475)	3.4	0.004 (1.346)	2.8
JUN 95	66	-0.006 (-2.353)*	7.9	0.012 (5.602)*	32.9	0.014 (5.311)*	30.6

* The coefficient, b, is significant.

4.5 Summary And Conclusions

The purpose of this chapter was to consider the daily behaviour of the FTSE 100 stock index and the FTSE 100 stock index futures contracts. We focused on the investigation of the existence of deviations of the stock index futures prices from their theoretical ones. The first stage of our empirical process focused on examining the difference in the results produced with the use of either dividend yields or actual dividends paid when applying the cost-of-carry model. Our findings suggest that there is no significant difference.

Mispricing was estimated based on the use of a spot index that was acquired in different ways. At first, mispricing was produced with the use of the spot index which was adjusted for non-synchronous trading in chapter two. However, we repeated our estimations with the use of the reported spot index in order to determine whether the presence of non-synchronicity is severe. Both these sets of empirical results and interpretations were compared in detail to the results of a similar study by Yadav and Pope (1990) who do not make any adjustments for non-synchronous trading. The results from the two different approaches are found to be similar, both between them and to those reached by Yadav and Pope. This allows us to suggest that the presence of non-synchronous trading does not significantly affect the pricing of the FTSE 100 index futures contracts. Moreover, our empirical results, which are found to be similar to the results reported in other studies, show the following.

First, it is found that the futures contracts are significantly undervalued. However, the percentage of undervaluation has been reduced in recent years in comparison to the earlier years that the index futures market was introduced. We therefore find the pricing relationship between the spot and futures market being systematically violated, producing a mispricing which is, on average, statistically significant.

Moreover, the majority of the contracts analysed exhibit high, positive first-order auto-correlation which implies that mispricing tends to persist and this persistence has only slightly declined over the years. On the other hand, the average value of mispricing appears to have decreased over the years which could be related to the fact that the futures market has matured and its participants have a better knowledge of its workings.

Furthermore, when examining the effect of the tax-timing option on pricing the futures we conclude that the observed mispricing cannot be explained by this option, leading us to believe that the tax-timing option is not valuable.

Finally, the level of mispricing is found to be related to time-to-maturity for the majority of the contracts. Specifically, we find average mispricing to increase as time-to-maturity increases, which can be attributed to the fact that it is difficult to predict the future and there is uncertainty about important factors such as dividends and interest rates. However, since the explanatory power of the regression of the absolute mispricing to time-to-maturity is not found to be very high, we conclude that it does not explain a lot of the observed mispricing and there are other factors affecting it.

Apart from the use of the reported spot index and the adjusted for non-synchronicity one, our research also utilised the implied index derived in chapter two, which was acquired from the use of American put FTSE 100 options. This approach overcomes the problem of non-synchronous trading without having to rely on any methods for adjusting the data. Based on this method mispricing is found to be higher and more persistent than when applying the unadjusted and the adjusted spot series.

On the whole, all different approaches to the subject of correctly pricing the FTSE 100 index futures contracts confirm the results of the previous chapter, in that it is documented the existence of a relatively small but statistically significant mispricing, which tends to be smaller in value in the recent years (the observed futures price comes closer to the theoretical one based on the cost-of-carry relationship) but still persistent. Having investigated the issue of mispricing in the futures market, the next chapter focuses on whether the observed deviations of the futures price from its theoretical price are big enough and persist long enough to induce profitable arbitrage opportunities. By examining the existence of profitable arbitrage we indirectly examine the efficiency of the futures market. That is because the presence of arbitrage profits imply the persistence of systematic mispricing, which is evidence of market inefficiency.

CHAPTER 5

INVESTIGATION OF ARBITRAGE PROFITABILITY IN THE FTSE 100 STOCK INDEX FUTURES CONTRACT.

5.1 INTRODUCTION

The existence of deviations between the actual futures price and its theoretical one documented in the previous chapter does not necessarily imply that if arbitrage trading takes place it will yield profits. This can be explained by the fact that there are transaction costs which allow futures prices to fluctuate within a bound around their theoretical price without giving rise to profitable arbitrage. The purpose of this chapter is to investigate the issue of profitable arbitrage opportunities in the FTSE 100 futures contract. Stock index arbitrage trading involves the simultaneous purchase and sale of futures contracts and a portfolio of stocks that replicates the underlying index in order to exploit the occurrence of a spread between prices in the spot and futures markets. This chapter is concerned with examining whether arbitrage opportunities, due to mispricing, can actually generate profits when transaction costs are taken into account.

If the observed arbitrage opportunities are profitable even when transaction costs are considered, then the presence of arbitrage trading serves the purpose of restoring prices and reducing and even eliminating the observed mispricing.

As a result, arbitrage trading becomes the mechanism that does not allow the spot and futures markets to drift apart for long, thereby linking them together. However, due to the presence of transaction costs arbitrage trading may not take place if it does not seem to be profitable. In that case, the absence of arbitrage trading will not necessarily imply that there is no mispricing to exploit. It will show instead that if mispricing is present then it is too small to be profitably exploited. Therefore, it can be assumed to be insignificant and the futures market can be said to be functioning effectively.

A wide range of studies have investigated mispricing in the stock index futures market amongst which a number have sought to identify whether the observed mispricing is large enough to be profitably exploited through arbitrage trading. On the whole, the existing literature finds that arbitrage profits exist but are small and have decreased over the years. Some of those studies are by Brennan and Schwartz (1990), Figlewski (1984a, 1984b), MacKinlay and Ramaswamy (1988), Merrick (1987), Modest and Sundaresan (1983), Saunders and Mahajan (1988) and Klemkosky and Lee (1991). In addition to the above, some studies, Merrick (1989) and Sofianos (1993), show that early unwinding and contract rollovers may lead to higher arbitrage profits than the simple hold-to-expiration strategy. On the other hand, Chung (1991) shows that previous studies have overestimated the size and frequency of profitable arbitrage in the futures market but also agrees that arbitrage profits have become smaller over the years. Finally, for the U.K. market, Yadav and Pope (1990) find similar results to those reported in America, which show that arbitrage profits are available but are generally small, especially if an early unwinding or rollover is not considered.

This chapter investigates the issue of profitable arbitrage for the FTSE 100 futures market based on the three mispricing series, derived in chapter two, which respectively do not adjust for non-synchronous trading, make adjustments for non-synchronous trading and use the Implied Index derived from Option contracts. This chapter builds upon the contribution established in the previous chapter by extending the existing research in the U.K. in particular. This is achieved mainly by investigating the argument that a recent article by Miller *et al.* (1994) in the U.S. suggests that some arbitrage trading may just be a statistical illusion due to the presence of non-synchronous trading. As such, the amount of real arbitrage trading present in the market may be less than the amount of arbitrage trading suggested by the mean reversion in the basis.

Briefly, the main findings of our research are as follows. Profitable arbitrage opportunities are present even for high levels of transaction costs. In addition, the frequency and size of arbitrage profits seem to increase with time to maturity but have decreased over the years as the futures market has matured. The early unwinding option is valuable and can lead to higher profits than the hold-until-expiration rule. Finally, arbitrage activity does take place, which contradicts the argument of Miller *et al.* about statistical illusion.

The rest of the chapter is organised as follows; Section two presents the methodology used, while section three presents and explains the data used. Our empirical findings about arbitrage in the stock index futures market are gathered in section four, while we complete our chapter with section five, which presents a summary and conclusions.

5.2 METHODOLOGY

The futures market and the underlying stock index market should effectively function as one market in order to have the futures serve their main role as the means of hedging stock market risk and as a vehicle for price discovery. When the balance between these markets is distorted and the two markets drift apart, then arbitrage is a primary mechanism acting to bring the markets back together under usual market conditions i.e. where arbitrage trading is not prohibited[1]. At the time when an opportunity emerges, an index arbitrageur could try to take advantage of it by buying in one market at one price and simultaneously selling in the other market at a higher price. What effectively happens is that the arbitrageur exploits the spread between prices in the spot and futures markets for stock indices. However, this price spread can only be temporary since it can easily be eliminated by the arbitrage process itself. That is done because the purchase in one market will drive prices up for that market while the sale in the other market will drive prices down. As a consequence, the arbitrage trading is the important link between the spot and futures markets.

[1]Other mechanisms may include swaps, trade-the-cheapest and treasury bill substitution.

5.2.1 Arbitrage Window - The Impact Of Transaction Costs

In reality, futures contracts almost never trade at their theoretical price given by the cost-of-carry formula (see chapter four, section 4.2.1, equation (4.3)). The reason why is because the calculation of the theoretical value does not consider the existence of transaction costs. The impact of the transaction costs is to allow the actual futures price to fluctuate within a range around the value given by the cost-of-carry expression without giving rise to profitable arbitrage. The width of the no profitable arbitrage window is defined by Yadav and Pope (1990) as follows;

$$|X_t| = (2T_S + T_D + T_F + T_F^*) \qquad (5.1)$$

where:

X_t : the percentage mispricing

T_S : the percentage one way transaction cost for equities including both commissions and any potential market impact

T_D : the value of taxes (i.e., stamp duty) payable as a percentage of asset value

T_F : the round trip percentage commissions in the futures market

T_F^* : the one way percentage market impact cost in the futures market

As Yadav and Pope (1990) state, the arbitrage window should depend on the arbitrageur with the lowest transaction costs. However, as Brennan and Schwartz (1990) and Kawaller (1987) argue, there are reasons for the no-profitable arbitrage window to be wider due to i.e. the tracking risk and the dividend uncertainty.

The tracking risk is faced when a portfolio of stocks does not exactly replicate the movements of the underlying basket of stocks therefore, portfolio and index changes are not perfectly positively correlated. According to Yadav and Pope (1990), index traders often replicate the underlying basket of stocks in an index by tracking the index with a small subset of maybe, 30 stocks. Replicating adds more costs due to the sophisticated computational techniques and more risk due to tracking error.

Since realised dividends are uncertain and the mispricing is estimated based on the expectation of the dividends, the size of the arbitrage window should be wider. However, Yadav and Pope (1990) state that in the U.K. dividends are paid semi-annually and the ex-dividend date could be predicted. They therefore, believe that there are no significant problems especially when we deal with the near contract, which is the most actively traded one. More specifically, they state that since dividends are declared several weeks before the stock goes ex dividend which makes them certain for many companies during the period of the near contract, misspecification of dividend expectation should not be significant in explaining mispricing.

On the other hand, there is a number of reasons for the arbitrage window to be narrower. For example we can refer to the option of closing out the position before expiration if the mispricing changes sign and, absolute value, exceeds the futures market impact cost that arises in an early unwinding. Therefore, as both studies by Yadav and Pope (1990) and Arditti, *et al.* (1986) state, a risky arbitrage strategy is possible even before the mispricing reaches the boundaries of the arbitrage window, in the expectation that at a time before expiration the mispricing will be reversed enough to exceed the additional market impact cost.

In a similar manner, as Yadav and Pope (1990) state, arbitrageurs have the option to roll forward their futures position in the next expiration date, if the direction of the mispricing at expiration is the same as the direction when the trade was initiated and if the mispricing at expiration exceeds $(T_F + T_F^*)$. There are no additional costs in the stock market and no additional stamp duty is due for the new arbitrage initiated at expiration. It is also possible to roll over even before expiration, if two conditions are satisfied; first, the direction of the mispricing on the day the position is rolled forward must be the same as the direction of mispricing on the day the position was initiated. Second, the difference, in absolute values, between mispricing of the near contract and mispricing of the next near contract must exceed the additional transaction costs $(T_F + 2T_F^*)$.

Our study examines both the case of holding until expiration and unwinding the position in the futures market before expiration. In addition to this, due to the fact that there are traders who face different circumstances and levels of transaction costs, our tests consider four different transaction cost bands as explained in the data description section.

5.2.2 SIMULATING ARBITRAGE STRATEGIES

In this section we try to simulate the profits that arbitrageurs would possibly exploit by assuming two trading rules. These trading rules are based on the assumption that trading in the market is continuous and it is possible to set a trade at the same price and time when it is first identified as profitable. Furthermore, borrowing and lending rates are assumed to be the same. The first trading rule assumes that the position in the futures market is held until expiration of the contract. As stated by Antoniou and Garrett (1993), if the misprice exceeds the transaction costs bounds which define the no arbitrage window then, dependent on whether the futures contract is undervalued (overvalued) due to, say, bullish[1] (bearish)[2] speculation in the stock index futures market, arbitrageurs will buy (sell) futures and sell (buy) stocks. This can be analysed in more detail; if the observed mispricing exceeds the transaction cost c%, then the trading strategy involves selling one futures contract, borrowing money and buying the equivalent underlying basket of stocks. This position (short futures, long stock) is only reversed at expiration, where the trader sells the stock bought initially and pays off the loan. On the other hand, if mispricing is less than -c%, then the strategy adopted involves buying one

[1]A bearish speculator sells securities because he/she expects a fall in prices.

[2]A bullish speculator buys securities in the belief that prices will rise and that he/she will be able to sell them again later at a profit.

futures contract, selling the underlying basket of stocks and lending the proceeds (long futures, short stock). At expiration the position is reversed by receiving the lent money and buying back the underlying basket of stocks.

The second trading rule involves unwinding the position in the futures market before the contract expires. As a result, this rule does not differ from the previous one in respect to initiating the arbitrage trade. However, unlike the first trading rule, the position in the futures market is closed out as soon as the mispricing changes sign and is at least equal to the additional transaction costs, described by Yadav and Pope as $T_F + T_F^*$ (commission and market impact cost in the futures market). Therefore, in this case the position is unwound early as soon as it is profitable to do so.

5.2.3 PATH DEPENDENCE IN MISPRICE

In the previous chapter we concluded that there is an obvious dependence of the level of the observed mispricing on the time remaining until the expiration of a futures contract. In addition to this, the high auto-correlation figures of the mispricing series suggested that mispricing tends to persist either above or below zero. After having constructed the transaction cost bounds in this chapter we continue our analysis based on the article by MacKinlay and Ramaswamy (1988), who investigate the path dependence of the mispricing.

In their study, MacKinlay and Ramaswamy state that an implication of the hypothesis that mispricing is path dependent is that, if the mispricing has crossed one of the arbitrage bounds, it is less likely to cross the opposite bound. This is claimed to be the result of the fact that arbitrageurs will close out their initial positions when mispricing is outside one bound before it reaches the other bound. We therefore, investigate this matter by examining the upper-bound and lower-bound mispricing violations and crossings for each contract of our sample period. Even the fact that a contract could have more upper-bound violations or more lower-bound violations and not both can imply that mispricing is path-dependent. The reason why is due to the fact that, if mispricing is path independent (independent of its past behaviour) then, there are equal chances of crossing either the upper or the lower bound. As a consequence, if mispricing tends to violate mostly one of the bounds it is evident that it is path dependent.

5.2.4 ARBITRAGE TRADING OR STATISTICAL ILLUSION

So far our empirical work tries to identify the existence of profitable arbitrage opportunities as a result of the observed mispricing in the futures contracts. On the other hand, arbitrage trading is assumed to be present and efficient when there is a mean reversion of the change in the mispricing (also known as mispricing returns). This is because, when the spot and the futures markets do not move closely then arbitrageurs are believed to react by trading in both markets and driving the index prices back to normal levels. The outcome of such an activity would be the decrease or even elimination of the initially observed mispricing, which would eventually result in the reversion of the mean of the change-in-the-mispricing series. Based on Yadav and Pope (1990), the mispricing returns series, $R^{X}_{t,T}$ is defined as follows;

$$R^{X}_{t,T} = \frac{X_{t,T}\, S_t - X_{t-1}\, S_{t-1}}{S_{t-1}} \qquad (5.2)$$

However, we take our research even further by investigating whether arbitrage trading does actually take place in order to exploit the observed profitable opportunities or it is merely a statistical illusion. This part of our analysis utilises the methodology adopted by Miller *et al.* (1994)[1],

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[1]The study by Miller et al. (1994) applies to intraday data. For daily data, there will be changes in the basis across days since dividend and interest entitlements change each day. These changes are known and as such, part of the change in the basis can be predicted. This point aside, the remainder of the basis

who argue that the mean reversion mentioned above, which has been documented in a number of studies[1], is not solely the result of the trading activity of stock index arbitrageurs and can be only a statistical illusion because many stocks in the index portfolio trade infrequently. They argue that even if arbitrage trading never occurred we would still observe a mean reversion in the mispricing changes because lagging stocks eventually trade and get their prices updated.

In order to discover whether the conclusions reached by Miller *et al.* for the American S&P 500 index can also apply for the FTSE 100 index in the U.K. market, we estimate the difference between the futures index price and the underlying stock index price which is referred to as the basis. Studying the basis is very important because as Harris (1989a) states:

> "...(the basis) is a measure of how well integrated the two markets are, and ... is related to tests for casualty among the prices in the two markets."
> (Harris 1989a, p 77)

The stock index basis, B_t, is the difference between the futures price, F_t, and the underlying stock index level, S_t, at time t as described in chapter three, section 3.2.3, and

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remains unpredictable.

[1]Some of them are by MacKinlay and Ramaswamy (1988), Yadav and Pope (1990).

given by equation (3.15). For convenience reasons the definition of the basis is redisplayed as follows;

$$B_t = F_t - S_t \tag{5.3}$$

The change in the index level, s_t, and the futures price, f_t, is described by the following expressions.

$$s_t = S_t - S_{t-1} \qquad f_t = F_t - F_{t-1} \tag{5.4}$$

As Miller *et al.* (1994) argue, if the markets are informationally efficient, then changes in the index level and the futures price should not be serially correlated. As a consequence, since the basis is just the difference between the futures and the spot prices then the change in the basis, b_t, should also be serially uncorrelated.

$$b_t = B_t - B_{t-1} = f_t - s_t \tag{5.5}$$

Miller *et al.* continue by saying that an observed negative first-order auto-correlation in the stock index basis changes is normally attributed to the actions of index arbitrageurs. That is because when the basis widens the arbitrageurs simultaneously sell the index futures and buy the underlying portfolio driving the difference between the futures and index prices back to the previous levels. In the case that the basis narrows then, opposite trading actions and price movements take place. However, they argue that differences in the frequency of trading of individual stocks within the index portfolio induces the mean reversion in the stock index basis changes and thus, the illusion of predictability in the basis.

In order to find whether and to what extent the observed negative auto-correlation in the basis changes can be attributed to the actions of the index arbitrageurs we examine the basis changes only for those observations that mispricing falls within the transaction cost bounds. This is because subsequent price changes are more likely to be arbitrage-induced when mispricing lies outside the transaction cost bounds and implies profits. We also apply the smallest transaction cost used in this chapter so as to make sure that any possibilities of profitable arbitrage opportunities are excluded. Since Miller *et al.* believe that the negative auto-correlation in the basis changes can be the result of the presence of non-synchronous trading, our tests take this problem into consideration. As a consequence we report results not only for the case that the reported spot index is used. On the contrary, our analysis also investigates the case where the reported index is adjusted for non-synchronicity, as well as the case where the implied index, derived from the option contracts, is utilised. If the presence of non-synchronicity is the main force of the mean reversion in the stock index basis changes, then our tests will be able to prove it.

5.3 DATA DESCRIPTION AND SOURCES

In order to examine the presence of profitable arbitrage opportunities based on the observed mispricing in the FTSE 100 futures contract, the empirical tests that follow rely on the use of the three different mispricing series that were produced in the previous chapter. For the first two cases, which involve both accounting and not accounting for non-synchronous trading in the underlying stock index, the data consists of 2,869 daily observations on 44 contracts, covering the period June 1, 1984 to May 31, 1995. The third case involves the use of the FTSE 100 option contracts in order to derive the implied spot index based on which mispricing was estimated. However, for this case, due to unavailability of data the period examined is from March 13, 1992 to May 31, 1995, 839 observations in total. Therefore, the period covers 13 contracts starting with June 92 and ending with June 95. In addition, in order to calculate the basis, we apply the three cases of spot index already mentioned and the observed futures price.

STRUCTURE OF TRANSACTION COSTS

Transaction costs can be given by the sum of commission costs in the stock and futures markets and the market impact cost of trading in the stock and in the futures market. The market impact cost is the most important component of transaction cost and is defined as the amount paid because of normal bid-ask differentials. It will apply to both markets when the spread (buy stock, sell futures) is set. To open an arbitrage position, a trader will have to pay a futures commission, a stock commission and the market impact. If the trader holds the arbitrage position until maturity then no market impact costs are incurred because the stock can be sold at the market-closing price which is the same as the final futures price. The only costs will be the commission to close out the futures position and the commission associated with the reversal of the stock position. However, if the position is closed out earlier then there will be an addition of the market impact cost on the futures position.

According to the study by MacKinlay and Ramaswamy (1988) the transaction costs in America are estimated to be approximately 0.6%. Based on the study by Yadav and Pope (1990) the transaction costs in the U.K. are generally higher and also include a stamp duty which is payable on every purchase transaction. They also say that certain groups of traders face lower transaction costs than others. As an example they refer, among others, to the market makers and brokers/dealers who can avoid the stamp duty if they buy and resell stocks within seven days and to arbitrageurs with an existing arbitrage position who can have the profitable choice of rolling forward their position into the next available maturity. As a result, they decide on the following four different transaction cost bands, 0.5%, 1.0%, 1.5% and 2.0%. In addition to this, the incremental transaction costs in the case of an early unwinding strategy is given to be 0.2%.[1] Following

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[1]For a more detailed analysis of the construction of the transaction costs for the U.K. refer to Yadav and Pope (1990), p 579.

them, our test results will be reported for the same transaction cost levels[1].

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[1]Additional transaction costs which have been identified are currency risk for index futures denominated in a foreign currency (this naturally is not an issue for this study) and execution risk, for which data is not available. Opportunity costs associated with margin deposits are normally avoided by using interest bearing assets as margin collateral.

5.4 Empirical Results

5.4.1 Frequency And Size Of Violation Of The Non-arbitrage Pricing Boundaries

We start our empirical tests by investigating the frequency of mispricing violations of the non-profitable arbitrage bounds for four different level of transaction cost bounds. The case of adjusting and not adjusting for non-synchronous trading are analysed along with the case of using the implied index from the FTSE 100 option contract. The results are shown in Tables 5.1, 5.2 and 5.3, which present the frequency of the violations of the no-profitable arbitrage conditions calculated for each contract over the sample period.

Table 5.1

Violations of no-profitable arbitrage pricing conditions for the FTSE 100 futures contract when non-synchronous trading is not considered. O: the number of overpriced (above the upper bound) observations; U:the number of underpriced (below the lower bound) observations;

CONTRACT	n	Transaction Costs (%)							
		0.5		1.0		1.5		2.0	
		O	U	O	U	O	U	O	U
OVERALL SAMPLE 01/06/84 ... 31/05/95	2869	463 (16%)	928 (32%)	107 (4%)	491 (17%)	25 (1%)	190 (7%)	4 (0.1%)	65 (2%)
SAMPLE PERIOD* 01/06/84 ... 31/05/88	1043	140 (13%)	570 (55%)	55 (5%)	335 (32%)	18 (2%)	154 (15%)	4 (0.4%)	65 (6%)
SEP 84	66	2	53	1	33	1	23	0	13
DEC 84	65	0	55	0	39	0	24	0	13
MAR 85	64	0	64	0	54	0	15	0	1
JUN 85	66	0	64	0	56	0	40	0	20
SEP 85	65	0	59	0	37	0	16	0	7
DEC 85	65	0	60	0	34	0	10	0	0
MAR 86	65	0	38	0	6	0	0	0	0
JUN 86	65	4	31	2	11	1	5	0	0
SEP 86	65	36	1	8	0	2	0	0	0
DEC 86	65	18	20	8	8	4	1	3	0
MAR 87	65	3	10	0	0	0	0	0	0
JUN 87	65	17	11	6	2	1	0	0	0
SEP 87	66	28	11	19	5	8	1	1	0
DEC 87	65	13	23	1	16	0	12	0	9
MAR 88	65	17	29	10	17	1	6	0	2
JUN 88	66	2	41	0	17	0	1	0	0
SEP 88	66	0	61	0	38	0	10	0	0

DEC 88	65	0	47	0	31	0	5	0	0
MAR 89	64	2	17	1	4	1	0	0	0
JUN 89	66	14	6	0	0	0	0	0	0
SEP 89	66	0	44	0	18	0	4	0	0
DEC 89	65	0	58	0	29	0	12	0	0
MAR 90	64	0	48	0	10	0	1	0	0
JUN 90	66	4	39	0	24	0	4	0	0
SEP 90	66	31	4	4	1	0	0	0	0
DEC 90	65	32	5	8	0	0	0	0	0
MAR 91	64	21	0	0	0	0	0	0	0
JUN 91	66	1	1	0	0	0	0	0	0
SEP 91	65	6	1	0	0	0	0	0	0
DEC 91	65	34	0	3	0	0	0	0	0
MAR 92	65	17	0	5	0	0	0	0	0
JUN 92	65	22	0	0	0	0	0	0	0
SEP 92	66	6	2	0	0	0	0	0	0
DEC 92	65	52	0	28	0	6	0	0	0
MAR 93	64	24	0	3	0	0	0	0	0
JUN 93	66	2	0	0	0	0	0	0	0
SEP 93	66	8	0	0	0	0	0	0	0
DEC 93	65	23	0	0	0	0	0	0	0
MAR 94	64	9	3	0	0	0	0	0	0
JUN 94	66	0	13	0	1	0	0	0	0
SEP 94	66	4	3	0	0	0	0	0	0
DEC 94	65	3	3	0	0	0	0	0	0
MAR 95	64	3	0	0	0	0	0	0	0
JUN 95	66	5	3	0	0	0	0	0	0

*We also refer to this smaller section of our whole sample period in order to compare its results to those by Yadav and Pope (1990).

Table 5.2

Violations of no-profitable arbitrage pricing conditions for the FTSE 100 futures contract when non-synchronous trading is considered. O: the number of overpriced (above the upper bound) observations; U:the number of underpriced (below the lower bound) observations;

CONTRACT	n	Transaction Costs (%)							
		0.5		1.0		1.5		2.0	
		O	U	O	U	O	U	O	U
OVERALL SAMPLE 01/06/84 ... 31/05/95	2869	412 (14%)	966 (34%)	91 (3%)	535 (19%)	14 (0.5%)	226 (8%)	4 (0.1%)	72 (2.5%)
SAMPLE PERIOD* 01/06/84 ... 31/05/88	1043	136 (13%)	589 (56%)	50 (5%)	368 (35%)	11 (1%)	174 (17%)	4 (0.4%)	69 (7%)
SEP 84	66	1	53	1	43	0	24	0	15
DEC 84	65	0	55	0	41	0	29	0	16
MAR 85	64	0	64	0	57	0	29	0	2
JUN 85	66	0	64	0	58	0	41	0	20
SEP 85	65	0	60	0	39	0	16	0	6
DEC 85	65	0	62	0	41	0	15	0	2
MAR 86	65	0	36	0	10	0	1	0	0
JUN 86	65	4	29	1	17	0	10	0	4
SEP 86	65	35	1	10	0	2	0	1	0
DEC 86	65	20	19	10	9	4	1	1	0
MAR 87	65	1	22	0	4	0	0	0	0
JUN 87	65	17	21	5	3	0	0	0	0
SEP 87	66	26	12	14	5	1	0	1	0
DEC 87	65	18	14	3	6	1	3	0	2
MAR 88	65	13	32	6	18	3	5	1	2
JUN 88	66	1	45	0	17	0	0	0	0
SEP 88	66	0	58	0	42	0	12	0	0
DEC 88	65	0	46	0	31	0	15	0	1
MAR 89	64	1	25	0	2	0	0	0	0

JUN 89	66	12	6	0	1	0	0	0	0
SEP 89	66	0	49	0	25	0	9	0	1
DEC 89	65	0	53	0	26	0	9	0	1
MAR 90	64	0	58	0	17	0	3	0	0
JUN 90	66	3	37	0	21	0	4	0	0
SEP 90	66	28	2	3	1	0	0	0	0
DEC 90	65	35	2	9	0	0	0	0	0
MAR 91	64	17	1	0	0	0	0	0	0
JUN 91	66	0	19	0	0	0	0	0	0
SEP 91	65	2	1	0	0	0	0	0	0
DEC 91	65	34	0	3	0	0	0	0	0
MAR 92	65	20	0	6	0	0	0	0	0
JUN 92	65	17	0	0	0	0	0	0	0
SEP 92	66	10	0	0	0	0	0	0	0
DEC 92	65	47	0	20	0	3	0	0	0
MAR 93	64	22	0	0	0	0	0	0	0
JUN 93	66	1	0	0	0	0	0	0	0
SEP 93	66	5	0	0	0	0	0	0	0
DEC 93	65	15	0	0	0	0	0	0	0
MAR 94	64	2	3	0	0	0	0	0	0
JUN 94	66	0	11	0	1	0	0	0	0
SEP 94	66	1	0	0	0	0	0	0	0
DEC 94	65	2	3	0	0	0	0	0	0
MAR 95	64	2	0	0	0	0	0	0	0
JUN 95	66	0	3	0	0	0	0	0	0

*We also refer to this smaller section of our whole sample period in order to compare its results those by Yadav and Pope (1990).

Table 5.3

Violations of no-profitable arbitrage pricing conditions for the FTSE 100 futures contract when using the implied index from options. O: the number of overpriced (above the upper bound) observations; U:the number of underpriced (below the lower bound) observations;

CONTRACT	n	Transaction Costs (%)							
		0.5		1.0		1.5		2.0	
		O	U	O	U	O	U	O	U
OVERALL SAMPLE 13/03/92 ... 31/05/95	839	253 (30%)	3 (0.3%)	89 (11%)	2 (0.2%)	17 (2%)	1 (0.1%)	1 (0.1%)	0
JUN 92	56	30	2	4	2	0	1	0	0
SEP 92	66	23	1	1	0	0	0	0	0
DEC 92	65	63	0	52	0	12	0	1	0
MAR 93	64	34	0	20	0	5	0	0	0
JUN 93	66	10	0	5	0	0	0	0	0
SEP 93	66	14	0	0	0	0	0	0	0
DEC 93	65	42	0	0	0	0	0	0	0
MAR 94	64	20	0	7	0	0	0	0	0
JUN 94	66	0	0	0	0	0	0	0	0
SEP 94	66	9	0	0	0	0	0	0	0
DEC 94	65	3	0	0	0	0	0	0	0
MAR 95	64	0	0	0	0	0	0	0	0
JUN 95	66	5	0	0	0	0	0	0	0

SAMPLE PERIOD 13/03/92 ... 31/05/95	n	Transaction Costs (%)							
		0.5		1.0		1.5		2.0	
		O	U	O	U	O	U	O	U
UNADJUSTED	839	158 (19%)	27 (3%)	31 (4%)	1 (0.1%)	6 (0.7%)	0	0	0
ADJUSTED	839	121 (14%)	20 (2%)	20 (2%)	1 (0.1%)	3 (0.3%)	0	0	0
IMPLIED INDEX	839	253 (30%)	3 (0.3%)	89 (11%)	2 (0.2%)	17 (2%)	1 (0.1%)	1 (0.1%)	0

All three Tables show that the number of violations of the non-profitable arbitrage bounds is significantly small when the level of the transactions cost involved is 1.5% and 2.0%. On the other hand, there are a relatively large number of violations of the 0.5% and 1.0% transactions cost bound. In addition to this, all three Tables show that when we examine each contract separately we find that the frequency of violations has dramatically decreased over the years.[1] For example, if we refer to the two cases that deal with non-synchronicity and cover the period June 84 to May 95 we find that, at the beginning of the sample and when the lowest transaction cost is considered, approximately 85% of the observations of a contract exceed the transaction cost bounds, while towards the end of the sample the percentage falls very much to, around 8%.

More specifically, for the cases when non-synchronicity is both considered and not considered, the results are very similar, with the frequency of underpricing exceeding the frequency of overpricing for all levels of transaction costs. However, when using the reported index and not adjusting it for non-synchronicity, the frequency of violations is, on the whole, slightly underestimated. In total, when non-synchronicity is not considered 48%, 21%, 8% and 2.1% of the 2,869 daily observations corresponding to the transaction costs being 0.5%, 1.0%, 1.5% and 2.0% respectively, suggest profitable arbitrage opportunities . On the other hand, when non-synchronicity is accounted for

[1]This is consistent with a large number of studies among which are those by Saunders and Mahajan (1988), Yadav and Pope (1990), Chung (1991).

the results are slightly higher (48%, 22%, 8.5% and 2.6% of the 2,869 observations indicate profitable arbitrage).

We can also examine the issue of profitable arbitrage opportunities for the period that Yadav and Pope (1990) investigate in order to discover how different our findings are to theirs. Their sample period covers only a small part of our sample, beginning in June 1984 and ending in May 1988. Tables 5.1 and 5.2 also present results based on this sample period. On the whole, for this test period our results are very close to those by Yadav and Pope. More specifically, when non-synchronicity is not considered 68%, 37%, 17% and 6.4% of the 1043 daily observations suggest profitable arbitrage opportunities with transaction costs being 0.5%, 1.0%, 1.5% and 2.0% respectively. Similarly, when non-synchronicity is accounted for 69%, 40%, 18% and 7.4% of the 1043 observations indicate profitable arbitrage. Yadav and Pope's findings show that the percentages of violations for the four different levels of transaction costs are 58%, 23%, 8% and 2% respectively. These results suggest that Yadav and Pope find a relatively smaller number of profitable arbitrage opportunities, though not much different.

This difference is not surprising if we recall that when constructing the data, Yadav and Pope look at the last three months of a contract including the expiration month. Unlike them, though, we exclude the expiration month and examine the three months preceding it. Therefore, we start analysing a contract a month earlier than the time Yadav and Pope do. Furthermore, we have seen that the further away we are from expiration the bigger the mispricing and thus the larger the possibility of profitable arbitrage opportunities. Therefore, by starting our sample earlier than Yadav and Pope we include a period that is expected to have a significant number of profitable arbitrage opportunities. As a result, it is not surprising that our tests suggest a slightly larger number of violations than that of Yadav and Pope. Despite that, our findings agree with theirs in respect to the significantly small number of violations for the transaction cost levels of 1.5% and 2.0% and to the relatively large number of violations for the transaction cost levels of 0.5% and 1.0%. Furthermore, Yadav and Pope also experience a dramatic decline in the profitable arbitrage opportunities over the years.

When we compare the cases of adjusting and not adjusting for non-synchronicity with the case of using the implied index, our results in Table 5.3 show the following; In all cases and for the sample period examined (839 observations) the frequency of overpricing exceeds the frequency of underpricing for all levels of transaction costs. However, when using the implied index the frequency of violations is suggested to be even higher. In total, when non-synchronicity is not considered 22%, 4.1%, 0.7% and 0.0% of the 839 daily observations suggest profitable arbitrage opportunities with transaction costs being 0.5%, 1.0%, 1.5% and 2.0% respectively. Similarly, when non-synchronicity is accounted for 16%, 2.1%, 0.3% and 0.0% of the 839 observations indicate profitable arbitrage. Finally, when the implied index is used, 30.3%, 11.2%, 2.1% and 0.1% of the observations violate the bounds of the four transaction costs respectively. As a result, for the years between 1992 and 1995, the highest number of profitable arbitrage opportunities is found to be when the implied index is applied, while the smallest number is implied when the reported index is used.

We can also see that some of the futures contracts exhibit definite mispricing patterns, which are found in all three cases of adjusting and not adjusting for non-synchronicity and using the implied index and for all levels of transaction costs. For example, Table 5.1 which deals with the case of not adjusting for non-synchronicity, shows that for the 0.5% transaction cost, the contracts expiring from September 84 to June 86, June 88 to March 89 and September 89 to June 90 are underpriced (mispricing exceeds the lower transaction cost bound), while the contracts expiring from June 87 to March 88 and September 90 to March 94 are overpriced (mispricing exceeds the upper transaction cost bound).

Finally, we analyse the non-profitable arbitrage pricing conditions in relation to the time that remains until the expiration of a futures contract. Every time a violation of the transaction cost bounds occurs, we find the corresponding number of days away from maturity for the specific futures contract. The results are presented in Tables 5.4 and 5.5. Table 5.4 refers to the entire sample period of 2,869 observations and explores both cases of adjusting and not adjusting for non-synchronicity. Table 5.5 refers only to the part of the sample that consists of 839 observations and reports the results not only for the adjusting and not adjusting for non-synchronicity case, but also for the case that the implied index was used.

Casual observations of the Tables indicate that in most cases and transaction cost levels the frequency of the violations of the transaction cost bounds tends to decrease the closer to expiration the contract is. As a consequence, the longer the time to maturity, the higher the frequency of profitable arbitrage opportunities.[1] This can be attributed to the fact that the future is difficult to predict and there is uncertainty about important factors such as dividends and the effect of interest rates to stock prices. This casual observation was tested by regressing the number of profitable mispricings against time. This analysis revealed that for the large sample size (June 1984, May 1995) in all cases there was a positive and significant relationship between the number of profitable mispricings and time i.e. the greater the time to maturity the more mispricings there are. These results are reported in Table 5.4a. However, for the smaller, most recent sample period (March 1992 to May 1995), no statistically significant relationship was found between profitable mispricing and time. These results are reported in Table 5.5a. The explanation for this is likely to be that the futures market has become more efficient. This finding also corroborates the earlier finding (chapter 4) that all mispricing, irrespective of its profitability, appears to have declined over the years.

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[1]This result is consistent with similar casual observations made by Klemkosky and Lee (1991).

Table 5.4

Violations of no-profitable arbitrage pricing conditions for the FTSE 100 futures contract when involving time-to-expiration. Both cases of adjusting and not adjusting for non-synchronicity are analysed for the period June 01, 1984 to May 31, 1995. DE: the number of days remaining until expiration; O: the number of overpriced (above the upper bound) observations; U:the number of underpriced (below the lower bound) observations;

DE	NOT ADJUSTING FOR NON-SYNCHRONICITY								ADJUSTING FOR NON-SYNCHRONICITY							
	Transaction Costs (%)								Transaction Costs (%)							
	0.5		1.0		1.5		2.0		0.5		1.0		1.5		2.0	
	O	U	O	U	O	U	O	U	O	U	O	U	O	U	O	U
10 - 20	3	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0
21 - 30	11	19	1	1	1	0	1	0	7	18	1	5	1	0	1	0
31 - 40	28	89	3	27	0	2	0	0	19	88	1	43	0	6	0	0
41 - 50	43	106	9	51	2	8	0	0	35	109	6	58	2	13	1	0
51 - 60	41	103	9	53	2	21	0	1	37	115	7	58	1	23	0	1
61 - 70	41	107	5	53	1	15	0	3	42	110	6	55	0	12	0	1
71 - 80	42	119	8	64	2	19	0	4	46	122	6	70	1	22	0	2
81 - 90	56	88	15	62	2	18	0	2	50	90	14	64	0	30	0	3
91 - 100	74	96	22	47	2	26	0	14	66	96	19	45	1	32	0	15
101 - 110	75	108	15	62	4	36	0	17	61	117	15	66	1	35	0	17
111 - 120	49	92	20	71	9	45	3	24	48	100	16	71	7	53	2	33
TOTAL	463	928	107	491	25	190	4	65	412	966	91	535	14	226	4	72

Table 5.4a

Regression of number of profitable mispricing against time for all levels of transaction costs. Both cases of adjusting and not adjusting for non-synchronicity are analysed for the period June 01, 1984 to May 31, 1995. Figures in parentheses are t-statistics: Reject Ho:coefficient of time is zero at 5% level of significance if t-value > |2.201|.

	Transaction Costs (%)			
	0.5	1.0	1.5	2.0
NOT ADJUSTING FOR NON-SYNCHRONICITY	13.300 (3.668)*	8.327 (6.433)*	4.745 (7.963)*	2.254 (4.459)*
ADJUSTING FOR NON-SYNCHRONICITY	13.773 (3.774)*	7.582 (5.143)*	5.000 (7.773)*	2.627 (3.806)*

*The coefficients are statistically significant.

Table 5.5

Violations of no-profitable arbitrage pricing conditions for the FTSE 100 futures contract when involving time-to-expiration. Both adjusting and not adjusting for non-synchronicity and the options implied index cases are analysed for the period March 13, 1992 to May 31, 1995. DE: the number of days remaining until expiration; O: the number of overpriced (above the upper bound) observations; U:the number of underpriced (below the lower bound) observations;

DE	OPTIONS IMPLIED INDEX								NOT ADJUSTING FOR NON-SYNCHRONICITY								ADJUSTING FOR NON-SYNCHRONICITY							
	Transaction Costs (%)								Transaction Costs (%)								Transaction Costs (%)							
	0.5		1.0		1.5		2.0		0.5		1.0		1.5		2.0		0.5		1.0		1.5		2.0	
	O	U	O	U	O	U	O	U	O	U	O	U	O	U	O	U	O	U	O	U	O	U	O	U
10-20	3	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0
21-30	12	0	0	0	0	0	0	0	8	6	0	0	0	0	0	0	3	6	0	0	0	0	0	0
31-40	11	0	4	0	0	0	0	0	4	1	0	0	0	0	0	0	3	0	0	0	0	0	0	0
41-50	21	0	10	0	0	0	0	0	16	1	2	0	0	0	0	0	14	0	0	0	0	0	0	0
51-60	27	1	9	0	1	0	0	0	19	0	6	0	0	0	0	0	15	0	2	0	0	0	0	0
61-70	25	0	6	0	1	0	0	0	20	1	5	0	1	0	0	0	13	0	4	0	0	0	0	0
71-80	35	1	15	1	3	1	0	0	18	4	3	1	2	0	0	0	17	4	2	1	1	0	0	0
81-90	29	1	12	1	8	0	0	0	21	1	7	0	1	0	0	0	18	0	4	0	0	0	0	0
91-100	48	0	12	0	3	0	1	0	23	6	5	0	1	0	0	0	18	5	4	0	1	0	0	0
101-110	42	0	21	0	1	0	0	0	26	6	3	0	1	0	0	0	19	4	4	0	1	0	0	0
111-120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	253	3	89	2	17	1	1	0	158	27	31	1	6	0	0	0	121	20	20	1	3	0	0	0

Table 5.5a

Regression of number of profitable mispricing against time for all levels of transaction costs. All cases of adjusting, not adjusting for non-synchronicity and using the implied index are analysed for the period March 13, 1992 to May 31, 1995. Figures in parentheses are t-statistics: Reject Ho:coefficient of time is zero at 5% level of significance if t-value > |2.201|.

	Transaction Costs (%)			
	0.5	1.0	1.5	2.0
NOT ADJUSTING FOR NON-SYNCHRONICITY	1.245 (1.322)	0.318 (1.295)	0.100 (1.652)	0.000 (0.000)
ADJUSTING FOR NON-SYNCHRONICITY	1.091 (1.439)	0.336 (2.139)	0.073 (1.809)	0.000 (0.000)
USING THE IMPLIED INDEX	2.200 (1.589)	1.100 (1.832)	0.291 (1.254)	0.027 (0.943)

5.4.2 Arbitrage Profitability

Klemkosky and Lee (1991) state that the hypothesis of an efficient market would require for the arbitrage profit of an arbitrage trading position not to be significantly different from zero. We therefore, test this hypothesis by setting a short arbitrage strategy (short futures, long stock) and a long arbitrage strategy (long futures, short stock) for every overpriced and underpriced observation respectively, and by examining the profits from both a holding-until-expiration and an early unwinding strategy. Once again, the transaction cost that is faced by an arbitrageur is of four different levels, 0.5%, 1.0%,1.5% and 2.0%.

HOLDING UNTIL EXPIRATION

The profits, in the form of pounds, earned from holding the futures position until expiration are presented in Table 5.6, for all levels of transaction costs and for all three cases of adjusting and not adjusting for non-synchronicity as well as when the implied index is utilised. Table 5.6 also reports the average profit per trade for the three sample periods examined and for all three cases of spot index used under the different transaction cost levels. The profits shown in the Table are based on the assumption of an open position of only one contract for each mispricing violation. However, since the trading volume of the futures is relatively high it would be possible to keep an open position on a larger number of contracts without affecting the market.[1]

For the two cases that involve adjusting and not adjusting for non-synchronicity, the Table shows that significant arbitrage profits (presented in £000's) could have been earned even when the transaction costs are of 1.5%[2]. When comparing our results to those by Yadav and Pope (1990) and for the sample period they examine, we find that despite the fact that they also report significant profits even for the 1.5% transaction cost level they find the profits to be lower than those of our results. However, as we explained in the previous section, due to the fact that the construction of our data series does not replicate exactly that of Yadav and Pope, our findings are perfectly justifiable.

For the smaller sample period that the Implied Index case can provide results, we find that among the three different cases of spot index used, the Implied Index method suggests the highest profits even for the 1.0% transaction cost level. This is expected, since it was found to suggest the highest number of violations of the transaction costs bounds. Finally, when examining each contract separately, we find that over the years the level of profits seems to have decreased in a great degree for all the transaction

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[1]This is consistent with Yadav and Pope (1990).

[2]The presence of trading lag can also have an impact on arbitrage profits (by reducing them), however, the effect of this is not considered here due to difficulties in obtaining estimates of trading lags.

cost levels. This could mean that futures contracts have been priced more correctly as the market has matured.[1]

[1]This is supported by a number of studies among which are those by Figlewski (1984), MacKinlay and Ramaswamy (1988), Modest and Sundaresan, Chung (1991) and Yadav and Pope (1990).

Table 5.6

Total arbitrage trading profits generated based on the holding-until-expiration trading rule. Profits are based on the assumption that for every mispricing violation there is an open position in only one contract.

CONTRACT	Total Arbitrage Profits (£'000)											
	Not Adjusting for Non-Synchronicity				Adjusting for Non-Synchronicity				Using the Implied Index			
	Transaction Costs (%)											
	0.5	1.0	1.5	2.0	0.5	1.0	1.5	2.0	0.5	1.0	1.5	2.0
SAMPLE PERIOD 01/06/84-31/05/95	325.2	114.8	36.8	13.7	328.6	117.3	38.2	14.2	-	-	-	-
SAMPLE PERIOD** 01/06/84-31/05/88	175.5	79.6	32.0	13.7	185.4	81.7	32.8	13.5	-	-	-	-
SAMPLE PERIOD*** 13/03/92-31/05/95	35.2	5.1	0.6	0	23.9	3.3	0.4	0	68.4	18.3	1.6	0.1
SEP 84	13.4	7.7	4.0	1.4	17.3	10.7	6.5	3.9	-	-	-	-
DEC 84	14.8	8.3	4.0	1.4	16.9	10.0	5.1	2.0	-	-	-	-
MAR 85	15.9	6.4	1.0	0.0002	18.4	8.9	2.1	0.04	-	-	-	-
JUN 85	26.8	16.9	8.6	4.1	28.1	18.2	9.7	4.7	-	-	-	-
SEP 85	14.1	6.1	2.2	0.4	14.1	5.8	1.9	0.4	-	-	-	-
DEC 85	12.2	4.3	0.6	*	15.0	5.8	1.2	0.1	-	-	-	-
MAR 86	3.5	0.3	*	*	5.2	1.0	0.04	*	-	-	-	-
JUN 86	7.0	2.3	0.4	*	9.4	4.6	1.8	0.2	-	-	-	-
SEP 86	5.4	1.2	0.2	*	5.3	1.1	0.2	0.03	-	-	-	-
DEC 86	8.2	2.9	1.0	0.3	8.3	2.8	0.4	0.1	-	-	-	-
MAR 87	0.8	*	*	*	3.3	0.3	*	*	-	-	-	-
JUN 87	5.2	0.8	0.05	*	5.8	0.8	*	*	-	-	-	-
SEP 87	14.3	5.8	1.4	0.5	11.0	3.1	0.8	0.5	-	-	-	-
DEC 87	17.1	10.7	7.7	5.4	6.9	3.3	2.0	1.4	-	-	-	-
MAR 88	12.6	4.5	0.9	0.2	11.9	4.2	1.1	0.2	-	-	-	-
JUN 88	8.2	1.4	0.02	*	8.5	1.1	*	*	-	-	-	-
SEP 88	18.4	6.5	0.8	*	19.1	7.2	1.1	*	-	-	-	-
DEC 88	13.4	5.0	0.2	*	14.5	5.7	0.9	0.009	-	-	-	-
MAR 89	2.7	0.5	0.003	*	2.8	0.1	*	*	-	-	-	-
JUN 89	1.5	*	*	*	1.5	0.01	*	*	-	-	-	-
SEP 89	11.4	3.2	0.5	*	16.4	5.6	0.9	0.02	-	-	-	-

DEC 89	20.7	7.9	2.2	*	17.8	6.4	1.6	0.6	-	-	-	-
MAR 90	9.6	1.5	0.05	*	13.2	2.6	0.2	*	-	-	-	-
JUN 90	13.3	4.0	0.4	*	11.7	3.1	0.3	*	-	-	-	-
SEP 90	5.6	0.4	*	*	3.9	0.1	*	*	-	-	-	-
DEC 90	6.1	0.5	*	*	6.5	0.7	*	*	-	-	-	-
MAR 91	2.0	*	*	*	1.5	*	*	*	-	-	-	-
JUN 91	0.1	*	*	*	1.3	*	*	*	-	-	-	-
SEP 91	0.4	*	*	*	0.1	*	*	*	-	-	-	-
DEC 91	5.9	0.3	*	*	5.2	0.3	*	*	-	-	-	-
MAR 92	3.4	0.3	*	*	3.8	0.5	*	*	-	-	-	-
JUN 92	3.0	*	*	*	1.5	*	*	*	6.3	0.8	0.1	*
SEP 92	0.3	*	*	*	0.6	*	*	*	1.8	0.1	*	*
DEC 92	17.9	4.8	0.6	*	14.1	3.2	0.4	*	28.4	10.5	1.3	0.1
MAR 93	5.2	0.1	*	*	3.0	*	*	*	14.4	5.2	0.2	*
JUN 93	0.2	*	*	*	0.06	*	*	*	3.1	0.4	*	*
SEP 93	0.4	*	*	*	0.3	*	*	*	1.0	*	*	*
DEC 93	2.9	*	*	*	1.5	*	*	*	5.6	*	*	*
MAR 94	1.4	*	*	*	0.7	*	*	*	6.8	1.3	*	*
JUN 94	2.9	0.2	*	*	1.7	0.1	*	*	*	*	*	*
SEP 94	0.4	*	*	*	0.01	*	*	*	0.6	*	*	*
DEC 94	0.4	*	*	*	0.3	*	*	*	0.1	*	*	*
MAR 95	0.09	*	*	*	0.07	*	*	*	*	*	*	*
JUN 95	0.2	*	*	*	0.1	*	*	*	0.3	*	*	*1.0

SAMPLE PERIOD	Average Arbitrage Profit Per Trade											
	Not Adjusting for Non-Synchronicity				Adjusting for Non-Synchronicity				Using the Implied Index			
	Transaction Costs (%)											
	0.5	1.0	1.5	2.0	0.5	1.0	1.5	2.0	0.5	1.0	1.5	2.0
01/06/84-31/05/95	234	192	171	198	238	187	159	187	-	-	-	-
1/06/84-31/05/88**	247	204	186	198	255	195	177	185	-	-	-	-
13/3/92-31/5/95***	190	159	100	0	169	157	133	0	267	201	89	100

*No violations of the transaction cost bounds occurred

**We also refer to this smaller section of our whole sample period in order to compare its results to those by Yadav and Pope (1990).

***The sample period that the Implied Index case can report results for. As mentioned before, due to unavailability of data it is smaller than the original sample period.

We also analyse the profits that could have been earned through arbitrage trading in relation to the time remaining until expiration of the futures contract. For every violation of the transaction cost bounds we find the profit that could be earned and the corresponding number of days away from maturity. Casual observation of Table 5.7 shows that for all different transaction cost levels and in all cases of adjusting and not adjusting for non-synchronicity and using the Implied Index, profits are larger the further away a futures contract is from its maturity. Once again this can be attributed to the uncertainty involved about future outcomes. This casual observation was tested by regressing the number of profitable mispricings against time. This analysis revealed that for the large sample size (June 1984, May 1995) in all cases there was a positive and significant relationship between arbitrage profits and time i.e. the greater the time to maturity the more profits there are. These results are reported in Table 5.7a. However, for the smaller, most recent sample period (March 1992 to May 1995), no statistically significant relationship was found between profits and time. These results are reported in Table 5.7b. The explanation for this is likely to be that the futures market has become more efficient.

Table 5.7

Arbitrage profits in relation to time-to-expiration for the three cases of adjusting and not adjusting for non-synchronicity and using the Implied Index. DE: the number of days remaining until expiration;

01/06/84 ... 31/05/95	Arbitrage Profits (£'000)							
	NOT ADJUSTING FOR NON-SYNCHRONICITY				ADJUSTING FOR NON-SYNCHRONICITY			
	Transaction Costs (%)							
DE	0.5	1.0	1.5	2.0	0.5	1.0	1.5	2.0
10 - 20	0.4	0	0	0	0.2	0	0	0
21 - 30	4.4	1.1	0.7	0.3	4.5	1.4	0.8	0.3
31 - 40	17.0	3.0	0.2	0	18.4	4.0	0.4	0
41 - 50	28.7	7.4	0.5	0	30.2	7.8	1.0	0.03
51 - 60	31.4	9.7	1.8	0.2	32.4	9.6	1.8	0.08
61 - 70	32.5	12.2	4.8	2.0	29.9	7.7	1.3	0.3
71 - 80	40.8	13.4	5.3	3.1	40.1	12.9	3.6	1.7
81 - 90	36.9	12.6	1.9	0.1	36.4	13.1	2.2	0.1
91 - 100	40.2	13.8	4.7	1.3	38.0	14.2	5.0	1.2
101 - 110	44.8	17.6	6.7	2.6	46.3	18.6	7.8	3.7
111 - 120	48.1	24.0	10.2	4.1	52.2	28.0	14.3	6.8
TOTAL	325.2	114.8	36.8	13.7	328.6	117.3	38.2	14.2

13/03/92 ... 31/05/95	Arbitrage Profits (£'000)											
	OPTIONS IMPLIED INDEX				NOT ADJUSTING FOR NON-SYNCHRONICITY				ADJUSTING FOR NON-SYNCHRONICITY			
	Transaction Costs (%)											
DE	0.5	1.0	1.5	2.0	0.5	1.0	1.5	2.0	0.5	1.0	1.5	2.0
10 - 20	0.2	0	0	0	0.4	0	0	0	0.2	0	0	0
21 - 30	1.1	0	0	0	1.6	0	0	0	0.9	0	0	0
31 - 40	2.1	0.2	0	0	0.5	0	0	0	0.1	0	0	0
41 - 50	5.5	0.7	0	0	2.9	0.07	0	0	1.2	0	0	0
51 - 60	6.4	1.2	0.009	0	4.6	0.7	0	0	2.8	0.2	0	0
61 - 70	5.0	1.0	0.0005	0	3.5	0.7	0.04	0	2.6	0.3	0	0
71 - 80	12.5	4.4	0.5	0	5.9	1.1	0.2	0	4.3	0.7	0.06	0
81 - 90	10.7	4.7	0.7	0	5.5	1.1	0.07	0	3.7	0.4	0	0
91 - 100	11.2	2.5	0.4	0.1	4.6	0.7	0.1	0	3.9	0.8	0.2	0
101 - 110	13.7	3.6	0.09	0	5.7	0.8	0.2	0	4.2	0.9	0.2	0
111 - 120	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	68.4	18.3	1.6	0.1	35.2	5.1	0.6	0	23.9	3.3	0.4	0

Table 5.7a

Regression of arbitrage profits against time for all levels of transaction costs. Both cases of adjusting and not adjusting for non-synchronicity are analysed for the period June 01, 1984 to May 31, 1995. Figures in parentheses are t-statistics: Reject Ho:coefficient of time is zero at 5% level of significance if t-value > |2.201|.

	Transaction Costs (%)			
	0.5	1.0	1.5	2.0
NOT ADJUSTING FOR NON-SYNCHRONICITY	4.504 (8.305)*	2.113 (11.594)*	0.862 (5.427)*	0.334 (3.370)*
ADJUSTING FOR NON-SYNCHRONICITY	4.601 (8.151)*	2.303 (8.936)*	1.068 (4.464)*	0.481 (3.337)*

*The coefficients are statistically significant.

Table 5.7b

Regression of arbitrage profits against time for all levels of transaction costs. All cases of adjusting, not adjusting for non-synchronicity and using the implied index are analysed for the period March 13, 1992 to May 31, 1995. Figures in parentheses are t-statistics: Reject Ho:coefficient of time is zero at 5% level of significance if t-value > |2.201|.

	Transaction Costs (%)			
	0.5	1.0	1.5	2.0
NOT ADJUSTING FOR NON-SYNCHRONICITY	0.302 (1.486)	0.070 (1.778)	0.013 (1.967)	0.000 (0.000)
ADJUSTING FOR NON-SYNCHRONICITY	0.274 (1.845)	0.066 (2.402)	0.013 (1.969)	0.000 (0.000)
USING THE IMPLIED INDEX	0.847 (1.979)	0.295 (1.914)	0.031 (1.347)	0.003 (0.943)

EARLY UNWINDING

In the case that the positions in both the spot and the futures markets are closed out before the expiration of the futures contract, then the additional cost is estimated by Yadav and Pope to be 0.2%. The early unwinding is assumed to take place as soon as it is profitable to do so, in other words when the mispricing changes sign and exceeds the incremental transaction cost. Table 5.8 reports the additional profits earned from the early unwinding trading rule for the four different transaction cost levels. For comparison reasons, the Table also presents the profits corresponding to the holding-until-expiration trading rule. Table 5.8 also reports the average additional profit per trade for the three sample periods examined and for all three cases of spot index used under the different transaction cost levels. Once again the profits are based on one contract only.

From the results reported in Table 5.8 we find that when following the early unwinding rule the additional profits generated are high and constitute an important part of the total arbitrage profits for all cases and transaction costs examined. In addition to this, when we examine the sample period analysed by Yadav and Pope (1990) we seem to reach the same conclusions.[1] Yadav and Pope (1990) suggest that these high additional profits imply a heavy transaction cost *discount* and should generate substantial arbitrage activity even when futures prices are within transaction

[1]Merrick (1989) also attains similar conclusions.

cost bounds. Once again the implied index case suggests the highest number of additional arbitrage profits.

These results are consistent with the results of the previous chapters suggesting that mispricing is present and by trading on it arbitrage profits could be made. However, the frequency of mispricing tends to be high, which implies lack of sufficient arbitrage activity also reported in chapter three where the supply of arbitrage was found to be inelastic. On the other hand, the value of the elasticity of the supply of arbitrage was found in chapter three to be very high, which seems to suggest that the presence of mispricing is incredibly high. However, the model applied for the derivation of the elasticity measure, δ, does not distinguish between profitable and non-profitable arbitrage opportunities. Consequently, a part of the persistence in mispricing reflected in δ, corresponds to the mispricing which falls within the transaction costs. As a matter of fact, this is confirmed in this chapter where approximately 60% of the entire sample suggests mispricing which is unprofitable to trade, thus, persists. Finally, so far, the results are unanimous about the issue of non-synchronous trading and the use of the implied index. The former does not appear to affect the results significantly, while the latter implies the largest mispricing and arbitrage profits.

Table 5.8

Arbitrage trading profits generated based on both holding-until-expiration and early unwinding trading rules. Profits (£'000), are based on the assumption that for every mispricing violation there is an open position in only one contract. V:the number of mispricing violations; AP:arbitrage profits generated from the holding-until-expiration rule; EU:the number of early unwindings; EUAP:additional arbitrage profits generated from the early unwinding rule.

	Transaction Costs (%)	SAMPLE PERIOD 01/06/84 - 31/05/95				SAMPLE PERIOD* 01/06/84 - 31/05/88				SAMPLE PERIOD** 13/03/92 - 31/05/95			
		V	AP	EU	EUAP	V	AP	EU	EUAP	V	AP	EU	EUAP
Not Adjusting for Non-synchronicity	0.5	1391	325.5	912	93.4	710	175.5	483	52.1	185	35.2	103	7.2
	1.0	598	114.8	364	36.1	390	79.6	242	24.0	32	5.1	11	1.0
	1.5	215	36.8	118	14.5	172	32.0	92	10.6	6	0.6	2	0.1
	2.0	69	13.7	28	4.1	69	13.7	28	4.1	0	0	0	0
Adjusting for Non-synchronicity	0.5	1378	328.6	945	112.1	725	185.4	501	64.5	141	23.9	81	5.3
	1.0	626	117.3	391	43.6	418	81.7	267	28.2	21	3.3	6	1.5
	1.5	240	38.2	154	12.7	185	32.8	111	9.5	3	0.4	1	0.2
	2.0	76	14.2	33	4.9	73	13.5	31	3.9	0	0	0	0
Using the Implied Index	0.5	-	-	-	-	-	-	-	-	256	68.4	172	11.2
	1.0	-	-	-	-	-	-	-	-	91	18.3	64	1.9
	1.5	-	-	-	-	-	-	-	-	18	1.6	5	0.3
	2.0	-	-	-	-	-	-	-	-	1	0.1	1	0.01

SAMPLE PERIOD	Average Additional Arbitrage Profit Per Trade											
	Not Adjusting for Non-Synchronicity				Adjusting for Non-Synchronicity				Using the Implied Index			
	Transaction Costs (%)											
	0.5	1.0	1.5	2.0	0.5	1.0	1.5	2.0	0.5	1.0	1.5	2.0
01/06/84-31/05/95	102	99	123	146	119	111	82	148	-	-	-	-
1/06/84-31/05/88**	108	99	115	146	129	106	86	126	-	-	-	-
13/3/92-31/5/95***	70	91	50	0	65	250	200	0	65	30	60	10

*We also refer to this smaller section of our whole sample period in order to compare its results to those by Yadav and Pope (1990).
**The sample period that the Implied Index case can report results for.

5.4.3 Results About Misprice And Path Dependence

We continue our research by investigating the issue of a path dependence in the observed mispricing. Even the tendency for a contract to have mainly either upper or lower transaction cost bound violations (but not both) can imply path dependence in the mispricing. Based on our results reported previously in Tables 5.1, 5.2 and 5.3 about the number of the violations of the transaction cost bounds, it is suggested that mispricing is path dependent.

As Tables 5.1, 5.2 and 5.3 show, with the exception of the December 1986 contract, each contract is found to be dominated by either upper-bound or lower-bound violations. For example, in Table 5.9, the September 1985 contract violated the -0.5% mispricing transaction cost bound 59 times and did not violate the upper bound for any of the observations. In contrast, the September 1986 contract violated the upper mispricing transaction cost bound of 0.5%, 36 times and violated the lower bound only once. On the whole, these observations suggest that mispricing is path dependent.

However, we can confirm these observations by investigating the issue of path dependence in mispricing even further. We estimate the number of bounds crossings that occurred for each contract and report our results in Table 5.9. Based on the study by MacKinlay and Ramaswamy (1988), an implication of the hypothesis that mispricing is path dependent is that, if mispricing has crossed one transaction cost bound, it is less likely to cross the opposite bound. As Table 5.9 shows the number of bounds crossings is particularly small. It should be noted that the contracts not shown in the Table as well as all the contracts of the Implied Index Options' case do not exhibit any transaction cost bounds crossings.

As a result our evidence supports the hypothesis that mispricing is path dependent, which is consistent with the fact that arbitrage traders have the option to unwind their positions before expiration. MacKinlay and Ramaswamy (1988), relate the path dependence and choice of early unwinding to the ability to predict the price movements of the expiration day. As they explain, even if during a contract's life the mispricing is substantially positive (negative) it is often the case that at some time before expiration mispricing is negative (positive). As a consequence, the arbitrage traders can often have the opportunity to profitably unwind their positions before maturity.

Table 5.9

Mispricing violations consisting of upper and lower transaction cost bound crossings. The contracts not showing as well as all the contracts of the Implied Index Options' case have zero number of transaction cost bounds crossings. UC:the number of upper bound crossings; LC:the number of lower bound crossings.

CONTRACT	n	Not Adjusting for Non-Synchronicity								Adjusting for Non-Synchronicity							
		Transaction Costs (%)															
		0.5		1.0		1.5		2.0		0.5		1.0		1.5		2.0	
		UC	LC	UC	LC	UC	LC	UC	LC	UC	LC	UC	LC	UC	LC	UC	LC
SEP 84	66	0	3	0	0	0	0	0	0	0	2	0	1	0	0	0	0
JUN 86	65	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
SEP 86	65	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MAR 87	65	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
JUN 87	65	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SEP 87	66	1	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0
DEC 87	65	0	2	0	0	0	0	0	0	4	3	1	0	0	0	0	0
MAR 89	64	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
JUN 89	66	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
MAR 91	64	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0

5.4.4 Results About Arbitrage Based On Miller *et al.* (1994)

Adopting the methodology used by Miller *et al.* (1994), who investigate the issue of whether the observed intraday mean reversion in the S&P 500 stock index basis changes is arbitrage-induced or just a statistical illusion due to the presence of non-synchronous trading, we examine the first-order auto-correlation of the basis changes using daily data. Following Miller *et al*'s methodology we exclude those observations for which mispricing falls outside the 0.5% transaction cost bounds. This is because when mispricing is profitable by exceeding the transaction costs, price changes are more likely to be driven by the actions of arbitrageurs. Our results are presented in Table 5.10.

Our immediate observation is that, due to the low transaction cost bounds imposed there is a large reduction in the number of price change observations. If we examine the first sample period analysed which consists of 2869 observations we find that the number of changes fall from 2869 to 1478 - for the unadjusted for non-synchronicity case - and to 1491 - for the adjusted for non-synchronicity case (a 48% drop in both cases). For the same sample period of 2869 observations, we find that the auto-correlation of the basis changes drops significantly. Specifically, for the unadjusted for non-synchronicity case there is a 49% drop, from -0.268 in the overall sample of 2869 observations to -0.137, after excluding all possible profitable arbitrage opportunities. Similarly, for the adjusted for non-synchronicity case there is a 65% drop, from -0.290 in the overall sample of 2869 observations to -0.099, after excluding all possible profitable arbitrage opportunities. These results imply that, in the U.K., the index arbitrage activity is responsible for the mean reversion of the observed basis changes and not the presence of non-synchronous trading. It is noted however, that not all of the reduction is explained in this way since the removal of observations (reflecting profitable mispricing) from the data set will also reduce serial correlation by virtue of the fact that observations have been removed.

Miller *et al.* find a small drop in the auto-correlation of the basis changes which suggests that in the American market the presence of non-synchronous trading and not the index arbitrage activity can be mainly responsible for the observed mean reversion in the stock index basis changes. Therefore, Miller *et al.* conclude that:

> "The mean reversion is merely a statistical artifact ... and has nothing to do with the actions of index arbitragers."
> (Miller *et al.* 1994, pp 19)

We should not be surprised about the difference in the conclusions between the study by Miller *et al.* and our research. This is because, at first, throughout this thesis empirical findings suggest that the presence of non-synchronous trading is not a severe problem in the U.K. (as opposed to America) and does not affect our results significantly. This can also be confirmed by the fact that throughout this thesis our empirical results when compared to those by Yadav and Pope (1990), who do not make any adjustments for non-synchronicity, are found to be similar. Therefore, it is not surprising to find that the presence of non-synchronous trading could not be the reason for the observed mean reversion in the stock index basis changes.

Another important reason that can explain the difference in conclusions between the Miller *et al.* study and our analysis is the fact that Miller *et al.* utilise intraday data unlike our research which concentrates on daily data. This arises because stale prices may persist within a day, as Miller *et al.* found, but are less likely to persist from one day to another, as found in our study.

Table 5.10 also reports the results for a small section of the sample period which consists of 839 observations and allow us to apply our tests in the case when the Options' Implied index is used. For this sample period the drop in the auto-correlation of the basis changes is found to be smaller than for the whole sample period of 2869 observations. All three cases of adjusting, not adjusting the spot index for non-synchronicity and using the implied index report a drop of approximately 25%. However, our conclusions about the insignificance of the role of non-synchronicity in the observed mean reversion of the index basis changes remain the same. This is because, this thesis has shown that over the years the frequency of profitable mispricing has been reduced. As a result, the possibility for profitable mispricing and thus, arbitrage activity in the last few years reflected in this sample period is very small.

This can also be seen in the number of observations which correspond to cases when mispricing falls within the transaction cost barriers. For the sample period of 839 observations only approximately 22% of them are found to reflect profitable mispricing. As opposed to this, for the sample period of 2869 observations approximately 50% of them suggest profitable mispricing. As a consequence, there is less profitable mispricing in the recent years leading to less arbitrage trading activity which is also reflected to the smaller decrease in the auto-correlation of the basis changes.

On the whole, the results reached from the tests performed about the relation between arbitrage activity, non-synchronous trading and negative auto-correlation in the stock index basis changes, suggest that the mean reversion in the basis changes is not a statistical illusion and can be sufficiently explained and attributed to the actions of index arbitrageurs.

Table 5.10

Estimated first-order auto-correlation ($\hat{\rho}_1$) of the FTSE 100 basis changes (b). Figures in parentheses are t statistics. Reject H_o: $\hat{\rho}_1=0$ at 5% level of significance if t-value > $|2.000|$. Obs: the number of observations where mispricing falls within the 0.5% transaction cost bounds.

CONTRACT	N	Not Adjusting for Non-Synchronicity			Adjusting for Non-Synchronicity			Using the Options' Implied Index		
		$\hat{\rho}_1$(b)	Obs	$\hat{\rho}_1$(b)	$\hat{\rho}_1$(b)	Obs	$\hat{\rho}_1$(b)	$\hat{\rho}_1$(b)	Obs	$\hat{\rho}_1$(b)
OVERALL SAMPLE 01/06/84 ... 31/05/95	2869	-0.268 (-8.506)*	1478	-0.137 (-4.876)*	-0.290 (-8.683)*	1491	-0.099 (-3.137)*	-	-	-
SAMPLE PERIOD 13/03/92 ... 31/05/95	839	-0.288 (-7.388)*	654	-0.216 (-5.221)*	-0.296 (-7.440)*	698	-0.222 (-5.246)*	-0.301 (-5.836)*	612	-0.219 (-3.040)*

* The auto-correlation coefficient is statistically significant.

5.5 Summary And Conclusions

This chapter concludes the empirical investigation about the price behaviour of the U.K. FTSE 100 stock index futures contract. In a simple perfect market environment the discounted futures price must equal the current spot price adjusted for dividends in order to prevent arbitrage. However, when transaction costs are recognised, the discounted futures prices are found to fluctuate within a window without inducing profitable arbitrage opportunities. The purpose of this chapter is to analyse and present the results about the presence, frequency and size of profitable arbitrage opportunities on the U.K. FTSE 100 contract traded in LIFFE. In order to do so we apply simple trading simulations of both holding the futures position until expiration and unwinding the futures position before maturity. Our results are based on the incorporation of different transaction costs for different classes of traders and the use of the three mispricing series derived in the previous chapter, which respectively do not adjust for non-synchronous trading, make adjustments for non-synchronous trading and use the Implied Index from Options.

Overall, the findings of this chapter are as follows; At first, we find frequent violations of the non-arbitrage pricing conditions for all transaction cost levels but the frequency becomes significantly smaller for the two higher transaction cost levels. We also found that as the futures market has matured with time, the level of mispricing and profitable arbitrage opportunities have declined, which can be attributed to the fact that the market participants are more aware of the workings of the futures market.

Moreover, for all the transaction cost levels the frequency and the size of profitable arbitrage opportunities is found to decrease the closer to expiration a futures contract is. This can be attributed to the fact that the future is difficult to predict and there is uncertainty about important factors such as dividends and the effect of interest rates to stock prices. In addition, the simple hold to expiration trading rule seems to generate only limited opportunities for arbitrage profits. The option of early unwinding of the arbitrage position can however, provide additional (although smaller) arbitrage profits and is therefore, also valuable.

We also provide extended evidence which supports that mispricing is path dependent, which is consistent with the fact that arbitrage traders have the option to unwind their positions early. Based on similar findings MacKinlay and Ramaswamy (1988) conclude that predictions about expiration day based on the identification of mispricing outside the arbitrage bounds is difficult.

In addition, we prove that the observed mean reversion in the stock index basis changes is not a statistical illusion as claimed by Miller *et al.* (1994) but can be sufficiently explained and attributed to the presence of the actions of index arbitrageurs. The difference between our conclusions and those by Miller *et al.* is due to the fact that in the U.S. non-synchronicity, which Miller *et al.* blame for the mean reversion in the basis changes, is found to be a serious problem while for the U.K. market it does not seem to be as severe. Moreover, non-synchronous trading is not found to be a severe problem and cannot explain the results. Finally, the use of the implied index generates results that suggest larger number of arbitrage profits and opportunities.

The empirical investigation of this thesis about the FTSE 100 futures contract concludes with the next chapter, which extends the issue of arbitrage in the futures market with the analysis of its association to volatile market prices.

CHAPTER 6

INDEX FUTURES ARBITRAGE AND MARKET VOLATILITY

6.1 INTRODUCTION

The thesis so far has investigated two major aspects of the index futures market. The first involves the correct pricing of the index futures contracts in relation to arbitrage opportunities. We documented that futures prices can deviate from their theoretical values defined by the cost-of-carry formula giving rise to potential arbitrage trading. The second aspect corresponds to the lead/lag relationship between the futures market and its underlying spot market. We found that new information does not appear to be transmitted simultaneously in the two markets in question. The thorough investigation of the index futures trading comes to an end with this final empirical chapter, which concentrates on the issue of market volatility.

The analysis presented tries to identify at first whether increased mispricing and thus arbitrage activity can generate increased volatility in both spot and futures markets. The second aspect of this investigation conversely investigates whether the occurrence of higher market volatility can increase mispricing.

Although the arbitrage trading provides the valuable link between the spot and the futures markets whenever they drift apart, a lot of criticism has been expressed about the association between arbitrage and increased volatility in both markets. Market agents who wish to reduce or even eliminate risk are likely to form portfolios to remove positions from those markets that are highly volatile. However, if the futures market through arbitrage trading leads to increased volatility and higher risk, then its value, purpose and existence need to be reconsidered.

The majority of previous studies tend to analyse only prices in order to identify a relation between market volatility and arbitrage and ignore the element of trading volume. Such studies are those by Edwards (1988a, 1988b), Becketti and Roberts (1990), Maberly et al (1989), Chan et al (1991), MacKinlay and Ramaswamy (1988), Yadav and Pope (1990), Antoniou and Holmes (1995b) and Board and Sutcliffe (1995). On the other hand, studies such as Bessembinder and Seguin (1992), Choi and Subrahmanyam (1994) and Chan and Chung (1993) incorporated the element of trading volume in their analysis of price volatility. Chan and Chung (1993) extend the investigation of volatility by applying a model which incorporates past levels of volatility (spot/futures markets), volatility transmitted from the other market (spot/futures) as well as trading volume of the spot market. Their study analyses the MMI and its futures contracts on an intraday basis for the period August 1, 1984 to June 28, 1985. Their results showed that mispricing has an effect on market volatility and spot trading volume. They also showed that a volatile market causes a decrease in the mispricing, which they attribute to an increase in the supply of arbitrage services or faster price adjustments. Following Chan and Chung, we investigate the issue of market volatility and index arbitrage including trading volume for the U.K. FTSE 100 index market. The analysis of Chan and Chung is extended in this chapter with the use of the superior GARCH technique to calculate price volatility instead of more traditional constructed volatility measures. Similar work has not taken place before.

Briefly, the main results of our research are as follows; A more volatile market reduces the arbitrage spread and thus does not cause the prices of the spot and the futures markets to diverge any further. In addition, arbitrage is followed by increased volatility of the prices in both the spot market and the futures market. However, this finding could also reflect the faster adjustment of the market to new information.

The rest of the chapter is organised as follows; Section two presents the methodology applied. Section three describes the data used. Section four presents and explains the empirical results. The chapter concludes with section five which provides and summary and conclusions.

6.2 METHODOLOGY

6.2.1 CHAN AND CHUNG (1993)

New information is transmitted first either in the spot or in the futures market. Given the findings of chapter three, information is mainly transmitted first in the futures market, due largely to lower transactions costs. However, results also showed that this relation does not remain stable over time and can be reversed with the spot market incorporating new information first. Different speed in the transmission of new information can generate mispricing and thus arbitrage opportunities. Additional delays can lead to an increase in the mispricing and initiate arbitrage trading, which will eventually bring both the spot and the futures prices back to line. The question which arises and forms the first hypothesis investigated in this chapter is whether increased mispricing and thus arbitrage activity can generate increased volatility in both the spot and the futures markets.

On the other hand, a volatile market shows that more information is being received and absorbed. Lack of fast and simultaneous incorporation of new information in both the spot and the futures markets can result in an increase in the mispricing and thus arbitrage opportunities. As a consequence, the second hypothesis tested is whether higher market volatility can increase mispricing.

Apart from the mispricing, the volatility of a market (either spot or futures), can also be related to past levels of volatility, volatility transmitted from the other market (spot or futures) and the volume of trading. Consequently, the investigation of volatility should consider all these different elements.

ARBITRAGE SPREAD

The model applied by Chan and Chung uses a number of variables starting with the absolute value of the difference between the actual futures price and its theoretical one given by the cost-of-carry formula, standardised by the spot series. This measure is referred to as the arbitrage spread and is the absolute value of the same measure as the mispricing produced in chapter four, equation (4.4). The arbitrage spread reflects the deviation of the futures price from its theoretical one and if it is large it could lead to index arbitrage opportunities. Although this measure does not consider the presence of transactions costs and thus does not distinguish between profitable and non-profitable arbitrage opportunities, this is not important for the investigation. This is due to a number of reasons. As Chan and Chung explain we expect higher mispricings to increase the possibilities of arbitrage trading. In that way we do not claim that the presence of mispricing itself guarantees arbitrage trading. Furthermore, Sofianos (1993) shows that the number of profitable arbitrage opportunities after accounting for costs is far less than the actual number of arbitrage trades and thus is not a better measure. As an example he refers to the first six months of 1990 where only 33 arbitrage opportunities were profitable but 3,000 arbitrage trades took place.

Chan and Chung (1993) express the change in the arbitrage spread ΔSPREAD, as follows, where F, F' and S have already been described as the actual futures price, the theoretical futures price and the spot price respectively.

$$\Delta SPREAD_t = \frac{|F - F'|_t - |F - F'|_{t-1}}{S_t} \qquad (6.1)$$

SPOT VOLATILITY - FUTURES VOLATILITY - TRADING VOLUME

The final variables required for the model involve the spot and futures price volatility and the trading volume of the spot index. The trading volume of the spot index (STRV) is used in the form of logs and standardised by the spot index.

When it comes to the spot price volatility (SVOL) and the futures price volatility (FVOL), Chan and Chung calculate them based on the following formulae, where S_t and F_t have already been described as the spot and the actual futures price series respectively.

$$SVOL_t = \left|\frac{S_t - S_{t-1}}{S_{t-1}}\right| \qquad (6.2)$$

$$FVOL_t = \left| \frac{F_t - F_{t-1}}{F_{t-1}} \right| \qquad (6.3)$$

However, section 6..2.2 explains why these measures of volatility are not the most appropriate and why the use of GARCH technique is superior to these traditionally constructed measures.

THE MODEL

The daily relationship between the actual futures price volatility (FVOL), the spot price volatility(SVOL), the change in the arbitrage spread (ΔSPREAD) and the spot trading volume (STRV), is examined using the following system of equations, where the number of lags are determined using serial correlation tests (see section 6.4.2);

$$FVOL_t = a_1 + \sum_{k=1}^{5} b_{1,t-k} FVOL_{t-k} + \sum_{k=1}^{4} c_{1,t-k} SVOL_{t-k} + \sum_{k=1}^{4} d_{1,t-k} STRV_{t-k} +$$

$$+ \sum_{k=1}^{4} e_{1,t-k} \Delta SPREAD_{t-k} + u_{1t} \qquad (6.4)$$

$$SVOL_t = a_2 + \sum_{k=1}^{5} b_{2,t-k} SVOL_{t-k} + \sum_{k=1}^{4} c_{2,t-k} FVOL_{t-k} + \sum_{k=1}^{4} d_{2,t-k} STRV_{t-k} +$$

$$+ \sum_{k=1}^{4} e_{2,t-k} \Delta SPREAD_{t-k} + u_{2t} \qquad (6.5)$$

$$STRV_t = a_3 + \sum_{k=1}^{5} b_{3,t-k} STRV_{t-k} + \sum_{k=1}^{4} c_{3,t-k} FVOL_{t-k} + \sum_{k=1}^{4} d_{3,t-k} SVOL_{t-k} +$$

$$+ \sum_{k=1}^{4} e_{3,t-k} \Delta SPREAD_{t-k} + u_{3t} \qquad (6.6)$$

$$\Delta SPREAD_t = a_4 + \sum_{k=1}^{4} b_{4,t-k}\Delta SPREAD_{t-k} + \sum_{k=1}^{4} c_{4,t-k} FVOL_{t-k} + \sum_{k=1}^{4} d_{4,t-k} SVOL_{t-k} +$$

$$+ \sum_{k=1}^{4} e_{4,t-k} STRV_{t-k} + u_{4t} \qquad (6.7)$$

The hypothesis tested are two; First, does increased arbitrage spread generate increased volatility in either the spot or the futures markets, and second, would higher market volatility cause increased arbitrage spread. Estimating the system of equations described above using OLS regression is a possible approach for the empirical investigation. However, as Chan and Chung state, if the error terms, u_1 to u_4, reflect information which is important and affects the dependent variables then there is contemporaneous correlation among the error terms. Under such circumstances, the regression of each equation separately through OLS is not appropriate and can produce misleading results. We therefore employ the Seemingly Unrelated Regression (SUR) technique, which uses the estimates of the covariance of the residuals across equations to produce better estimations about the parameters.

6.2.2 GARCH ANALYSIS

Previous research has used constructed measures of volatility, for example Chan and Chung (1993) use the equations shown in (6.2) and (6.3) to compute a volatility series for spot and futures prices. It has been suggested, however, that studies on volatility are sensitive to the measure of volatility which is used and research based on constructed volatility measures could generate results that are dependent on the specific measure used (see in particular Board and Sutcliffe (1990)).Such constructed volatility series assume that the distribution of the price series is homoskedastic. This can be misleading since there is significant empirical evidence that price series for speculative assets tend to be heteroskedastic, due largely to the reliance of such prices on information, and the non-constant arrival of information on the markets (Bollerslev, Chou and Kroner (1992), Ross (1989)).

As a result of the above considerations this analysis presents a methodological improvement by using GARCH techniques to derive the volatility series required for the model described in equations (6.4...6.7).

Introduced by Engle (1982), the Autoregressive Conditional Heteroscedastic model (ARCH) allows the variance of a price series to be modelled as it varies over time.

Empirically, the ARCH model gives an expression for the conditional variance of a series (such as the price series Z_t in equation 6.8) made up of the past error terms. The conditional variance (h_t) changes over time and is at the heart of the ARCH model. A univariate model with serially uncorrelated errors that follow an ARCH(q) process is given as follows where q represents the number of previous errors which are significant in explaining the conditional variance;

$$Z_t = a + bZ_{t-1} + w_t \qquad w_t \sim N(0,h_t) \tag{6.8}$$

$$h_t = k_0 + \sum_{i=1}^{q} k_i w_{t-i}^2 \tag{6.9}$$

As the description shows, the variance of a process will change according to the previous errors. Since these errors reflect adjustments in the price series (Z_t) due to the arrival of new information, the fundamental link between information flow and price change is measured by the ARCH process. This also illustrates how price variability can change over time since the size of the variance will depend upon the quantity and significance of information coming to the market.

Following Engle (1982), Bollerslev (1986) developed a Generalised Autoregressive Conditional Heteroscedasticity (GARCH) technique where the conditional variance is a function of past error variances plus lags of the conditional variance. A simple GARCH(p,q) process is given as follows where q describes the effect of past errors on volatility, while p measures the influence of previous volatility levels;

$$h_t = k_0 + \sum_{i=1}^{q} k_i w_{t-1}^2 + \sum_{j=1}^{p} l_j h_{t-j} \qquad (6.10)$$

The GARCH model describes the time-varying nature of the volatility not just from past errors (which may be considered to reflect information flows), but also with lags of the conditional variance, (see h_t in equation 6.10). Such lags may be viewed as summarising the extent to which the level of volatility 'persists' from one period to the other. Indeed, it is this factor which allows the GARCH model to explain the existence of volatility clustering in price series, where large price changes are followed by large changes and small price changes are followed by small changes. The volatility clustering of price series has been documented by Fama (1965). The empirical investigation of this chapter produces the price volatilities required for the Chan and Chung (1993) model described in equations (6.4...6.7) by applying GARCH instead of ARCH modelling in order to capture observed volatility clustering. Where ARCH models volatility as the product of previous shocks or news events (w_t in equation (6.9), GARCH also includes the impact of previous volatility, by including lags of the ARCH (h_t) coefficient, see equation (6.10). Thus if yesterday's volatility was high, then a GARCH effect would be detected if today's volatility was also high since h_{t-1} describes h_t. As such, where the ARCH component measures the volatility from news the GARCH also measures the volatility clustering.

6.3 Data Description And Sources

The empirical tests that follow rely on the use of the observed spot series for the FTSE 100 index, the adjusted for non-synchronicity spot series and the implied index series. The tests also require the use of the observed price series of the FTSE 100 futures contract and the theoretical futures price series calculated using the cost-of-carry model. All these data series have already been described and used in previous chapters. In addition, we acquired data related to the trading volume of the spot FTSE 100 index from Datastream. However, due to unavailability of data for the trading volume, the sample period is restricted to 2,243 observations and covers the period between October 27, 1986 and May 31, 1995. On the other hand, when using the implied index series the period examined is March 13, 1992 to May 31, 1995.

6.4 Empirical Results

6.4.1 GARCH Results

The returns series for both the spot and the futures are calculated as the first difference of their log prices and were initially tested for the presence of ARCH effects. In all cases the ARCH effects were present as shown in the following table where the null hypothesis states that heteroscedasticity is not present. At 5.% level of significance the $\chi^2(1)$ critical value is 3.841.

Tests of Heteroscedasticity		
Series	Sample period 27/10/86-31/05/95	Sample period 13/03/92-31/05/95
Futures price Volatility	243.608*	16.326*
Unadjusted Spot Volatility	917.683*	15.320*
Adjusted Spot Volatility	968.291*	15.460*
Implied Index volatility	-	16.981*

*Ho is rejected

The returns series for both the spot and the futures are tested for the presence of GARCH in an equation which regressed the series on a constant and an AR(1) component, see equation (6.8), where Z represents the spot series and futures series in each case. A number of GARCH specifications were tested including a GARCH(0,1) i.e. ARCH, such as that illustrated in equation (6.9). The results are shown in Tables 6.1ai to 6.1eii. For all three cases of unadjusted/adjusted for non-synchronicity and implied index, the series were found to be most adequately described by a GARCH(1,1) process as shown in equation (6.10), where p equals one and q equals one. Figures 6.1a and 6.1b give a graphical presentation of the unadjusted spot volatility series and the futures volatility series and clearly demonstrate the changing nature and clustering of the volatility series. This justifies the use of the GARCH technique to model.

The estimated coefficients reported in Tables 6.1ai to 6.1eii show that the correct specification is for a GARCH(1,1) model. The GARCH-estimated measures of spot and futures volatility are more appropriate than the constructed measures of volatility for the spot and futures markets given in equations (6.2) and (6.3) respectively. Therefore, the GARCH-measures of volatility are applied on the Chan and Chung model described in equations (6.4...6.7).

Table 6.1ai

GARCH (0,1) for spot (both unadjusted and adjusted case) and futures volatility (27/10/86-31/05/95). H_0:coefficient=0 at 5% level of significance if t-value > |1.960|.

GARCH	Unadjusted Spot		Adjusted Spot		Futures	
Coefficients	parameter	t-stat	parameter	t-stat	parameter	t-stat
k_0	0.00008	103.541*	0.00008	99.983*	0.0001	52.244*
k_1	0.119	9.247*	0.144	10.772*	0.176	7.195*

Table 6.1aii

GARCH (0,1) for spot (unadjusted,adjusted and implied index case) and futures volatility (13/03/92-31/05/95). H_0:coefficient=0 at 5% significance level if t-value > |1.960|.

GARCH	Unadjusted Spot		Adjusted Spot		Implied Index		Futures	
Coefficients	parameter	t-stat	parameter	t-stat	parameter	t-stat	parameter	t-stat
k_0	0.00006	23.231*	0.00006	23.185*	0.00007	18.375*	0.00007	16.020*
k_1	0.125	5.802*	0.126	5.866*	0.185	5.757*	0.165	5.029*

*The coefficients are statistically significant

Table 6.1bi

GARCH(1,1) for spot (both unadjusted and adjusted case) and futures volatility (27/10/86-31/05/95). H_o:coefficient=0 at 5% level of significance if t-value > $|1.960|$.

GARCH Coefficients	Unadjusted Spot		Adjusted Spot		Futures	
	parameter	t-stat	parameter	t-stat	parameter	t-stat
k_0	0.000006	8.338*	0.000006	7.469*	0.000003	6.027*
k_1	0.099	8.985*	0.107	9.421*	0.081	10.240*
l_1	0.830	55.607*	0.832	57.547*	0.896	84.779*

Table 6.1bii

GARCH(1,1) for spot (unadjusted,adjusted and implied index case) and futures volatility (13/03/92-31/05/95). H_o:coefficient=0 at 5% significance level if t-value > $|1.960|$.

GARCH Coefficients	Unadjusted Spot		Adjusted Spot		Implied Index		Futures	
	parameter	t-stat	parameter	t-stat	parameter	t-stat	parameter	t-stat
k_0	0.000001	2.081*	0.000001	2.127*	0.000001	2.096*	0.0000009	1.970*
k_1	0.051	3.876*	0.052	3.830*	0.061	3.357*	0.038	3.214*
l_1	0.925	44.423*	0.922	41.969*	0.918	37.937*	0.951	61.529*

*The coefficients are statistically significant

Table 6.1ci

GARCH(2,1) for spot (both unadjusted and adjusted case) and futures volatility (27/10/86-31/05/95). H_0:coefficient=0 at 5% level of significance if t-value > $|1.960|$.

GARCH Coefficients	Unadjusted Spot		Adjusted Spot		Futures	
	parameter	t-stat	parameter	t-stat	parameter	t-stat
k_0	0.000002	3.012*	0.000002	2.770*	0.000003	3.673*
k_1	0.0005	9.458*	0.0008	10.023*	0.079	4.265*
l_1	0.971	5.642*	0.975	6.003*	0.901	3.969*
l_2	0.0004	0.002	0.0005	0.003	0.000	0.000

Table 6.1cii

GARCH(2,1) for spot (unadjusted,adjusted and implied index case) and futures volatility. Sample period 13/03/92-31/05/95.H_0:coefficient=0 at 5% significance level if t-value > $|1.960|$.

GARCH Coefficients	Unadjusted Spot		Adjusted Spot		Implied Index		Futures	
	parameter	t-stat	parameter	t-stat	parameter	t-stat	parameter	t-stat
k_0	0.000001	1.206	0.000001	1.261	0.000001	1.050	0.000001	1.465
k_1	0.047	1.270	0.049	1.312	0.060	1.321	0.055	1.231
l_1	0.934	1.192	0.925	1.226	0.920	1.104	0.407	0.837
l_2	0.0001	0.0002	0.0001	0.0002	0.000	0.000	0.521	1.122

*The coefficients are statistically significant

Table 6.1di

GARCH(1,2) for spot (both unadjusted and adjusted case) and futures volatility (27/10/86-31/05/95). H_o:coefficient=0 at 5% level of significance if t-value > $|1.960|$.

GARCH	Unadjusted Spot		Adjusted Spot		Futures	
Coefficients	parameter	t-stat	parameter	t-stat	parameter	t-stat
k_0	0.000007	7.015*	0.000007	6.942*	0.000005	6.122*
k_1	0.067	7.227*	0.071	8.514*	0.050	3.953*
k_2	0.081	1.845	0.090	1.904	0.064	1.900
l_1	0.751	41.678*	0.777	44.956*	0.858	72.989*

Table 6.1dii

GARCH(1,2) for spot (unadjusted,adjusted and implied index case) and futures volatility (13/03/92-31/05/95). H_o:coefficient=0 at 5% significance level if t-value > $|1.960|$.

GARCH	Unadjusted Spot		Adjusted Spot		Implied Index		Futures	
Coefficients	parameter	t-stat	parameter	t-stat	parameter	t-stat	parameter	t-stat
k_0	0.000001	2.079*	0.000002	2.126*	0.000001	2.106*	0.0000009	1.677
k_1	0.024	0.844	0.026	0.880	0.029	0.692	0.037	1.185
k_2	0.030	0.973	0.030	0.933	0.034	0.777	0.000	0.000
l_1	0.921	42.682*	0.918	40.382*	0.915	36.242*	0.952	61.274*

*The coefficients are statistically significant

Table 6.1ei

GARCH(2,2) for spot (both unadjusted and adjusted case) and futures volatility (27/10/86-31/05/95). H_0:coefficient=0 at 5% level of significance if t-value > $|1.960|$.

GARCH Coefficients	Unadjusted Spot		Adjusted Spot		Futures	
	parameter	t-stat	parameter	t-stat	parameter	t-stat
k_0	0.000003	0.224	0.000003	0.125	0.000006	3.096*
k_1	0.0004	4.357*	0.0005	5.272*	0.047	3.942*
k_2	0.354	0.007	0.419	0.009	0.104	1.752
l_1	0.841	0.091	0.951	0.114	0.536	1.432
l_2	0.018	0.001	0.021	0.002	0.277	0.850

Table 6.1eii

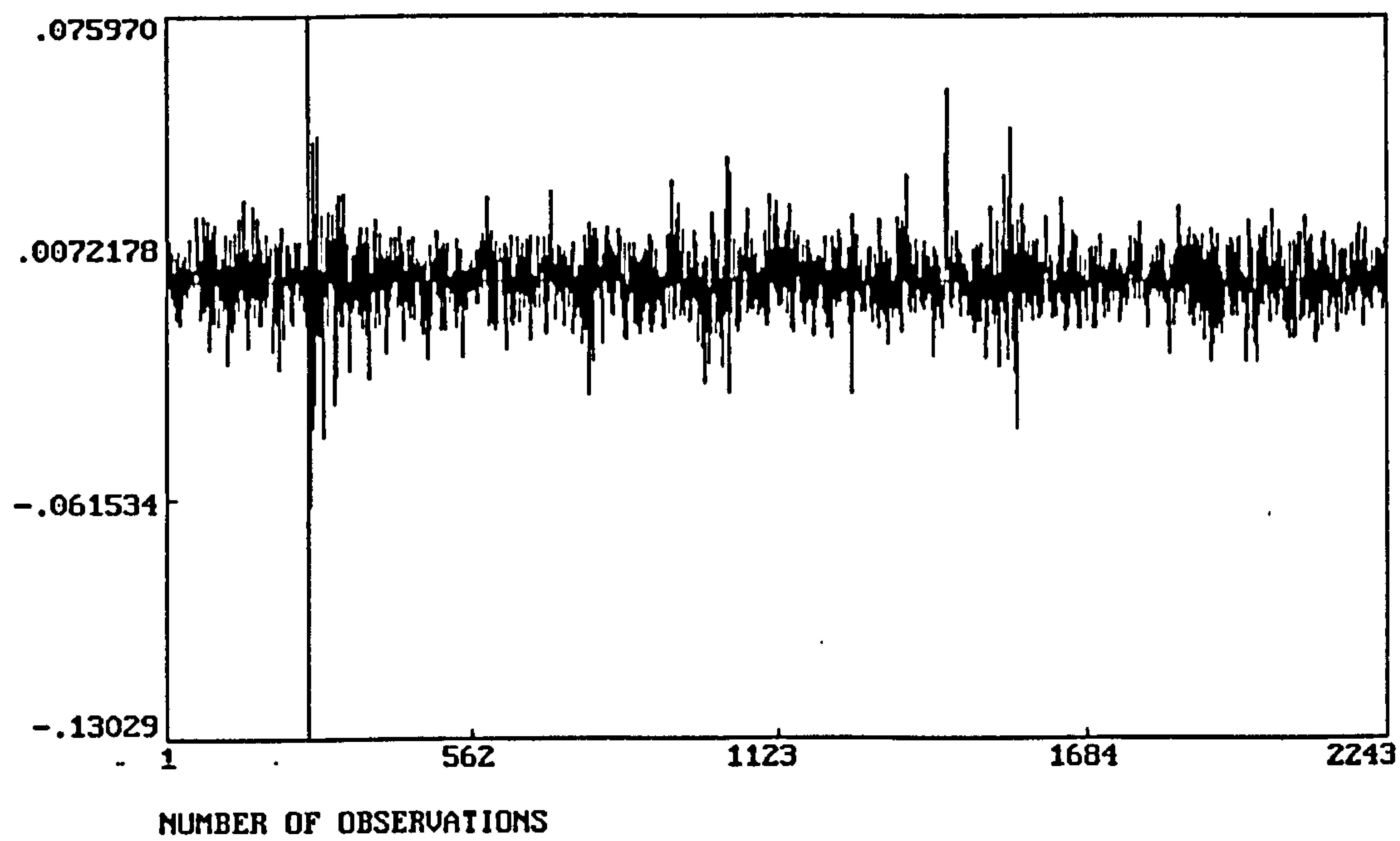
GARCH(2,2) for spot (unadjusted,adjusted and implied index case) and futures volatility (13/03/92-31/05/95). H_0:coefficient=0 at 5% significance level if t-value > $|1.960|$.

GARCH Coefficients	Unadjusted Spot		Adjusted Spot		Implied Index		Futures	
	parameter	t-stat	parameter	t-stat	parameter	t-stat	parameter	t-stat
k_0	0.000003	0.237	0.000001	1.053	0.000003	1.172	0.000001	1.299
k_1	0.072	0.957	0.0167	0.622	0.041	1.190	0.044	1.310
k_2	0.107	0.031	0.040	0.769	0.067	1.852	0.018	0.385
l_1	0.868	0.198	0.923	0.999	0.850	0.829	0.264	0.350
l_2	0.000	0.000	0.000	0.000	0.000	0.000	0.655	0.918

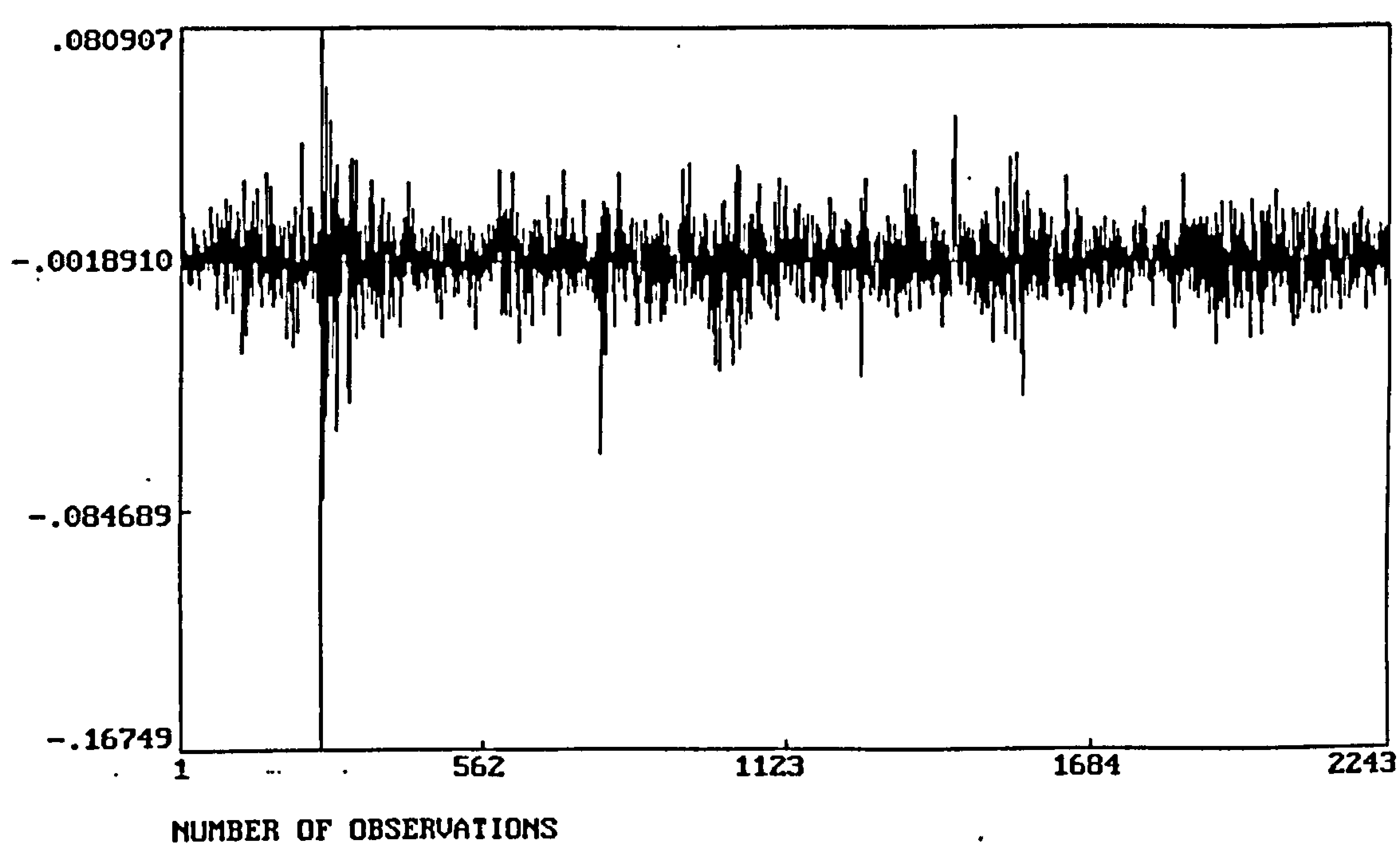
*The coefficients are statistically significant

Figure 6.1

A) Daily FTSE 100 Spot Volatility (unadjusted case) for the period October 27, 1986 to May 31, 1995.



B) Daily FTSE 100 Futures Volatility for the period October 27, 1986 to May 31, 1995.



6.4.2 The Auto-Correlation Of The Variables

After applying GARCH method for estimating measures of both the spot and futures volatility, the auto-correlation coefficients of each time series under question are reported in Table 6.2. The Table considers the entire sample period of 2,243 observations and the smaller period of 839 observations so as to account for all three cases of spot series. We can see that all series exhibit auto-correlation. The existence of positive auto-correlation in the arbitrage spread suggests that mispricings tend to persist, which is consistent with the findings of previous chapters.

As a result of the presence of auto-correlation in the arbitrage spread, the model described in equations (6.4...6.7) uses the first difference of arbitrage spread, given in equation (6.1), instead of the arbitrage spread itself. This is also explained by Chan and Chung (1993) as a better approach since the current spread already incorporates previous fluctuations of it. When we apply lags of arbitrage spread levels to the model it is possible that problems of multicollinearity may arise, thus making interpretation of the models difficult. This occurs because the model already has present within it current and lagged values for the spot market (S_t-S_{t-1}) and current and lagged values for the futures market (F_t-F_{t-1}). Thus, when a variable for the spread is introduced it is already being largely described by the model. This problem is overcome with the use of the change in the arbitrage spread in place of the arbitrage spread as recommended by Chan and Chung (1993).

Due to auto-correlation being exhibited by all the variables, the number of lags chosen for the right-hand side lagged dependent variables of the model described in equations (6.4...6.7) was tested by specifying a model with twelve lags and analysing the statistical significance of the lags. That way, we avoid having the residuals being auto-correlated. As illustrated in Table (6.2a) for the larger sample, a model with five lags on the dependent variable was found to be appropriate. An exception is made for the arbitrage spread, which is less auto-correlated than the other variables and thus we chose the lag order to be four. For the remaining regressors (i.e. variables other than the lagged dependent variable) the number of lags decided is four because attempts to use higher orders showed that the additional lagged variables do not exhibit statistical significance in the model. As illustrated in Table (6.2b) for the smaller sample period, a model with one lag on the dependent variable was found to be appropriate with the exception of the arbitrage series and the spot trading volume series which require the lag order to be two. Finally, for the remaining regressors (i.e. variables other than the lagged dependent variable) for this smaller sample period, the number of lags decided is one because attempts to use higher orders showed that the additional lagged variables do not exhibit statistical significance in the model.

Table 6.2a

Auto-correlation coefficients (ρ) of the FTSE 100 futures price volatility, spot price volatility (both unadjusted and adjusted for non-synchronicity), arbitrage spread (both unadjusted and adjusted for non-synchronicity) and spot trading volume covering the period October 27, 1986 to May 31, 1995. Figures in parentheses are t statistics. $H_o: \rho = 0$ at 5% level of significance if t-value > |1.960|.

	Auto-correlation coefficients (ρ)					
Lag	Futures price volatility	Unadjusted Spot price volatility	Adjusted Spot price volatility	Unadjusted Arbitrage spread	Adjusted Arbitrage spread	Spot Trading volume
1	0.184 (12.785*)	1.523 (10.114*)	1.583 (15.558*)	0.434 (12.391*)	0.407 (19.191*)	0.447 (5.615*)
2	-0.124 (-7.361*)	-0.734 (-6.152*)	-0.830 (-9.898*)	0.117 (3.773*)	0.130 (5.691*)	0.145 (6.237*)
3	-0.023 (-3.789*)	0.099 (2.384*)	0.144 (3.318*)	0.133 (3.104*)	0.107 (4.625*)	0.110 (4.715*)
4	-0.171 (-5.257*)	0.173 (4.149*)	0.166 (3.811*)	0.085 (1.987*)	0.081 (3.524*)	0.065 (2.769*)
5	0.113 (3.459*)	-0.166 (-3.962*)	-0.160 (-3.675*)	-0.014 (-0.498)	-0.002 (-0.105)	0.182 (7.733*)
6	-0.046 (-1.402)	0.003 (0.073)	-0.006 (-0.145)	-0.039 (-1.395)	-0.013 (-0.578)	-0.015 (-0.635)
7	0.040 (1.233)	0.053 (1.271)	0.062 (1.418)	0.037 (1.450)	0.027 (1.188)	0.012 (0.502)
8	-0.039 (-1.197)	0.011 (0.275)	0.022 (0.523)	0.021 (0.850)	0.006 (0.282)	0.005 (0.225)
9	0.117 (3.590*)	-0.067 (-1.620)	-0.086 (-1.804)	0.025 (0.712)	0.052 (2.231*)	0.020 (0.837)
10	-0.163 (-4.999*)	0.093 (2.246*)	0.091 (2.091*)	0.029 (0.956)	0.035 (1.544)	0.079 (3.385*)
11	0.112 (3.431*)	-0.059 (-1.533)	-0.048 (-1.220)	0.008 (0.265)	0.014 (0.624)	-0.017 (-0.735)
12	-0.042 (-1.003)	0.012 (0.585)	0.012 (0.472)	-0.015 (-0.550)	-0.013 (-0.616)	-0.043 (-1.035)

* The auto-correlation figures are statistically significant

Table 6.2b

Autocorrelation coefficients (ρ) of the FTSE 100 futures price volatility, spot trading volume, spot price volatility and arbitrage spread. The last two were estimated based on the use of the unadjusted and the adjusted for non-synchronicity spot series as well as the implied index series. The sample period covers March 13, 1992 to May 31, 1995. Figures in parentheses are t statistics. $H_o: \rho = 0$ at 5% level of significance if t-value > $|1.960|$.

	Autocorrelation coefficients (ρ)							
Lag	Futures price volatility	Unadjusted Spot price volatility	Adjusted Spot price volatility	Implied Index price volatility	Unadjusted Arbitrage spread	Adjusted Arbitrage spread	Implied Index Arbitrage spread	Spot Trading volume
1	1.057 (21.799*)	1.034 (11.750*)	1.031 (11.651*)	1.010 (19.636*)	0.459(13.132*)	0.423(12.097*)	0.578(16.825*)	0.417(11.969*)
2	-0.088 (-1.736)	-0.114 (-1.076)	-0.115 (-1.077)	-0.086 (-1.749)	0.149(3.888*)	0.148(3.908*)	0.227(5.717*)	0.104(2.764*)
3	0.002 (0.045)	0.069 (1.378)	0.070 (1.390)	0.040 (0.818)	0.069(1.796)	0.077(2.020*)	0.037(0.932)	0.033(0.887)
4	-0.046 (-0.902)	-0.075 (-1.493)	-0.076 (-1.511)	-0.041 (-0.820)	0.033(0.866)	0.028(0.736)	0.122(3.047)	0.079(2.125*)
5	0.024 (0.477)	0.037 (0.736)	0.038 (0.756)	0.014 (0.291)	0.061(1.568)	0.051(1.331)	-0.063(-1.564)	0.171(4.585*)
6	0.015 (0.304)	-0.032 (-0.629)	-0.032 (-0.639)	-0.031 (-0.638)	-0.053(-1.357)	-0.032(-0.848)	-0.043(-1.078)	-0.081(-2.160*)
7	0.016 (0.311)	0.074 (1.459)	0.074 (1.472)	0.044 (0.894)	-0.010(-0.268)	-0.047(-1.236)	0.036(0.896)	-0.120(-3.183*)
8	0.027 (0.537)	-0.041 (-0.809)	-0.042 (-1.172)	0.080 (1.628)	0.027(0.691)	0.027(0.705)	0.058(1.437)	-0.062(-1.655)
9	-0.085 (-1.681)	-0.054 (-1.080)	-0.055 (-1.097)	-0.091 (-1.850)	0.054(1.402)	0.093(2.441*)	-0.057(-1.429)	0.013(0.343)
10	0.065 (1.500)	0.062 (1.527)	0.063 (1.550)	0.070 (1.696)	0.064(1.648)	0.063(1.651)	-0.028(-0.620)	0.210(5.621*)
11	0.039 (1.091)	0.033 (1.055)	0.032 (1.025)	0.048 (1.425)	0.023(0.604)	0.038(1.005)	0.077(1.954)	-0.013(-0.337)
12	-0.041 (-1.641)	-0.023 (-1.032)	-0.021 (-0.945)	-0.088 (-2.763*)	-0.067(-1.926)	-0.073(-2.099*)	-0.020(-0.591)	-0.092(-2.647*)

* The auto-correlation figures are statistically significant

6.4.3 OLS REGRESSION OF EACH EQUATION SEPARATELY

We start with the use of OLS regression estimation on each equation of the model separately. As Chan and Chung state, the use of SUR estimation is preferred to the simple OLS because there could be contemporaneous correlation among the error terms of the equations. This would mean that there is relevant information in the error terms that is common to all equations and affects the dependent variables. In order to find whether such a case applies in our data series we perform and present the results of the OLS regression of each equation separately in Tables 6.3a, 6.3b and 6.4.

We also examine and report in Table 6.5 the correlation coefficients of the each equation, $u_{1t}...u_{4t}$, of the model after the separate OLS regression of the equations. This is done as an initial comparison of the two methods of analysis, the OLS and the SUR. The correlation coefficients are very low, implying that the error terms are not related and do not contain common and relevant information. However, an exception must be made for the error terms of the first two equations of the model (where the dependent variables are the futures and the spot volatility) which appear to be highly correlated, 0.9. This means that information from the futures volatility regression is also relevant for the spot volatility regression. This is not surprising since it actually means that the spot and the futures markets volatilities are related. On the other hand, the contemporaneous correlation between the two error terms may play a vital role when different method of estimation is used.

Table 6.3a

The results of the OLS regression of equations (6.4, 6.5, 6.6 and 6.7) separately, for the period 27/10/86-31/05/95 (unadjusted case) .$H_o:\mu = 0$ at 5% level of significance if t-value > $|1.960|$.

Dependent	Futures Volatility ($FVOL_t$)		Spot Volatility ($SVOL_t$)		Spot Trading Volume ($STRV_t$)		Change in Arbitrage Spread ($\Delta SPREAD_t$)	
Independent	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
Intercept	0.000003	0.465	0.000004	1.108	0.00006	2.488*	0.00003	0.105
$FVOL_{t-1}$	1.226	25.011*	0.751	22.199*	0.241	1.158	-14.519	-3.103*
$FVOL_{t-2}$	-0.090	-1.684	-0.490	-13.256*	0.136	0.598	-6.020	-1.538
$FVOL_{t-3}$	0.002	0.042	0.043	1.123	-0.028	-0.134	18.883	4.644*
$FVOL_{t-4}$	-0.191	-4.000*	-0.196	-6.111*	-0.270	-1.348	0.372	0.100
$FVOL_{t-5}$	0.020	0.589	-	-	-	-	-	-
$SVOL_{t-1}$	-0.053	-0.761	0.651	13.353*	-0.015	-0.050	-20.985	-3.172*
$SVOL_{t-2}$	0.038	0.467	0.096	1.738	-0.097	-0.280	5.126	0.747
$SVOL_{t-3}$	-0.230	-2.835*	-0.358	-7.067*	0.032	0.116	-31.214	-7.767*
$SVOL_{t-4}$	0.240	4.140*	0.513	11.942*	0.069	0.386	5.602	1.759
$SVOL_{t-5}$	-	-	-0.130	-6.158*	-	-	-	-
$STRV_{t-1}$	0.045	9.193*	0.033	9.874*	0.424	20.108*	-0.626	-0.849
$STRV_{t-2}$	-0.047	-8.691*	-0.033	-9.172*	0.129	5.593*	1.383	2.656*
$STRV_{t-3}$	-0.0006	0.117	0.0005	0.141	0.107	4.550*	-0.614	-1.718
$STRV_{t-4}$	0.003	0.611	0.0006	0.171	0.090	3.834*	-0.124	-0.313
$STRV_{t-5}$	-	-	-	-	0.235	10.915*	-	-
$\Delta SPREAD_{t-1}$	0.006	19.199*	0.003	14.029*	0.003	2.404*	-0.532	-11.932*
$\Delta SPREAD_{t-2}$	0.004	9.871*	0.002	7.828*	0.002	1.630	-0.349	-8.811*
$\Delta SPREAD_{t-3}$	0.002	4.387*	0.001	3.973*	0.002	1.587	-0.178	-5.206*
$\Delta SPREAD_{t-4}$	0.0009	2.716*	0.0004	1.756	0.001	0.779	-0.094	-2.887*

*The coefficients are statistically significant.

Table 6.3b

The results of the OLS regression of equations (6.4, 6.5, 6.6 and 6.7) separately, for the period 27/10/86-31/05/95 (adjusted case). $H_o:\mu = 0$ at 5% level of significance if t-value > $|1.960|$.

Dependent	Futures Volatility ($FVOL_t$)		Spot Volatility ($SVOL_t$)		Spot Trading Volume ($STRV_t$)		Change in Arbitrage Spread ($\Delta SPREAD_t$)	
Independent	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
Intercept	0.000003	0.465	0.000001	1.211	0.00006	2.502*	0.00003	0.093
$FVOL_{t-1}$	1.232	23.335*	0.965	19.704*	0.222	1.014	-12.963	-3.960*
$FVOL_{t-2}$	-0.134	-1.375	-0.649	-12.300*	0.059	0.253	0.744	0.212
$FVOL_{t-3}$	-0.063	-1.021	0.028	0.519	-0.074	-0.356	16.035	5.213*
$FVOL_{t-4}$	-0.125	-2.610*	-0.201	-4.623*	-0.188	-0.950	-4.909	-1.667
$FVOL_{t-5}$	0.045	1.323	-	-	-	-	-	-
$SVOL_{t-1}$	-0.051	-0.904	0.711	13.499*	-0.027	-0.117	-6.900	-1.984*
$SVOL_{t-2}$	0.107	1.577	0.096	1.543	0.015	0.052	7.042	0.673
$SVOL_{t-3}$	-0.150	-2.257*	-0.371	-6.387*	0.0001	0.001	-22.903	-6.990*
$SVOL_{t-4}$	0.098	2.128*	0.478	9.982*	0.006	0.043	9.544	1.714
$SVOL_{t-5}$	-	-	-0.134	-5.860*	-	-	-	-
$STRV_{t-1}$	0.052	10.479*	0.050	10.892*	0.436	20.644*	-0.407	-1.316
$STRV_{t-2}$	-0.051	-9.317*	-0.049	-9.759*	0.123	5.321*	1.291	3.766*
$STRV_{t-3}$	-0.0001	0.013	0.002	0.473	0.108	4.554*	-0.493	-1.408
$STRV_{t-4}$	-0.0002	-0.047	-0.002	-0.377	0.088	3.732*	-0.367	-1.151
$STRV_{t-5}$	-	-	-	-	0.229	10.601*	-	-
$\Delta SPREAD_{t-1}$	0.005	13.781*	0.003	8.860*	0.002	1.970*	-0.538	-25.396*
$\Delta SPREAD_{t-2}$	0.002	6.431*	0.001	4.363*	0.001	0.787	-0.307	-12.555*
$\Delta SPREAD_{t-3}$	0.001	2.911*	0.001	2.581*	0.002	1.174	-0.184	-7.497*
$\Delta SPREAD_{t-4}$	0.001	3.217*	0.0006	1.793	0.001	0.585	-0.109	-4.895*

*The coefficients are statistically significant.

Table 6.4

The results of the OLS regression of equations (6.4, 6.5, 6.6 and 6.7) separately, for the period 13/03/92-31/05/95. $H_o:\mu = 0$ at 5% level of significance if t-value > $|1.960|$.

(A) Unadjusted Case

Dependent	Futures Volatility ($FVOL_t$)		Spot Volatility ($SVOL_t$)		Spot Trading Volume ($STRV_t$)		Change in Arbitrage Spread ($\Delta SPREAD_t$)	
Independent	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
Intercept	-0.00001	-2.287*	-0.00002	-2.142*	0.00009	2.050*	-0.0004	-0.463
$FVOL_{t-1}$	0.953	26.311*	-0.029	-1.070	0.068	0.322	-4.904	-1.006
$SVOL_{t-1}$	-0.009	-0.761	0.937	33.898*	-0.101	-0.497	5.505	1.191
$STRV_{t-1}$	0.005	2.266*	0.006	2.095*	0.722	19.792*	0.114	0.508
$STRV_{t-2}$	-	-	-	-	0.256	6.890*	-	-
$\Delta SPREAD_{t-1}$	0.0001	1.105	-0.0002	-1.090	-0.0004	-0.278	-0.420	-9.060*
$\Delta SPREAD_{t-2}$	-	-	-	-	-	-	-0.197	-4.705*

(B) Adjusted Case

Dependent	Futures Volatility ($FVOL_t$)		Spot Volatility ($SVOL_t$)		Spot Trading Volume ($STRV_t$)		Change in Arbitrage Spread ($\Delta SPREAD_t$)	
Independent	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
Intercept	-0.00001	-2.293*	-0.00002	-2.133*	0.00009	2.053*	-0.0001	-0.163
$FVOL_{t-1}$	0.953	27.613*	-0.033	-1.141	0.070	0.203	-4.997	-1.144
$SVOL_{t-1}$	-0.008	-0.557	0.934	36.472*	-0.099	-0.555	5.187	1.354
$STRV_{t-1}$	0.004	2.284*	0.007	2.093*	0.724	19.866*	0.052	0.248
$STRV_{t-2}$	-	-	-	-	0.254	6.866*	-	-
$\Delta SPREAD_{t-1}$	0.00001	0.543	-0.0004	-1.767	-0.00003	-0.018	-0.432	-8.307*
$\Delta SPREAD_{t-2}$	-	-	-	-	-	-	-0.202	-4.288*

(C) Implied Index Case

Dependent	Futures Volatility ($FVOL_t$)		Spot Volatility ($SVOL_t$)		Spot Trading Volume ($STRV_t$)		Change in Arbitrage Spread ($\Delta SPREAD_t$)	
Independent	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
Intercept	-0.00001	-2.307*	-0.00002	-2.291*	0.00009	2.123*	-0.0007	-0.985
$FVOL_{t-1}$	0.933	21.101*	-0.071	-0.903	0.112	0.476	-6.408	-1.536
$SVOL_{t-1}$	0.009	0.587	0.968	22.469*	-0.119	-0.663	5.220	1.638
$STRV_{t-1}$	0.005	2.332*	0.008	2.315*	0.731	19.678*	0.192	1.089
$STRV_{t-2}$	-	-	-	-	0.246	6.524*	-	-
$\Delta SPREAD_{t-1}$	0.00004	0.226	-0.0003	-1.423	0.002	1.380	-0.400	-5.636*
$\Delta SPREAD_{t-2}$	-	-	-	-	-	-	-0.174	-3.328*

*The coefficients are statistically significant.

Table 6.5

Correlation coefficients of the error terms of equations (6.4), (6.5), (6.6) and (6.7) after separate OLS regression.

A) October 27, 1986 to May 31, 1995.

Error Terms	Unadjusted Case				Adjusted Case			
	u_{1t}	u_{2t}	u_{3t}	u_{4t}	u_{1t}	u_{2t}	u_{3t}	u_{4t}
u_{1t}	1.00	0.90	0.18	-0.10	1.00	0.91	0.20	-0.11
u_{2t}	0.90	1.00	0.16	-0.09	0.91	1.00	0.18	-0.10
u_{3t}	0.18	0.16	1.00	0.07	0.20	0.18	1.00	0.01
u_{4t}	-0.10	-0.09	0.07	1.00	-0.11	-0.10	0.01	1.00

B) March 13, 1992 to May 31, 1995

Error Terms	Unadjusted Case				Adjusted Case				Implied Index Case			
	u_{1t}	u_{2t}	u_{3t}	u_{4t}	u_{1t}	u_{2t}	u_{3t}	u_{4t}	u_{1t}	u_{2t}	u_{3t}	u_{4t}
u_{1t}	1.00	0.93	-0.06	-0.03	1.00	0.93	-0.06	-0.06	1.00	0.95	-0.07	0.01
u_{2t}	0.93	1.00	-0.10	-0.02	0.93	1.00	-0.11	-0.06	0.95	1.00	-0.06	-0.005
u_{3t}	-0.06	-0.10	1.00	0.04	-0.06	-0.11	1.00	0.01	-0.07	-0.06	1.00	-0.06
u_{4t}	-0.03	-0.02	0.04	1.00	-0.06	-0.06	0.01	1.00	0.01	-0.005	-0.06	1.00

SAMPLE PERIOD OCTOBER 27, 1986 TO MAY 31, 1995

For the larger sample period analysed the results of using the unadjusted for non-synchronicity spot and those of using the adjusted for non-synchronicity spot are very similar and produce the same conclusions. These findings are presented and analysed as follows;

THE FUTURES PRICE VOLATILITY AS THE DEPENDENT VARIABLE

At first we use the futures price volatility as the dependent variable and find that the trading volume of the spot, $STRV_{t-1}$ is highly significant and positively related to the futures price volatility, $FVOL_t$. This means that past values of the trading volume in the spot index explain current levels of futures volatility even after including the spot price volatility. This shows the importance of the spot trading volume in the analysis of market volatility, which previous studies have ignored. Furthermore, we observe a positive statistically significant relation between current futures price volatility and past changes in the arbitrage spread. An interpretation of this finding shows that increases in the change of arbitrage spread result in significant increases in the futures price volatility[1].

At this point we tested a different version of this regression, which included a dummy variable DUMΔSPREAD, to identify profitable and non-profitable mispricing.

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[1]It is noted that a positive change in arbitrage spread could be associated with both an increase in overpricing or a change from underpricing to overpricing.

$$FVOL_t = a_1 + \sum_{k=1}^{4} b_{1,t-k} FVOL_{t-k} + \sum_{k=1}^{4} c_{1,t-k} SVOL_{t-k} + \sum_{k=1}^{4} d_{1,t-k} STRV_{t-k} +$$

$$+ \sum_{k=1}^{4} e_{1,t-k} \Delta SPREAD_{t-k} + \sum_{k=1}^{4} f_{t-k} DUM\Delta SPREAD_{t-k} + u_{1t} \qquad (6.11)$$

If the arbitrage spread at time t-1 exceeds the transactions costs (profitable mispricing), then the dummy variable acquires the value one, otherwise (non-profitable mispricing) it becomes zero. The transactions cost used for this purpose is the lowest and is given as the 0.5% of the underlying spot index. That way we test whether the volatility in the futures prices is affected differently when previous arbitrage opportunities are profitable or non-profitable. The results showed that the use of the dummy variable is not statistically significant, implying that the profitability of mispricing cannot explain the observed futures volatility. This finding is also consistent with the results by Chan and Chung (1993). Sofianos (1993) explains this by showing that index arbitrage traders open positions even when the mispricing does not exceed the transactions costs, based on the expectation that the markets will move in the desirable direction to such a degree that high profits will emerge. One interesting observation from the results of this equation is that the first lag on futures volatility is greater than one suggesting that futures volatility increases over time. Unfortunately, there is no clear interpretation for this result.

THE SPOT PRICE VOLATILITY AS THE DEPENDENT VARIABLE

We continue, by using the spot price volatility as the dependent variable. The results show that current spot price volatility is explained by previous futures price volatility. This finding shows that futures prices have the tendency to lead the spot prices, which is consistent with the results of chapter three. It is also observed a possible relation between current spot price volatility and past spot trading volume, which implies that spot trading volume can predict part of the future volatility in the spot prices.

Finally, there is a positive relation between current spot price volatility and previous changes in the arbitrage spread. This means that an increase in the arbitrage spread results in an increase in the spot price volatility. Therefore, index arbitrage can be responsible for spot price volatility. It is also noted that the impact of arbitrage spread is both stronger and longer lasting on the futures price volatility than on the spot price volatility.

THE SPOT TRADING VOLUME AS THE DEPENDENT VARIABLE

We continue with the regression of equation (6.6) where the trading volume of the spot index is the dependent variable. It is found that current trading volume of the spot index is not related to past price volatility of either the spot market or the futures market. However, there is a positive and significant relation between past changes in arbitrage spread and current spot trading volume. Therefore, an increase in the arbitrage spread is followed by an increase in the trading volume of the spot index. This is explained by the fact that when the futures contracts (or the spot) are significantly mispriced as dictated by the cost-of-carry model, then arbitrage activity is initiated which involves trading in both the spot and the futures markets simultaneously.

CHANGE IN THE ARBITRAGE SPREAD AS THE DEPENDENT VARIABLE

Last we regress equation (6.7) where the change in the arbitrage spread is the dependent variable. The presence of arbitrage spread could be attributed to the occurrence of highly volatile prices in the spot and futures markets. This is confirmed by the results of in Table 6.3 where past values of both spot and futures volatility are significantly related to current arbitrage spread. Specifically, an increase in both the spot and futures price volatility leads to a decrease in the arbitrage spread.

Overall, the results of this analysis are very significant. It is found that arbitrage opportunities are related to changes in the spot and futures prices. An increase in the arbitrage spread, which is likely to induce arbitrage activity, results in significant increases in the spot price volatility, the spot trading volume and the futures price volatility. As a result, arbitrage appears to cause higher volatility in the markets. However, more volatile spot and futures markets do not increase arbitrage spread but decrease it. This means that more volatile prices induce more arbitrage trading which causes the prices to adjust to new information faster and eventually reduce the size of the arbitrage spread. Consequently, arbitrage may appear to induce higher volatility in the markets but could actually be improving the speed by which prices are adjusted to new information. More specifically, futures prices are observed to move first in the arrival of new information, which is consistent with the findings of chapter three. This can cause the arbitrage spread to increase which then attracts arbitrage activity. Since arbitrage involves trading in both the spot and the futures markets simultaneously, prices of the spot market are then adjusted to new information. As a consequence, arbitrage appears to induce volatility as a result of faster adjustment to new information. In a way, arbitrage seems to improve the speed that new information is transmitted and absorbed by the markets.

The observed increase in the market volatility is found not to be followed by an increase in the arbitrage spread. On the contrary, the arbitrage spread is reduced. This shows that a volatile market does not cause the spot and futures markets to drift apart but brings them closer.

SAMPLE PERIOD MARCH 13, 1992 TO MAY 31, 1995

For the smaller sample period analysed the results produced from all three cases of spot series analysed are very similar and produce the same conclusions. However, the findings of the smaller sample period appear to be different from the findings of the larger sample period analysed, in that there is no apparent relationship between volatility and arbitrage. One possible explanation for this is the increasing liquidity and maturity of the futures market captured by the sample which covers the more recent years. These findings support the observations made in chapters four and five that the futures market has become less prone to mispricing and so offers fewer arbitrage opportunities as the market has grown and has attracted more sophisticated market participants.

6.4.4 SUR Results Of The Model

In addition to applying OLS estimation we also employ seemingly unrelated regression of the model described by equations (6.4), (6.5), (6.6) and (6.7) and present the results of the SUR regression of each equation separately in Tables 6.6 and 6.7.

Both the SUR method and the individual OLS regressions produce results that are very similar. The level of the coefficients and their statistical significance are not affected by the difference in the method applied. Our findings so far lead us to the conclusion that there is no relevant information contained in the error terms which can affect the dependent variables. Consequently, there is no contemporaneous correlations among the four error terms of the model.

The findings of this chapter's empirical investigation are largely consistent with the findings of the study by Chan and Chung (1993). Based on their results they also experience the arbitrage spread to be followed by significant increases in both the spot and the futures price volatility. Their study concludes that higher market volatility attracts more arbitrage activity which in turn reduces the arbitrage spread. This general finding is supported here.

Table 6.6a

The results of the SUR of the model described by equations 6.4, 6.5, 6.6 and 6.7, for period 27/10/86-31/05/95 (unadjusted case). $H_o:\mu = 0$ at 5% level of significance if t-value>|1.960|.

Dependent	Futures Volatility ($FVOL_t$)		Spot Volatility ($SVOL_t$)		Spot Trading Volume ($STRV_t$)		Change in Arbitrage Spread ($\Delta SPREAD_t$)	
Independent	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
Intercept	0.000003	0.599	0.000004	1.174	0.00006	2.508*	0.00003	0.088
$FVOL_{t-1}$	1.200	24.279*	0.735	21.977*	0.239	1.149	-14.519	-4.387*
$FVOL_{t-2}$	-0.077	-1.422	-0.507	-13.849*	0.137	0.601	-6.020	-1.661
$FVOL_{t-3}$	0.234	4.419*	0.089	2.543*	-0.029	-0.137	18.883	-5.616*
$FVOL_{t-4}$	-0.133	-2.782*	-0.201	-6.271*	-0.269	-1.340	0.372	0.117
$FVOL_{t-5}$	-0.207	-12.187*	-	-	-	-	-	-
$SVOL_{t-1}$	-0.011	-0.159	0.682	14.309*	-0.008	-0.028	-20.985	-4.474*
$SVOL_{t-2}$	-0.027	-0.326	0.090	1.615	-0.102	-0.294	5.126	0.930
$SVOL_{t-3}$	-0.569	-8.197*	-0.424	-9.315*	0.032	0.117	-31.214	-7.206*
$SVOL_{t-4}$	0.514	10.897*	0.596	18.075*	0.068	0.382	5.602	1.968*
$SVOL_{t-5}$	-	-	-0.184	-17.186*	-	-	-	-
$STRV_{t-1}$	0.043	8.802*	0.032	9.643*	0.427	20.298*	-0.626	-1.902
$STRV_{t-2}$	-0.045	-8.355*	-0.032	-8.903*	0.123	5.341*	1.383	3.803*
$STRV_{t-3}$	0.0001	0.023	0.0004	0.107	0.110	4.674*	-0.614	-1.658
$STRV_{t-4}$	0.002	0.490	0.0005	0.136	0.090	3.868*	-0.124	-0.368
$STRV_{t-5}$	-	-	-	-	0.235	11.175*	-	-
$\Delta SPREAD_{t-1}$	0.006	19.450*	0.003	14.212*	0.003	2.385*	-0.532	-24.980*
$\Delta SPREAD_{t-2}$	0.004	10.331*	0.002	7.652*	0.002	1.630	-0.349	-14.116*
$\Delta SPREAD_{t-3}$	0.002	4.683*	0.0009	3.740*	0.002	1.574	-0.178	-7.158*
$\Delta SPREAD_{t-4}$	0.0009	2.726*	0.0004	1.576	0.001	0.770	-0.094	-4.139*

*The coefficients are statistically significant.

Table 6.6b

The results of the SUR of the model described by equations 6.4, 6.5, 6.6 and 6.7, for period 27/10/86-31/05/95 (adjusted case). $H_o:\mu = 0$ at 5% level of significance if t-value>|1.960|.

Dependent	Futures Volatility ($FVOL_t$)		Spot Volatility ($SVOL_t$)		Spot Trading Volume ($STRV_t$)		Change in Arbitrage Spread ($\Delta SPREAD_t$)	
Independent	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
Intercept	0.000001	0.201	0.000001	0.218	0.00006	2.498*	0.00003	0.093
$FVOL_{t-1}$	1.208	22.641*	0.949	19.582*	0.222	1.012	-12.963	-3.960*
$FVOL_{t-2}$	-0.077	-1.113	-0.670	-12.898*	0.059	0.252	0.743	0.212
$FVOL_{t-3}$	0.201	3.805*	0.082	1.973*	-0.071	-0.343	16.035	5.213*
$FVOL_{t-4}$	-0.070	-1.470	-0.208	-4.795*	-0.190	-0.959	-4.909	-1.667
$FVOL_{t-5}$	-0.205	-12.573*	-	-	-	-	-	-
$SVOL_{t-1}$	-0.020	-0.357	0.735	14.244*	-0.028	-0.121	-6.900	-1.984*
$SVOL_{t-2}$	0.059	0.855	0.095	1.539	0.014	0.050	7.043	1.673
$SVOL_{t-3}$	-0.437	-7.727*	-0.434	-8.587*	-0.0001	-0.0006	-22.903	-6.990*
$SVOL_{t-4}$	0.331	9.137*	0.551	15.985*	0.006	0.042	9.544	4.715*
$SVOL_{t-5}$	-	-	-0.178	-17.005*	-	-	-	-
$STRV_{t-1}$	0.052	10.294*	0.049	10.823*	0.435	20.641*	-0.407	-1.316
$STRV_{t-2}$	-0.052	-9.314*	-0.049	-9.788*	0.123	5.309*	1.291	3.765*
$STRV_{t-3}$	0.002	0.324	0.003	0.545	0.108	4.540*	-0.493	-1.408
$STRV_{t-4}$	-0.001	-0.167	-0.001	-0.361	0.087	3.703*	-0.367	-1.151
$STRV_{t-5}$	-	-	-	-	0.231	10.933*	-	-
$\Delta SPREAD_{t-1}$	0.005	14.012*	0.003	9.080*	0.002	1.971*	-0.538	-25.397*
$\Delta SPREAD_{t-2}$	0.003	6.856*	0.001	4.316*	0.001	0.793	-0.307	-12.555*
$\Delta SPREAD_{t-3}$	0.001	3.540*	0.0009	2.548*	0.002	1.174	-0.184	-7.497*
$\Delta SPREAD_{t-4}$	0.001	2.994*	0.0005	1.661	0.001	0.583	-0.109	-4.895*

*The coefficients are statistically significant.

Table 6.7

The results of the SUR of the model described by equations (6.4, 6.5, 6.6 and 6.7) separately, for the period 13/03/92-31/05/95. $H_o: \mu = 0$ at 5% level of significance if t-value > $|1.960|$.

(A) Unadjusted Case

Dependent	Futures Volatility ($FVOL_t$)		Spot Volatility ($SVOL_t$)		Spot Trading Volume ($STRV_t$)		Change in Arbitrage Spread ($\Delta SPREAD_t$)	
Independent	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
Intercept	-0.00001	-3.856*	-0.00001	-4.101*	0.00009	2.436*	-0.0004	-0.463
$FVOL_{t-1}$	0.987	71.749*	-0.023	-1.325	0.078	0.367	-4.904	-1.006
$SVOL_{t-1}$	-0.020	-1.559	0.920	54.630*	-0.099	-0.490	5.504	1.191
$STRV_{t-1}$	0.003	4.421*	0.004	4.588*	0.733	21.852*	0.114	0.507
$STRV_{t-2}$	-	-	-	-	0.244	7.206*	-	-
$\Delta SPREAD_{t-1}$	0.0002	1.954	-0.0001	-0.800	-0.0004	-0.280	-0.420	-12.347*
$\Delta SPREAD_{t-2}$	-	-	-	-	-	-	-0.196	-5.771*

(B) Adjusted Case

Dependent	Futures Volatility ($FVOL_t$)		Spot Volatility ($SVOL_t$)		Spot Trading Volume ($STRV_t$)		Change in Arbitrage Spread ($\Delta SPREAD_t$)	
Independent	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
Intercept	-0.00001	-3.884*	-0.00001	-4.077*	0.00009	2.468*	-0.0001	-0.164
$FVOL_{t-1}$	0.985	75.012*	-0.023	-1.261	0.081	0.397	-4.997	-1.143
$SVOL_{t-1}$	-0.018	-1.539	0.919	56.211*	-0.096	-0.539	5.187	1.353
$STRV_{t-1}$	0.003	4.458*	0.004	4.601*	0.739	22.103*	0.052	0.249
$STRV_{t-2}$	-	-	-	-	0.238	7.048*	-	-
$\Delta SPREAD_{t-1}$	0.0001	1.518	-0.0003	-1.791	-0.00002	-0.016	-0.433	-12.727*
$\Delta SPREAD_{t-2}$	-	-	-	-	-	-	-0.203	-5.997*

(C) Implied Index Case

Dependent	Futures Volatility ($FVOL_t$)		Spot Volatility ($SVOL_t$)		Spot Trading Volume ($STRV_t$)		Change in Arbitrage Spread ($\Delta SPREAD_t$)	
Independent	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
Intercept	-0.00001	-3.823*	-0.00002	-3.920*	0.00009	2.479*	-0.0007	-0.985
$FVOL_{t-1}$	0.968	64.529*	-0.009	-0.378	0.125	0.529	-6.407	-1.535
$SVOL_{t-1}$	0.001	0.099	0.950	49.640*	-0.119	-0.661	5.220	1.638
$STRV_{t-1}$	0.003	4.538*	0.005	4.658*	0.743	22.182*	0.191	1.088
$STRV_{t-2}$	-	-	-	-	0.232	6.851*	-	-
$\Delta SPREAD_{t-1}$	0.0001	1.078	-0.0002	-1.209	0.003	1.424	-0.399	-11.715*
$\Delta SPREAD_{t-2}$	-	-	-	-	-	-	-0.174	-5.112*

*The coefficients are statistically significant.

6.5 Summary And Conclusions

The purpose of this chapter is the investigation of the criticism about the link between arbitrage trading and market volatility. This analysis tries to discover whether increased mispricing of the FTSE 100 futures contracts, which could induce increased arbitrage activity, would lead to increased volatility in both the spot and the futures markets. In addition, we examine whether the occurrence of higher market volatility could increase mispricing and thus the possibility of more arbitrage activity.

Unlike the majority of relevant studies, the investigation of the relationship between arbitrage and market volatility is conducted after taking into consideration the trading volume of the spot index as a possible contributor to market volatility. Empirically, the analysis incorporates the estimation of a system of seemingly unrelated regressions of daily spot and futures price volatility, spot trading volume and changes in the arbitrage spread. The main methodological improvement of this research is the use of the GARCH technique to derive spot and futures volatility instead of traditional constructed measures of volatility.

The results show that market volatility and arbitrage are related. Specifically, increases in the arbitrage spread, which is likely to induce arbitrage trading, contribute to significant increases in the volatility of both the spot and futures markets. However, this could be the result of faster price adjustment to new information. In addition, higher volatility is followed by a decrease instead of an increase in the arbitrage spread, which shows that a volatile market does not cause the spot and futures prices to diverge. Based on the findings, the futures market reacts first to new information creating arbitrage spread which then encourages more arbitrage activity. Since such an activity involves the simultaneous trading in both the spot and futures markets, these markets experience higher volatility which is then followed by a reduction in the arbitrage spread. Therefore, arbitrage could be seen as way by which the speed of transmitting new information is improved.

The analysis also distinguishes between profitable and non-profitable arbitrage spread in order to find whether it can affect market volatility any differently. The results show that the profitability or not of the mispricing does not change the behaviour of market volatility in any way. This finding is also consistent with the results by Chan and Chung (1993). Sofianos (1993) explains this by showing that index arbitrage traders open positions even when the mispricing does not exceed the transactions costs, based on the expectation that the markets will move in the desirable direction to such a degree that high profits will emerge Consistent with chapter three, the results showed that the futures market tends to dominate the spot market.

Finally, use of the smaller sample for the more recent period indicates no statistically significant link between arbitrage and market volatility. This is interpreted as suggesting that the futures market is less prone to mispricing due to greater sophistication of participants and improved liquidity and functioning of the market. This observation supports similar findings of previous chapters.

Overall, the findings show that higher change in the arbitrage spread leads to increased volatility in the spot and the futures markets, which could be seen as the result of faster adjustment of prices to new information through arbitrage trading. Finally, we find that more volatile markets do not generate higher arbitrage spread. In other words, a volatile market does not necessarily make the spot and the futures prices diverge more. On the contrary, spot and futures price are more close when the market is volatile.

After having concluded the empirical investigation of the thesis, the following chapter focuses on providing the fundamental conclusions reached throughout the entire analysis of this thesis.

CHAPTER 7

Summary And Conclusion

This thesis began with a presentation of the evolution and development of the futures markets and paid particular attention to stock index futures and their role of providing hedging and price discovery functions to spot markets. We also explained the importance of spot and futures markets being closely related so that the futures market is able to carry out these attributed roles. This emphasises the significance of the presence of arbitrage trading as the mechanism which brings the two markets close together and does not allow them to drift apart without bound. If brief, arbitrage could be viewed as a form of market discipline, keeping spot and futures prices together over the long run. Thus, the issue of arbitrage is central to an analysis of the relationship between a futures market and its underlying spot market.

Although a number of studies have investigated the subject of arbitrage for the U.S. market, research for the U.K. market is very limited. This thesis addresses this by examining the pricing relationship of FTSE 100 futures and the FTSE 100 stock index in terms of the role of arbitrage in supporting the key market functions of futures, namely hedging and price discovery. The thesis presented five related empirical essays, which extended existing research with the application of a number of techniques new to the field.

As a result of the increasing concern in the U.S. about the problems for performing accurate research of non-synchronous trading in spot markets, the starting point of our empirical investigation was to analyse the effects of non-synchronous trading and remove them from the data series. Testing of different methodologies for removing non-synchronicity led to the use of a state space model as the most appropriate solution. This is because it is more appropriate for the specifics of this investigation and has fewer data requirements. It also provides more reliable results than other methods in that it does not remove genuine features from the data series which are unrelated to non-synchronous trading.

The work of Chapter two was further extended by developing and applying a new approach to account for the presence of non-synchronous trading. This approach relied upon the use of options contracts to generate the correct spot index and is referred to as the implied index. Unlike all other methodologies, this approach does not need to use the observed spot series (which suffers from the effects of non-synchronicity) neither do the various adjusting techniques need to be applied. In addition, it overcomes asynchronicity in the closing times between the spot and futures markets since the options and futures markets close at the same time.

Using the indices provided in chapter two, which are treated for non-synchronous trading, chapter three analysed the relationship between spot and futures markets in terms of both the elasticity of supply of arbitrage and the ability of the futures to discover price. In doing so the chapter probes the effectiveness and usefulness of the index futures market. This is achieved by considering both long-term and short-term efficiency. The results of cointegration regressions and error-correction models show that although the futures market appears to be efficient in the long-run it is not the case in the short-run. Such findings show the importance of considering the short-run aspect, which appears to have been ignored in the existing research. The supply of arbitrage is found to be small suggesting persistence in mispricing. However, the futures market appears to serve its role for price discovery by having most of the information incorporated first in the futures market before it is transmitted to the spot market.

The importance of the chapter also lies in the fact that previous research and in particular research about stock indices, has failed to account for all possible routes through which information in transmitted between two markets. Previous studies have also neglected to consider the potentially time-varying nature of the relationship between spot and futures markets. Chapter three sought to contribute to the literature by using a generalised model to incorporate all information channels between markets and also applied time-varying estimation methods to capture the time-varying nature of the relationships under question. The results justify such analysis by demonstrating that previous studies have not fully accounted to information transfers and that price discovery and arbitrage varies over time.

Chapter four provided an estimate of the theoretically correct futures prices for the FTSE 100 computed using the cost-of-carry model. When calculating the theoretical futures price, some existing studies have used dividend yields, while others use actual dividends. This chapter used both dividend yields and actual dividend inflows and found no significant difference in the results. This suggests, at least for the data used in this study, that the choice of dividend yield or dividend payments is trivial. Findings show the futures contract to be mispriced and mainly undervalued when mispriced.

The mispricing series produced is statistically significant but its size appears to have declined over the last years. This observation was attributed to a growth in the number and sophistication of participants in the futures market. Furthermore, the tax-timing option available in the spot market but not in the futures market was found not to be of significant value. The level of mispricing appears to increase with the time remaining until the maturity of a futures contract, a finding which is attributed to the difficulty involved in predicting the future and uncertainty about dividends and interest rates. Finally, the presence of auto-correlation in the mispricing series suggests persistence in mispricing.

Although the majority of the existing studies focuses only on the analysis of the presence and persistence of mispricing and so do not fully investigate profitable arbitrage opportunities, chapter five fully explores the issue. Given the results provided in chapter four, chapter five used transactions costs bounds to estimate and investigate the arbitrage profitability of the observed mispricing. Results showed that a large part of the observed mispricing could be profitably exploited through the actions of arbitrageurs even when transactions costs are accounted for.

Such findings are contrary to the findings of Miller et al. (1994) in which it is suggested that apparent arbitrage trading is mostly a statistical illusion due to the presence of non-synchronous trading. Chapter five finds arbitrage trading to be real rather than a statistical illusion. Therefore, non-synchronous trading cannot fully explain arbitrage opportunities. An important finding is that the frequency and size of the arbitrage profits appear to have decreased over the years as the futures market has matured. This supports the notion that as markets become larger and more mature, their pricing efficiency improves as the market's participants become even more sophisticated. Efficient pricing and diminishing arbitrage opportunities are a characteristic of well developed financial markets. Finally, the early unwinding option, which is rarely considered in the existing literature is found to be valuable and can generate higher profits than the hold-until-expiration rule.

The final empirical chapter of the thesis concludes the investigation of the price relationship between spot and futures markets by examining the association between market volatility and arbitrage trading. Due to increasing criticism about the role that arbitrage trading plays in the occurrence of volatile prices in the markets, the chapter provides a valuable insight by adopting an approach not previously used in the U.K. and by improving it with the use of GARCH models. The results provide evidence that arbitrage activity of arbitrage can cause increased volatility in both the spot and futures markets. However, the observed volatility could be interpreted as the result of improved price response to new information through arbitrage, i.e. arbitrage acts to speed up the import of news on prices making them appear more volatile. In a similar manner we discover that an increase in the volatility of prices causes a decrease in the arbitrage spread, thus bringing the spot and futures markets closer.

Throughout the thesis the results of the empirical investigation suggest that the effects of non-synchronous trading in the U.K. are not as severe as in the U.S. and so have less explanatory power regarding arbitrage and mispricing. On the other hand, the use of the more reliable implied index derived from option contracts suggests that the results of the unadjusted and the adjusted for non-synchronicity indices can underestimate the presence, frequency and level of mispricing in the futures contracts and also the profitability of arbitrage opportunities. As a consequence, we could argue that previous research fails to fully consider the true size of the issue.

The analysis presented in this thesis has a number of important policy implications. The futures market for the FTSE 100 stock index is found to be effective and useful in serving its role of discovering new information and incorporating it in its prices. On the other hand, the closeness of the spot and the futures market, which is very important for the overall performance and efficiency of the futures market in terms of transferring risk/hedging in particular, does not always perform properly. Despite the fact that arbitrage trading takes place and manages to remove mispricing, thus bringing the two markets closer, it seems not to be enough to remove all the observed mispricing even in cases when it is profitable. Such a result could suggest that arbitrageurs are mainly interested in large profits rather than small ones and so do not respond to smaller arbitrage opportunities. It could also mean that the market participants do not become aware of the profitable opportunities immediately.

The futures market is expected to act as the vehicle for reducing risk due to price fluctuations and discover new information. Amongst the common criticisms of futures markets is that they can induce volatility in the underlying spot markets and that by failing to function properly they offer hedging and price discovery functions which are not as effective and reliable as would normally be expected. However, it is not always the failure of futures markets which are to blame, but can also be the environment in which futures operate. For example, the presence of market imperfections such as high margin requirements, position limits on the price movements, high transactions costs and other trading restrictions can all play a role in reducing the effective functioning of futures markets.

This thesis has found evidence of the existence of mispricing which cannot be removed by arbitrage activities due to transaction costs bounds. The transaction costs bounds are a function of many of the imperfections listed above. For example, margin requirements and trading fees influence the width of transaction costs bounds. Such margin requirements are under the control of the London Clearing House (LCH), while transaction fees are under the direct control of the futures exchange. The clearing house and the exchange, when setting margins and trading fees need to consider the requirements of the market to operate without severe restrictions, while both covering trading costs (in the case of trading fees), and to insure that the clearing function has adequate risk management procedures (in the case of margin requirements). Thus, while the removal of margin requirements and the lowering of transaction fees may motivate greater arbitrage trading this may not be acceptable to the exchange and clearing house.

A further imperfection responsible for the observation of even profitable arbitrage opportunities is the presence of short sale restrictions in the spot market. This has the effect of restricting arbitrage by preventing market participants from selling stocks when they are expensive relative to the futures. This restriction comes under the control of the regulator. One possible way in which arbitrage activity could be motivated would be the removal or alleviation of such restrictions. This is currently being proposed.

Finally, the lack of arbitrage trading when profitable arbitrage opportunities are present can be attributed to the arbitrageurs themselves. Explanations for this could include a temporary lack in available funds for arbitrage activity (for example, restrictions on the ability to borrow money in order to buy spot assets to execute an arbitrage strategy), the presence of more profitable returns elsewhere, or corporate restrictions on the positions of traders, for example, a trader may be limited as to which futures contracts he/she is able to trade. Finally, it cannot be assumed that the presence of an apparently profitable opportunity would attract arbitrage interest from sections of the financial markets which would otherwise not taken interest in the futures contracts.

The analysis provided in this thesis suggests a number of areas for future research. Where applicable, the results of this thesis have been compared to those by Yadav and Pope (1992), and a number of differences were found. These were attributed to differences in the construction of the data series, namely that Yadav and Pope include the expiration month, while this study excludes it on the grounds that trading interest on a futures contract diminishes rapidly when it enters its expiration month. It would be interesting to explore the impact of diminishing trading interest by reapplying the tests in this thesis to a data series equivalent to that used by Yadav and Pope. Differences in the findings could shed light on the maturity effects of trading interest transferring from the expiring contract to the next nearest contract.

A further area for potential future research is to explore the arbitrage opportunities available for a trading strategy which, on detecting a mispricing between spot and futures, responds by trading an option contract on the spot rather than the spot asset itself. Trading an option contract will have many of the benefits attributed to trading a futures contract, i.e. low transactions costs, speed of execution and high leverage compared with a spot transaction. The main perceived advantage of responding to arbitrage opportunities by trading an option rather than the spot is that the lower transaction costs (and higher speed of execution) associated with options trading would mean that arbitrage profits can be made in the presence of small mispricings (or shorter lived mispricings), where spot asset transaction costs (and execution times) would be prohibitive. This could also have important implications for price discovery between futures and options contracts.

It was assumed in the thesis that there are no arbitrage opportunities between options and futures prices on the FTSE 100 Index. It would be constructive to explore this relationship and therefore test this assumption.

In chapter six the model applied by Chan and Chung (1993) did not consider the possible contribution of futures trading volume in explaining the relationship between market volatility and arbitrage spread. This could be extended by including such data to measure the possible role of futures volume in explaining such relationships.

The approaches presented and developed in this thesis could be applied on other financial markets such as smaller/younger European Indices i.e. OBX (Norway), OMX (Sweden), and IBEX-35 (Spain), etc. Since these capital markets are less liquid and developed than that of the UK, and/or that the indices are less well diversified than the FTSE 100, they may offer greater scope for mispricing and arbitrage. It may also be observed, where the futures market is relatively new that price discovery is dominated by the spot markets.

It would also be interesting to see how the approaches detailed in this thesis can perform in different market environments, with different regulatory structures. A key feature of the arbitrage opportunities presented by futures contracts is their relative freedom from trading restrictions and transaction costs. For example, different restrictions on the short selling of stocks by national regulators, or different rules on margin requirements and transactions costs etc by stock and futures exchanges may all play a role in defining the scope for mispricing between futures and stocks. It would be constructive to analyse how such restrictions affect the functioning of futures markets, and whether such things as higher transaction costs or margin requirements lead to more mispricing. This could provide valuable information for exchanges and regulators.

GLOSSARY

CBOT	Chicago Board Of Trade
CME	Chicago Mercantile Exchange
FTSE	Financial Times Stock Exchange
LIFFE	London International Financial Futures & Options Exchange
LSE	London Stock Exchange
MMI	Major Market Index
NYSE	New York Stock Exchange
OLS	Ordinary Least Squares
S&P 500	Standard and Poor's 500 Index
SEAQ	Stock Exchange Automated Quotation System
SUR	Seemingly Unrelated Regressions
VLI	Value Line Index

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