Behaviour of the FTSE 100 Basis

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Abstract

Using data on the London International Financial Futures Exchange FTSE 100 index contract, from the beginning of 1988 until the end of 1989, we look at deviations of transaction prices from calculated 'fair' values. Taking into account the fortnightly accounting periods used by the London Stock Exchange we examine the size, direction, and persistency of mispricing. Our results show that the fair value pricing formula is frequently violated, often by large amounts, with the tendency for mispricing to be negative and persistent. We also show that there are significant profitable opportunities for arbitrageurs who unwind the simple buy and hold cash/futures strategy early, or who roll forward the futures position involved in the arbitrage into the next nearest contract during the expiry month. Finally, we provide evidence to suggest that the mispricing time series follows an AR2 process.

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1. Introduction

Since the introduction of stock index derivative contracts both academics and practitioners have been interested in the relative pricing of these contracts and their underlying indexes. Stock index futures contracts have become significant investment realities in both the US and the UK, as well as on exchanges in Singapore, Australia and Japan. Significant and sustained deviations between actual futures prices and theoretically calculated values have been documented in the US (e.g., MacKinlay and Ramaswamy (1987), Cornell and French (1983) and Figlewski (1984)), Japan (Brenner, Subrahmanyam and Uno (1989, 1990)) and the UK (Yadav and Pope (1989)).

This paper looks at the deviation of index futures prices from 'fair' values in the London market for the Financial Times Stock Exchange Index (FTSE) 100 index futures contracts. In particular, we look at the time series properties of the mispricing series. We employ a price database of all quotes and transactions prices on the FTSE 100 index futures contract during a 2 year period beginning 04 January 1988 and extending to 29 December 1989, in conjunction with hour by hour index quotes on the index.

We look at how the London practice of using fortnightly accounting periods for settlement of equity transactions may help to explain the basis. The size, direction and persistency of mispricing is studied, and we also examine whether the mispricing is systematically related to dividends and the time-to-maturity which are two of the important parameters in the relationship linking theoretical index futures prices with actual prices. During the months that a futures contract expires we also compare the nearest maturing futures contract mispricing with the second nearest. We study the profits which would have been available to arbitrageurs in the London market during the period of our study, by looking at four simple trading rules. We compare the profits obtainable from a simple buy and hold strategy with those available to arbitrageurs who unwind the buy and hold strategy early, or who roll forward the futures position involved in the arbitrage into the next nearest contract during the expiry month, or a combination of the two.

Finally, we report our analysis on estimating the process and the parameters of the mispricing time series and on how we might attempt to analyse whether path dependency of the type found in the basis by MacKinlay and Ramaswamy (1987) in their empirical study on US data exists in the UK.

The paper is organised as follows. Section 2 derives the basic pricing model for stock index futures contracts. Section 3 describes the institutional details of the FTSE 100 index futures contract and the database of prices that we employ. Section 4 reviews previous studies of deviations between actual stock index futures prices and theoretically calculated prices. In section 5 we describe the arbitrageurs who may operate in the London market. In section 6 we present the analysis and results of the paper and in section 7 the summary and conclusions.

2. Pricing of Stock Index Futures Contracts

This section describes the theoretical equilibrium value for the futures price to prevent profitable arbitrage. Throughout this paper we shall neglect the distinctions addressed in Cox, Ingersoll and Ross (1981), between futures and forward prices and shall treat all futures contracts as though they were forward contracts. Studies to determine the economic significance of marking to market of the futures suggest that it is rather small, e.g. Elton, Gruber and Rentzler (1983).

In perfect markets, a stock index futures contract can be priced using the substitution or replication principle. The 'fair' price of the derivative security is given by the price of a replicating portfolio that gives the same future payoffs as the derivative. The replicating portfolio of a stock index futures contract combines a position in the underlying index stocks with a riskless asset. The fair price for a stock index future is the price of the basket of stocks plus its 'cost-of-carry'. This carrying cost relationship predicts that the price of the futures contract is higher than the current level of the index by an amount equal to the cost of 'carrying' the spot between the current date and the expiration date of the futures contract. Carrying costs for index futures are calculated as the difference between the interest costs and the dividends received. The fair price of a stock index futures contract, in a market with zero transaction costs, taxes or market impact costs, can thus be written as

$$F^*_{t,T} = I_t e^{r(T-t)} - Div_t \qquad (1)$$

where
$t =$ current date
$T =$ Expiration date of the futures contract
$I_t =$ the value at time t of the index portfolio
$F^*_{t,T} =$ theoretical value of a futures contract with expiration date T valued at time t;
$Div_t =$ future value at time T of the dividends between t and T on the spot index.
$r =$ riskfree rate corresponding to the maturity of the futures contract.

The elements Div_t are the effect on the index of all the FTSE 100 constituent companies going ex-dividend (XD) on that date, expressed in index points. In so far as these amounts are based on known dividends and XD dates our analysis has perfect foresight and this introduces a potential source of error. In the United Kingdom dividends are paid, by most companies, semi-annually and the XD date is fairly predictable, especially given the fact that XD dates are nearly always associated with the beginning of a new Stock Exchange trading account. The futures contract studied in most of our analysis is the FTSE index future nearest to expiration, as this is almost always the most heavily traded index contract. As most companies declare their dividends several weeks before the stock goes XD, the potential errors due to misspecification of dividends should not be significant. This methodology has been followed by a number of previous researchers.

To calculate the effect on the index of constituent companies going XD on any particular day the market value of the total dividend (for each company paying a dividend) is first calculated by multiplying the number of shares by the dividend and summing over all the companies paying dividends and dividing this by the total market capitalisation.

A market futures price, $F_{t,T}$, different from $F^*_{t,T}$ implies that a potential arbitrageur could generate riskless profits by taking a position in both the index and index futures contracts. The advantages associated with this sort of activity ensure that any disparity will be quickly discovered, and prices will tend to move back into line as buying pressure drives up the price of the 'cheap' investment and the selling pressure drives down the price of the other. The extent to which prices can get out of line are thus restricted by the possibility of arbitrage between the cash and index futures market.

The fact that non zero transaction costs are present in any real world market mean that the theoretical assumption of perfect markets cannot be accomplished and the above relationship may not hold precisely. There will now exist a band around this fair price within which arbitrage is not possible, allowing the actual futures price to move around within this band. The bounds of this band are given by:

$$F^{+}_{t,T} = I_t(1+C_t)e^{r(T-t)} - Div_t$$

$$F^{-}_{t,T} = I_t(1-C_t)e^{r(T-t)} - Div_t \qquad (2)$$

Where C_t represents the transaction costs as a percentage of the spot index at time t. Note that the time subscript for C does not imply that transaction costs vary over time, it relates the costs to the index level. We are assuming here that transaction costs are generated on the stock side of the transaction.

The equity side of any stock index arbitrage in London is carried out on the International Stock Exchange (ISE). The ISE operates a series of (approximately) fortnightly accounting periods. Any shares which are bought or sold within each fortnightly account have to be settled on an account settlement day which is normally 6 business days after the end of the account. This has the following effects on our analysis. Firstly, any stock which is bought (sold) as part of any short (long) futures arbitrage position at t will be settled on the account settlement date associated with t. Secondly, the corresponding unwinding of the stock position at maturity will be settled at the account settlement date associated with T, the maturity of the contract. We also take into account the fact that dividends are not received on the XD date, but usually some time afterwards on dividend payment dates. Note, however, that we only take into account dividends whose XD date is between t and T, but it is the dividend payment date that goes into the valuation.

Equations (1) and (2) now become

$$F^{*}_{t,T} = I_t e^{r(T'-t')} - Div_t \qquad (1)'$$

where t' = Account date associated with current date
T' = Account date associated with expiration date of the futures contract
Div_t = Ex-dividend effect on the spot index adjusted for delay in payment.

$$F^{+}_{t,T} = I_t(1+C_t)e^{r(T'-t')} - Div_t$$

(2)'

$$F^{-}_{t,T} = I_t(1-C_t)e^{r(T'-t')} - Div_t$$

3. Institutional Characteristics and Data

The FTSE 100 index was launched in January 1984 with futures contracts on the index being introduced in the same year. The underlying index, the FTSE 100 index, is constructed from 100 of the largest blue chip UK quoted companies. The futures contract trades in the March, June, September, December cycle, with the nearest 3 months available for trading at any one time. The standard method of delivery is cash settlement with the final settlement price being calculated, during the period studied, based on the underlying FTSE 100 index level between 11.10 and 11.20 on the last trading day, known as the Exchange Delivery Settlement Price (EDSP). The unit of trading for the futures contract has a value of £25.00 per index point with half a full index point being the minimum price move. The typical contract value during our sample period is about £4500. Initial minimum margin is currently set at £2500 with gains and losses being marked to market daily.

During the period of our study FTSE index quotes were calculated every minute between 9.00am and 5.00pm every trading day. Trading hours on the London International Financial Futures Exchange (LIFFE) were from 9.05am to 4.05pm.

The database we use in our empirical investigations consists of hourly FTSE 100 index levels for the period 04 January 1988 to 29 December 1989 which were obtained from the ISE. The ISE also provided data which showed the effect on the index for any companies going XD on any particular day. Futures price data was obtained from LIFFE. The futures price data base consists of time stamped bid and ask quotes as well as transaction prices in the FTSE 100 futures contract for the period covered by the hourly FTSE quotes. Records are also tagged as being canceled, corrected, or designated open or close. The data was used to obtain market quotes for the near contract and the second nearest contract at hourly intervals between 10am and 4pm.

The interest rate that we use is a linear interpolation using one month and three month Treasury Bill rates. This is an estimate of the interest rate for a maturity exactly matching the maturity of the futures contract each trading day. Daily one and three month Treasury Bill rates were obtained from Datastream.

4. Review of Previous Studies on Stock Index Future Mispricing

Recent work by a number of authors has shown that there have existed substantial and sustained deviations of theoretical futures prices on stock indexes from their actual market prices. Although most of the studies have concentrated on index contracts trading on US exchanges, a few recent studies look at deviations in Japanese contracts and those on the FTSE 100 index traded in London.

Figlewski (1984), using a data set of NYSE composite index futures and S&P 500 futures for the second half of 1982, finds that the actual futures price was on average below the theoretical level with discounts on the NYSE futures being larger than on the S&P 500 futures. The author argues that stock index futures may be priced below their theoretical value due to a situation of disequilibrium caused by a lack of knowledge about how these markets work, a situation which will disappear as "large investors begin to integrate stock index futures into their overall equity investment programs".

Bhatt and Cakici (1990) using a 6 year data set on the S&P 500 futures contract, beginning in 1982 find that the mispricing between the theoretical futures price is usually small but positive, in contrast to Figlewski's results. They find that the percentage error is larger, in absolute value, the longer to maturity of the contract, and also that the mispricing has decreased over the study period. This last evidence supports Figlewski's arguments that futures prices become more efficient as knowledge of the futures markets has increased.

MacKinlay and Ramaswamy (1987), working with transactions data on the S&P 500 index futures contract along with minute by minute index quotes, focus on the stochastic behaviour of the deviation of these futures prices from their cost of carry fair values. Their results imply that the magnitude of the mispricing increases with time to maturity, which the authors suggest may be due to tracking errors due to employing a subset of index stocks, and unanticipated changes in dividends and interest costs. The authors also find a particular type of path dependency in the basis which they attribute to arbitrageurs unwinding positions, which were initiated when the basis crossed one arbitrage bound, before the basis reaches the other arbitrage bound, thus making it less likely to cross the opposite bound.

Brenner, Subrahmanyam and Uno (1989, 1990) examine the relations between prices of the Nikkei Stock Average futures contract traded on SIMEX and the theoretical prices based on the underlying portfolio of stocks traded on the Tokyo stock exchange. They find, in their 1989 paper, that deviations of actual from theoretical prices tend to be large with actual prices lower than theoretical prices, although as the markets matured these deviations have declined substantially with the same direction of mispricing persisting (1990 paper).

Yadav and Pope (1990), working with a data set of opening and closing prices based on the FTSE 100 index futures contract, substantiate the evidence based on US data that the forward pricing formula provides, on average, a downward biased estimate of actual futures prices, and thus conclude that deviations in pricing are independent of the economic, institutional and regulatory environment.

A number of studies have suggested models to describe the stochastic process of the mispricing series.

Brenner, Courtadon, and Subrahmanyam (1987), Brennan & Schwartz (1987) and Duffie (1987) all assume that the basis (associated with a given futures contract) is not at its theoretical level but follows a continuous-time Brownian Bridge process

$$db = \frac{-b}{(T-t)}\mu dt + \sigma dz \qquad (3)$$

where μ is a speed of mean reversion parameter, σ is the instantaneous standard deviation of the process and dz is the increment to a Weiner process. This Brownian bridge process allows for a non-zero stochastic basis at all times up to maturity. At maturity the basis must be zero with probability one. The deviation of the basis is, therefore, by assumption, independent of any arbitrageurs operating in the market.

The main criticism that we can level against using a continuous-time Brownian Bridge process to describe the stochastic process of the mispricing series is that the basis is not affected at all by the action of arbitrageurs, although it is generally agreed that these are the traders that keep stock indexes and their futures contracts in line. This model is rejected by MacKinlay and Ramaswamy (1987) because of the path dependency that they find in their mispricing series.

Cooper and Mello (1990) develop a model of index futures arbitrage which partly endogenises the stochastic process for the basis. Their model consists of stochastic demand by liquidity traders, who trade only in the cash market, inducing variability in the basis. Optimal trading by arbitrageurs then modifies this process so that it is path dependent in the way observed by MacKinlay and Ramaswamy. They are able to do this by describing the change in the basis by two state variables; the current level of the basis, as in the Brownian Bridge models, and the volume of open arbitrage positions.

5. Arbitrageurs Operating in the UK Market

Index arbitrage in practice operates differently according to the market structure and conventions of individual financial centers; arbitrage between US stock index futures contracts and their underlying indexes is very different from arbitrage between the FTSE 100 index and its futures contract in the UK. The arbitrage bounds for futures contract mispricing in the UK derive from round trip stock and futures commissions, market impact costs of opening and closing such positions, as well as market imperfections introduced by the means of trading the index, shorting the stock, taxation, closing the arbitrage at expiry, uncertainty of dividends and allocation of capital.

Commissions in both the stock and futures market are incurred whenever an arbitrage trade is initiated, with transaction costs in terms of potential market impact also occurring at this time.

In order to be able to execute an index arbitrage, a large basket of index stocks must be bought (long arbitrage) or sold (short arbitrage) as one transaction. The more difficult this aim is to achieve, the wider will be the arbitrage bounds. In the US, stock transactions for program index arbitrage trades are executed via the NYSE's (for S&P 500 stocks) automatic order routing system (superdot), and are executed within 30 seconds, thus treating the orders as a single transaction. In the UK, firms executing arbitrage trades must either undertake the stock side of the transaction with their own market-makers, or pay a premium for another firm to do it for them.

If the futures contract is trading at a discount the arbitrage strategy involves buying the index futures contract and selling the stocks in the underlying index. If the arbitrageur is long of index stock he can sell shares that he already owns. Market-makers have special stock borrowing privileges which are not available to non-market-makers, but in reality there may be a limit on this. Thus an arbitrage trade which involves borrowing stock will result in wider arbitrage bounds.

Taxation issues will have a direct effect on the size of the arbitrage bounds. In the US there is no tax levied on stock or futures transactions. In the UK non market-makers pay stamp duty of 0.5% on stock purchases.

Arbitrageurs who hold their positions until expiry will be left with a long or short stock position to unwind because index futures are cash settled. In the US arbitrageurs close their position by employing market-on-close or market-on-open orders. In this way they achieve a perfect match between the prices of the individual stocks and the prices which go to make up the index settlement price. For arbitrageurs in the UK there is no way to guarantee that the prices which the stock position is closed at are the same as the prices upon which the index is calculated. The FTSE 100 index is calculated as a weighted average of the mid-prices of the touch bid and offer for each of the 100 stocks, and as such not all arbitrageurs will be able to deal at this price. The settlement of the FTSE 100 futures is calculated as the EDSP and as, during the study period, this is an average of 9 index values it is impossible to guarantee that the price which an arbitrageur unwinds his stock position is the same as the price which makes up the settlement price.

Dividend uncertainty will also widen an arbitrageurs transaction cost window, although, as discussed previously, we do not expect misspecification of dividends to produce significant mispricing errors. Finally one of the major factors influencing arbitrage activity in the UK is the amount of capital that firms are willing to allocate to this activity.

In real markets it would seem sensible to suggest that there exist several different categories of arbitrageurs each category distinguished by their levels of transaction costs. The category of arbitrageurs which would seem to have the lowest level of transaction costs, and as such the narrowest arbitrage channel, are firms that undertake index arbitrage in-house with their own equity market makers. They may trade at the SEAQ mid-price, at the SEAQ bid or offer, or at the in-house bid or offer. The member firms that can trade the index stocks most cost effectively are those whose market-makers make markets in a large proportion (generally all) of the FTSE 100 stocks. Another category of arbitrageurs, those who have to borrow stock to initiate an arbitrage position will have a wider arbitrage channel than the category who already have a pool of available index stocks, e.g., pension funds.

Merrick (1987) highlights two categories of arbitrageurs who may operate cash and carry arbitrage within transaction costs bands that are dictated by a buy-and-hold arbitrage strategy. The first category consists of arbitrageurs who open arbitrage positions in the hope of exploiting mispricing reversals, the absolute magnitude of which exceeds the additional market impact cost in chasing the futures position. Alternatively arbitrageurs may be able to profitably roll forward existing futures contracts into the next maturity contract. Finally Pope and Yadav (1990) single out a final category of arbitrageurs, who wish to change their position in the cash market and find it advantageous to use the futures market as an intermediary for their transaction. For example, if the futures are trading at a discount to their fair value, an institution wishing to increase its exposure to the cash market can outperform the cash market, until expiration of the futures contract, by buying the futures.

Because of the nature of transaction costs in the UK we would normally expect the equity market makers to be the main agents limiting the basis deviations in the market. Investors using the futures market as an intermediary will be active participants in the market, but their actions will not determine the boundary.

6. Analysis and Results

We derived the relationship that should exist between the value of a stock index futures contract and its underlying index in section 2. In order for us to compare our results with MacKinlay and Ramaswamy (1987) and Yadav and Pope (1990), we define the percentage mispricing series as $X_{t,T}$, the difference between the market futures price and the theoretically calculated futures price normalised by the Index;

$$X_{t,T} = \frac{F_{t,T} - F^{*}_{t,T}}{I_t} \quad (4)$$

where I_t is the index at time t.

This percentage error represents the profit that is possible to generate, via arbitrage.

If $X_{t,T} < 0$ with $|X_{t,T}| > C_t$ an arbitrageur can create a profit by buying the futures contract and selling the underlying stocks short. If $X_{t,T} > 0$ with $|X_{t,T}| > C_t$ a riskless profit can be generated by selling the futures contract short and borrowing to buy the underlying stocks.

The above trading rules have assumed that there are no taxes and that the arbitrage trades are held to expiration of the futures contract. If deviations outside of these transaction costs bounds persist we can conclude that the arbitrage capital extended by firms is limited.

Table 1 presents summary statistics of percentage price changes for both the FTSE 100 index futures contract and the underlying index.

If arbitrageurs maintain an effective link between the FTSE 100 index and its futures contract then as long as interest rates and dividends are non stochastic the variability of the two time series should be equal. However, past studies have found that the standard deviation of the futures series is higher than that of the index. This may be due to the fact that stocks and stock index futures receive and respond to the same information, but that the futures market responds quicker to news of a macro-economic nature as this news can be more easily related to the aggregate stock market than to the individual companies whose stocks comprise the index. The variability of the index futures time series exceeds that of the cash index in all of the contracts. Over the whole sample period the variability of the futures contract, as measured by the standard deviations of returns, is 0.2598 (measured at hourly observations) compared to 0.2148 for the underlying index. These results substantiate the conclusions of MacKinlay and Ramaswamy (1987) for the US market, and are in line with those of Yadav and Pope (1990) who base their analysis on opening and closing prices, as well as daily high and low prices. With regard to the relative variability of the index and the index futures contract, there seems to be a trend for the standard deviations of the two instruments to converge for the first 4 contracts after the October 1987 crash. During 1989 the difference in standard deviations of the two contracts remains fairly stable but increases for the contract covering the mini crash in late 1989. To establish formerly whether or not the markets are becoming more efficient and moving more in line with one another would require, however, a larger data set and is beyond the scope of this present paper. Tests on the autocorrelations of the series returns, not presented here, suggest that both are random walks.

Table 1: Return of FTSE 100 Index & Index Futures based on Hourly Observation

Contract		Index	Futures	Obs.
MAR88	Avg	-0.0127	-0.0170	307
	Max	2.2020	3.7225	
	Min	-0.8058	-1.3909	
	Std	0.2373	0.3315	
JUN88	Avg	-0.0080	-0.0143	314
	Max	0.9406	1.0634	
	Min	-1.2026	-1.4021	
	Std	0.2052	0.2565	
SEP88	Avg	-0.0017	-0.0162	367
	Max	0.7724	1.0528	
	Min	-1.2046	-0.9975	
	Std	0.1874	0.2090	
DEC88	Avg	-0.0118	-0.0089	358
	Max	0.6640	0.9147	
	Min	-1.2368	-1.4231	
	Std	0.1893	0.2084	
MAR89	Avg	0.0130	0.0100	344
	Max	0.9178	1.1076	
	Min	-1.1213	-0.9768	
	Std	0.2191	0.2539	
JUN89	Avg	0.0093	0.0050	349
	Max	0.5458	0.9162	
	Min	-1.2629	-1.5275	
	Std	0.1939	0.2340	
SEP89	Avg	0.0057	-0.0009	373
	Max	2.2974	2.0239	
	Min	-0.8614	-1.1237	
	Std	0.2085	0.2311	
DEC89	Avg	0.0052	0.0000	372
	Max	2.1135	2.0039	
	Min	-1.6536	-2.0212	
	Std	0.2670	0.3321	
TOTAL	Avg	0.0002	-0.0050	2784
	Max	2.2974	3.7225	
	Min	-1.6536	-2.0212	
	Std	0.2148	0.2598	

We now turn to the time series of mispricing of the FTSE 100 index futures contract as measured by the premiums and discounts given by equation (4). We are interested in this time series for a number of reasons. Firstly, mispricing outside of an arbitrageurs transaction cost band will lead to profitable arbitrage opportunities; so how much can he earn and how often? Secondly, if we don't know what the transaction cost levels are for index arbitrageurs in the UK we can attempt to estimate them by looking at the time series. Thirdly, because hedging a stock position which is different in composition from the underlying index portfolio with an index futures contract, is effectively a cross-hedge, the risk and return for an index futures hedge will depend on the behaviour of the basis.

Table 2 summarises the mispricing in the near FTSE 100 futures contract, measured by the premiums and discounts of the 8 expiration dates during the study period. Figures 1 to 3 illustrate these premiums and discounts for the closest maturing futures contract over three different expiration cycles. All of the statistics are computed using hourly intervals. We ignore the time lags involved when exchanges are closed.

Several interesting observations arise from Figures 1 to 3 and Table 2. Firstly, there are many deviations. Secondly, the average mispricing was negative for 6 out of the 8 contracts with the number of negative mispricing observations dominating the number of positive observations in the same 6 contracts . The mean positive deviation, over the whole sample, is approximately 45% of the mean negative deviation. The standard deviation of the percentage mispricing has remained fairly constant, although the December contract in both years exhibits slightly higher variability. Over all contracts the average mispricing is calculated at -0.468% and the average absolute mispricing at 0.648%. The former figure compares to Yadav and Pope's figures of -0.40% using closing prices and -0.35% using opening prices only. Yadav and Pope split their data sample into two sections: pre-big bang, and post-big bang. The statistics of the pre-big bang sub-period are closer to ours than the post-big bang period, i.e., a significantly higher number of negative mispricing observations and average mispricing of -0.55%. By using opening and closing prices only, a potential source of error is introduced into their analysis due to asynchronicity in index and futures prices producing noise in the time series of mispricing. The plots of percentage mispricing reveal that the mispricing level generally stays within the band dictated by transaction costs of +0.5% and -1.5%. Another interesting feature of Table 2 is the number of mispricing reversals. Mispricing reversals allow arbitrageurs to participate in the early unwinding aspect of stock index futures program trading which we analyse later. The number of reversals suggests that early unwinding may prove to be a profitable strategy for this data set.

Table 2: Premiums and Discounts on FTSE 100 Index Futures Contracts

	Obs	Num +ve	Num −ve	Max	Min	Ave	SD	Ave Abs	Ave ve+	Ave −ve	Rev
MAR88	359	65	294	0.509	−1.771	−0.443	0.418	0.449	0.155	−0.575	26
JUN88	367	53	314	0.514	−1.446	−0.510	0.449	0.558	0.166	−0.625	39
SEP88	429	8	421	0.287	−1.649	−0.792	0.417	0.797	0.144	−0.809	10
DEC88	419	70	349	0.511	−2.076	−0.658	0.636	0.721	0.189	−0.828	30
MAR89	403	310	93	1.461	−0.689	0.299	0.426	0.439	0.481	−0.305	30
JUN89	408	292	116	1.133	−0.545	0.200	0.311	0.296	0.346	−0.169	59
SEP89	436	68	368	0.4332	−1.715	−0.502	0.432	0.553	0.163	−0.625	14
DEC89	435	5	430	0.113	−2.992	−1.249	0.711	1.250	0.050	−1.264	5
TOTAL	3256	871	2385	1.461	−2.992	−0.468	0.688	0.648	0.338	−0.762	213

Table 3 presents summary statistics for changes in mispricing levels. The overall hourly standard deviation of 0.15%, for changes in mispricing for mispricing levels that generally stay within a band +0.5% and -1.5%, is consistent with the implication that when mispricing deviates towards its bounds, it is pulled back by the action of arbitrageurs.

Table 3
Summary Statistics of Changes in Mispricing in FTSE 100 Index Futures Contracts

Contract	Max	Min	Avg	Std Dev
Mar 88	1.5026	-0.7414	-0.0043	0.1957
Jun 88	0.5828	-0.6706	-0.0063	0.1496
Sep 88	0.5163	-0.3667	-0.0144	0.1357
Dec 88	0.3730	-0.4537	0.0030	0.1238
Mar 89	0.6201	-0.6046	-0.0031	0.1747
Jun 89	0.4587	-0.5022	-0.0044	0.1441
Sep 89	0.4213	-0.4751	-0.0068	0.1149
Dec 89	0.8525	-0.6758	-0.0052	0.1762
Total	1.5026	-0.7414	-0.0052	0.1524

Yadav and Pope (1990) provide formal evidence on actual transaction costs faced by arbitrageurs in the UK market. By analysing bid-ask spreads of index stocks and index futures contracts they calculate that all arbitrageurs operating in London will incur transaction costs of between 0.5% and 2.0%. Lines drawn on Figures 1 to 3 show bands created by transaction costs of 0.5%, 1.5%, and 2.0%. Mispricing which is greater than these bands will represent a profitable opportunity for arbitrageurs whose transaction costs are represented by these bounds.

Table 4 documents statistics for the mispricing violations of these transaction costs bounds.

Table 4: Mispricing Violations of Transaction Cost Bounds

	Obs	Num +0.5	Num −0.5	Ave +0.5	Ave −0.5	Num +1.0	Num −1.0	Ave +1.0	ave −1.0	Num −1.5	Ave −1.5	Num −2.0	Ave −2.0
MAR88	359	1	167	0.509	−0.806	0	33	0.000	−1.172	2	−1.658	0	0.000
JUN88	367	1	197	0.514	−0.870	0	59	0.000	−1.122	0	0.000	0	0.000
SEP88	429	0	320	0.000	−0.982	0	154	0.000	−1.238	4	−1.558	0	0.000
DEC88	419	1	230	0.511	−1.123	0	127	0.000	−1.473	58	−1.744	3	−2.040
MAR89	403	133	21	0.742	−0.607	15	0	1.177	0.000	0	0.000	0	0.000
JUN89	408	62	3	0.693	−0.531	3	0	1.075	0.000	0	0.000	0	0.000
SEP89	436	0	221	0.000	−0.840	0	52	0.000	−1.259	7	−1.602	0	0.000
DEC89	435	0	339	0.000	−1.527	0	273	0.000	−1.723	187	−1.919	66	−2.268
TOTAL	3256	198	1498	0.723	−1.066	18	699	1.160	−1.459	258	−1.869	69	−2.258

Mispricing equals 0 if the actual futures price is within the band around the theoretically calculated price dictated by the amount of transaction costs. Mispricing for actual prices higher than the upper band are calculated as the difference between the market price and the theoretical upper band normalised by the index value, with mispricing for market prices below the theoretical lower bound calculated as the difference between actual prices and theoretical lower bound prices normalised by the index.

The transaction costs band of 0.5% eliminates nearly all the positive mispricing exhibited in 1988, which is totally eliminated by a transaction cost level of 1.0%. By introducing a transaction cost filter of 2.0% both positive and all but 3 of the negative mispricing observations are eliminated. For the 4 contracts expiring in 1989 we experience mixed results. The two contracts which have a significant proportion of positive mispricing observations, have a greater percentage of their observations outside of the +0.5% level than outside of the -0.5% level, but with none of the observations outside of the band dictated by transaction costs of 1.5%. The December 1989 contract contains nearly all of the study's observations outside of the -2.0% filter.

Table 4 shows that 52% of our observations exceed the transaction costs band of 0.5%, 8% of the observations exceed the 1.5% band, and 2% exceed the band imposed by transaction costs of 2.0%. Yadav and Pope (1990), calculating with closing prices over their whole sample, find that the same transaction costs bands are exceeded by 56%, 8%, and 2% of their observations respectively. The slight difference in the narrower transaction cost band figure is probably again due to the fact that non-synchronous prices were used.

Merrick (1987) analyses the early unwinding and contract rollover aspects of stock index futures program trading. He concludes that unwindings and rollovers create effective transaction cost 'discounts' when compared with the costs from a sequence of hold-to-expiration trades, and help explain arbitrage activity even when prices are within transaction cost bounds. In fact Sofianos(1990) using a database of S&P 500 index arbitrage transactions during the first half of 1990 finds that, on average, index arbitrage transactions were established when the cash-futures mispricing did not cover transaction costs.

Trading strategies which involve rolling over existing futures positions into the next available maturity contract depend on the relative mispricing of the two contracts. We now compare the mispricing in the second nearest maturing futures contract with the nearest contract. We restrict our analysis to only expiration months, i.e.. March, June, September, and December, when the open interest in the second nearest futures contract begins to increase. Table 5 presents comparative summary statistics for both the near and the far contracts during these months. For each expiry month we detail the near and the far contract mispricing details, as well as the difference in mispricing measured by subtracting the far contract mispricing from the near contract mispricing. There are several interesting observations from this table. Firstly the difference in mispricing is predominantly positive. Secondly the number of positive observations correspondingly decreases as we compare the near with the far contract (to such an extent that 3 out of the 8 contracts have no positive mispricing observations), and the number of negative mispricing observations increases. Thirdly, the absolute values of mispricing are significantly larger for the far contract than the near contract. Fourthly, overall, the number of mispricing reversals is considerably greater in the near contract. All these points are consistent with the far contract trading at a bigger discount to its theoretical value than the near contract. With longer times until expiration there is an increased risk of unanticipated movements in the level of dividends which will widen the arbitrage bounds. A more important reason for the wider arbitrage bounds may be that a greater margin of error has to be allowed for, with longer times to expiration, if less than the full basket of index stocks is employed in the arbitrage. It can also be conjectured that there existed strong 'bearish' sentiment over this period. Finally, we observe that, in general, the variability of the near contract is less than that of the far contract.

Rollover strategies involve rolling the index future side of the buy and hold strategy forward into the next available maturity contract when the sign of the mispricing in the far contract is the same as the sign of the original mispricing and the difference in mispricing between the two contracts is greater than the incremental transaction costs. The figures in Table 5 suggest that stock index futures strategies which incorporated rollovers during 1988 and 1989 could have generated substantial arbitrage activity. We now go on to study how valuable the rolling over option and early unwinding option, mentioned earlier, would have been to arbitrageurs during this period.

Table 5: Premiums and Discounts on Near & Far FTSE 100 Index Futures Contracts

		Obs	Num +ve	Num -ve	Max	Min	Ave	Ave Abs	Rev	S.D.
MAR88	NEAR	142	45	97	0.292	-0.921	-0.237	0.301	19	0.314
	FAR	142	16	126	0.239	-1.256	-0.472	0.497	8	0.359
	DIFF	142	132	10	1.039	-0.122	0.236	0.243	5	0.198
JUN88	NEAR	157	37	120	0.443	-1.034	-0.226	0.290	29	0.311
	FAR	157	0	157	0.000	-1.049	-0.655	0.655	0	0.235
	DIFF	157	154	3	1.079	-0.219	0.429	0.433	6	0.181
SEP88	NEAR	149	8	141	0.287	-1.155	-0.354	0.369	10	0.264
	FAR	149	0	149	0.000	-2.581	-1.920	1.920	0	0.255
	DIFF	149	149	0	2.276	0.000	1.566	1.566	0	0.215
DEC88	NEAR	139	70	69	0.511	-0.471	0.009	0.181	30	0.221
	FAR	139	6	133	0.192	-1.296	-0.603	0.610	5	0.325
	DIFF	139	138	1	0.912	-0.033	0.612	0.613	1	0.198
MAR89	NEAR	122	120	2	1.190	-0.150	0.495	0.498	4	0.261
	FAR	122	109	13	1.318	0.000	0.626	0.626	0	0.304
	DIFF	122	19	103	0.877	-0.481	-0.132	0.257	26	0.278
JUN89	NEAR	156	89	67	0.623	-0.524	0.064	0.196	38	0.243
	FAR	156	21	135	0.319	-1.340	-0.334	0.367	16	0.309
	DIFF	156	149	7	1.340	-0.524	0.398	0.409	12	0.237
SEP89	NEAR	149	61	88	0.423	-0.701	-0.136	0.277	8	0.287
	FAR	149	0	149	0.000	-2.125	-1.458	1.458	0	0.401
	DIFF	149	144	5	1.676	-0.643	1.322	1.347	8	0.344
DEC89	NEAR	127	5	122	0.113	-1.049	-0.357	0.360	5	0.217
	FAR	127	5	122	0.162	-1.146	-0.377	0.382	8	0.272
	DIFF	127	73	54	0.336	-0.697	0.021	0.092	44	0.142
TOTAL	NEAR	1141	435	706	1.190	-1.155	-0.102	0.304	143	0.367
	FAR	1141	157	984	1.318	-2.581	-0.684	0.827	37	0.769
	DIFF	1141	958	183	2.276	-0.697	0.583	0.639	102	0.604

We analyse profits that could have been earned by arbitrageurs following some simple trading rules. The trading rules that we use are those which have been used previously by Merrick[1987] and Yadav and Pope[1989]. The first trading rule is the simple buy and hold strategy. If mispricing exceeds TC%, go short one futures contract and long the basket of index stocks, unwinding the position at expiration of the futures contract. Mispricing below -TC% involves shorting the basket and buying the futures contract. The early unwinding strategy involves initiating the arbitrage as in the buy and hold strategy but unwinding the positions prior to expiration if the sign of the mispricing changes, and the magnitude of the mispricing is sufficient to cover the additional market impact cost of dealing in the futures market, EC%. Thirdly, the rollover option involves rolling the futures side of the arbitrage into the next nearest contract during the expiry month if the direction of mispricing of the far contact is the same as that when the buy and hold strategy was initiated, and the magnitude of the difference of mispricing between the near and far contracts exceeds the incremental transaction costs, RC%. Finally, the fourth trading strategy involves a combination of the early unwinding, and rollover of the buy and hold strategy, whichever option becomes profitable first at an earlier date.

Tables 6.1, 6.2, and 6.3 detail the profits, in index points for 1 futures contract, for each of these strategies, at different levels of transaction costs for initiation of the buy and hold strategy. The first column in each table details the expiry of the contract. The second column gives the profits for the simple buy and hold strategy. We then have two columns for the early unwinding option. In the first, the figure in brackets corresponds to the highest profit that could have been made, ex-post. i.e., we look back over the contract and choose the parameters which would maximise the arbitrageurs profit. The figure without the brackets corresponds to the ex-ante trading profit, where the parameters are estimated from the previous four contracts (where that number of previous contracts exists in our database) as the 'optimal' parameters which maximise the profit for that contract[1]. The naive column corresponds to the profit obtained by using the parameters for TC, EC, and RC at the top of each table. The two columns for the remaining trading strategies are similarly defined.

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1 Note that the arbitrage position could be initiated and/or unwound within the usual arbitrage boundary in anticipation of future arbitrage opportunities. However, it can be argued that such an arbitrage is not completely risk free.

Table 6.1: Trading Profits From Arbitrage Strategies
(TC=0.5%, EC=0.2%, RC=0.3%)

	Naive Buy & Hold	Optimal Ear. Unw.	Naive Ear. Unw.	Optimal Rollover	Naive Rollover	Optimal Ear. Unw. & Rollover	Naive Ear. Unw. & Rollover
JUN88	2.6360	14.8157 (23.2881)	19.6255	0.0000 (30.6788)	3.9983	10.6890 (30.6788)	16.4842
SEP88	4.9997	6.1738 (22.8261)	6.5747	41.0567 (56.1303)	24.8052	24.8052 (56.1303)	24.8052
DEC88	22.0451	18.6888 (34.4522)	24.4145	31.7353 (39.3673)	30.5811	30.6073 (39.3673)	30.5811
MAR89	0.5719	19.5907 (46.6466)	11.5622	19.5907 (22.8168)	0.5719	19.5907 (51.1914)	10.8652
JUN89	11.2043	27.1165 (29.1402)	19.8701	0.0000 (13.1287)	11.2043	0.0000 (29.1402)	16.4015
SEP89	10.1449	15.6448 (32.7360)	12.0093	16.5252 (57.2907)	33.4513	47.3678 (57.2907)	33.4513
DEC89	24.1909	24.1909 (57.6142)	24.1909	24.1909 (53.1956)	24.3425	24.1909 (57.6142)	24.3425
TOTAL	75.7928	126.2212 (246.7034)	118.2472	133.0988 (272.6082)	128.9546	157.2509 (321.4129)	156.9310

Note: The profits are denominated in index points per futures contract.

Table 6.2: Trading Profits From Arbitrage Strategies
(TC=1.0%, EC=0.2%, RC=0.3%)

	Naive Buy & Hold	Optimal Ear. Unw.	Naive Ear. Unw.	Optimal Rollover	Naive Rollover	Optimal Ear. Unw. & Rollover	Naive Ear. Unw. & Rollover
JUN88	3.6990	4.2972 (12.3098)	8.2025	0.0000 (21.9273)	5.0612	0.0000 (21.9273)	5.0612
SEP88	1.3499	12.0027 (13.5776)	2.9248	31.8082 (46.8818)	21.1553	31.8082 (46.8818)	21.1553
DEC88	12.9581	12.8035 (25.2457)	14.8780	22.6483 (30.1608)	21.4941	21.4941 (30.1608)	21.4941
MAR89	9.3957	9.3957 (28.5923)	9.3957	9.3957 (12.6218)	8.6987	9.3957 (31.8184)	8.6987
JUN89	0.8338	0.0000 (10.1876)	1.4063	0.0000 (2.7667)	0.8338	0.0000 (10.1876)	1.4063
SEP89	5.7117	5.7117 (21.5305)	7.5761	9.0262 (46.0852)	29.0182	29.0182 (46.0852)	29.0182
DEC89	12.8294	12.8294 (41.4020)	12.8294	12.8294 (42.5536)	12.9810	12.8294 (42.5536)	12.9810
TOTAL	46.7776	57.0402 (153.8455)	57.2128	85.7058 (202.9972)	99.2423	104.5466 (229.6147)	99.8148

Note: The profits are denominated in index points per futures contract.

Table 6.3: Trading Profits From Arbitrage Strategies
(TC=1.5%, EC=0.2%, RC=0.3%)

	Naive Buy & Hold	Optimal Ear. Unw.	Naive Ear. Unw.	Optimal Rollover	Naive Rollover	Optimal Ear. Unw. & Rollover	Naive Ear. Unw. & Rollover
JUN88	0.0000	0.0000 (3.5583)	0.0000	0.0000 (13.1758)	0.0000	0.0000 (13.1758)	0.0000
SEP88	2.7542	2.7542 (4.3291)	4.3291	22.5597 (37.6333)	22.5597	22.5597 (37.6333)	22.5597
DEC88	3.8711	3.7165 (16.0392)	5.7910	13.5613 (20.9543)	12.0471	12.4071 (20.9543)	12.0471
MAR89	0.0000	0.0000 (9.2193)	0.0000	- 0.7993 (2.4268)	0.0000	- 0.7993 (9.4802)	0.0000
JUN89	0.0000	0.0000 (0.0000)	0.0000	0.0000 (0.0000)	0.0000	0.0000 (0.0000)	0.0000
SEP89	1.1133	0.0000 (10.3250)	2.9777	1.1133 (34.8797)	24.4197	21.4917 (34.8797)	24.4197
DEC89	1.4679	6.6837 (31.7600)	1.4679	6.6837 (31.9116)	1.6195	6.6837 (31.9116)	1.6195
TOTAL	9.2065	13.1544 (74.2309)	14.6747	43.1187 (140.9815)	60.6460	62.3429 (148.0349)	60.6460

Note: The profits are denominated in index points per futures contract.

The profits from early unwinding and rollover are significant. For the transaction cost band of 0.5% the naive form of trading rules 2, 3, and 4 give profits greater than the simple buy and hold strategy of 56%, 7%, and 107% respectively. The higher the transaction cost band the greater is the proportion of profit of the early unwinding and rollover strategies over the buy and hold strategy, with the proportion of rollover profits exceeding that of early unwinding. We find that difference between the profit levels from the naive trading strategies and the 'optimal' trading strategies are not significant, implying that the parameter estimates are not consistent across contracts. With a TC band of 0.5% the 'optimal' strategies perform slightly better than the naive ones. Widening the band leads to the 'optimal' version of trading rule 4 only slightly outperforming the naive strategy, but the naive versions of trading rules 2 and 3 outperforming their 'optimal' counterparts. Finally, at TC levels of 0.5% the ex-ante strategies earn about half of the ex-post maximum profits, with this ratio declining when we increase TC.

We now analyse whether the mispricing is systematically related to the future value at maturity of the dividends, between each observation and maturity, and the time to maturity of the contract, both important parameters in the pricing relationship. We seek to test whether the magnitude of mispricing is positively related to time to maturity and dividends. In separate tests we find that the calculated dividend effect and the time to maturity are highly correlated and so we perform two simple regressions; the regression of absolute mispricing on the time between the current account date and the account date associated with the expiration of the contract and on the accumulated dividend effect. The results of the regressions are contained in Table 7. As we would expect, due to the high degree of correlation between the two variables, the results from the two simple regressions are similar. For the absolute mispricing verses time regression, except for the March 1989 contract, the slope coefficients are positive and statistically significant, confirming that the longer the time to expiration the greater the mispricing. The explanatory power varies from one contract to another in the range of 19.1% to 76.6%. For the March 1989 contract the slope coefficient is negative and significant, but the R^2 is extremely low compared with the other contracts.

Table 7: Regression Results

$$|X_t| = a_0 + a_1(T' - t') \qquad and \qquad |X_t| = b_0 + b_1 Div_t$$

	a_0	a_1	R^2
MAR88	0.00267 (8.84)	0.000053 (9.24)	19.1%
JUN88	0.00367 (11.4)	0.000056 (7.39)	12.8%
SEP88	0.00275 (16.1)	0.000134 (37.0)	76.1%
DEC88	−0.00231 (−7.96)	0.000183 (37.0)	76.6%
MAR89	0.00530 (21.2)	−0.000023 (−4.32)	4.2%
JUN89	0.00172 (9.77)	0.000034 (8.57)	15.1%
SEP89	0.00216 (8.99)	0.000088 (17.1)	40.0%
DEC89	0.00170 (3.38)	0.000203 (24.1)	57.1%
TOTAL	0.00195 (14.0)	0.000107 (38.7)	31.4%

	b_0	b_1	R^2
MAR88	0.00247 (8.68)	0.000275 (10.7)	24.2%
JUN88	0.00370 (11.8)	0.000346 (7.53)	13.2%
SEP88	0.00275 (14.7)	0.000568 (33.6)	72.5%
DEC88	−0.00329 (−8.11)	0.001143 (28.2)	65.6%
MAR89	0.00489 (16.9)	−0.000045 (−1.95)	0.7%
JUN89	0.00158 (8.57)	0.000159 (8.93)	16.2%
SEP89	0.00193 (7.93)	0.000357 (17.7)	41.8
DEC89	0.00201 (4.92)	0.001095 (29.4)	66.5%
TOTAL	0.00270 (17.9)	0.000416 (29.7)	21.3%

We now wish to identify and estimate the process followed by the mispricing time series. The first step in this analysis is to produce an autocorrelogram and partialcorrelogram for the mispricing series X_t. Table 8 presents the results which indicate that an AR2 process provides a reasonably good description of the mispricing series, implying that the basis is mean-reverting. A smooth geometric decay in the autocorrelation implies that the time series of mispricing is stationary. The partial autocorrelations are generally close to zero after the first two lags which is a strong indication of an AR2 process. Another argument in favour of this process is that overfitting the model does not improve the explanatory power, except for the December 1988 contract. Finally, residual analysis confirms the above findings. Table 9 gives the parameters for the estimated ARIMA model for the mispricing time series. The estimated parameters are consistent across different contracts which indicates that, although the sign and magnitude of mispricing changes substantially for different contracts, the process followed by X_t is stable over time. The finding that the mispricing time series tends to an AR2 process is different from that of Yadav and Pope (1990) whose series, based on opening and closing prices, tends to an AR1 process.

In order for us to build a greater understanding of mispricing behaviour and to be able to provide normative analysis for optimal index arbitrage activity we now look at how we might examine the path dependency of the mispricing series. Both MacKinlay and Ramaswamy (1988) and Merrick (1989) find that the basis is influenced by the behaviour of arbitrageurs. MacKinlay and Ramaswamy suggest that the path dependency is due to arbitrageurs unwinding positions established when the mispricing was outside one bound before it reaches the other bound. They look at all the cases where the mispricing crossed the upper (lower) bound, returned to 0 and then again crossed the upper (lower) bound. Their results support their hypothesis that the mispricing series is path dependent. Because their data has each contract dominated by either upper bound violations or lower bound observations they set their arbitrage bounds as the transaction cost bounds of -0.6%. Our data shows the mispricing to be consistently negative. To use symmetric arbitrage bounds on our database would result in very few observations of the form upper, 0, upper or upper, 0, lower. It is not clear how we should define the arbitrage bounds in London. The problem of short selling in London is greater than the short selling problems in US markets, and leads us to the conclusion that symmetric arbitrage bounds do not fit the London market well.

7. Summary and Conclusions

This paper examines the relationship between futures prices on the FTSE 100 index in London, and theoretically calculated 'fair' values based on the underlying index. We adapt the fair value 'cost-of-carry' forward pricing formula to take into account the fact that the stock side of any cash-futures arbitrage is settled not on the date of the transaction but on an account settlement date associated with each transaction date.

After reviewing the previous studies on stock index futures mispricing we suggest that there exist several different categories of arbitrageurs in the London market and that, because of the nature of transaction costs in the UK we would only expect the category with the lowest level of transaction costs (normally firms who make markets in all FTSE 100 stocks) to be active in this market.

Our results, which are based on an hourly database of futures and index prices of the FTSE 100 index, show that the variability of the futures market has consistently been higher than that of the cash market. The results suggest that the fair value forward pricing formula is frequently violated; often by large amounts with the tendency for mispricing to be negative and persistent. Violations of the 0.5% transaction costs band are frequent (52% of all observations) but are nearly eliminated when we introduce a filter of 2% (2% of all observations).

Analysis of the relative mispricing of the near and far contracts during months with reliable quotes, i.e. contract expiration months, reveals that the far contract is nearly always mispriced to a greater extent than the near contract, with a greater number of negative mispricing observations and less reversals in mispricing sign.

We find that the profits available from the early unwinding and rollover options are significant. The higher the transaction cost band for the initiation of the strategies, the greater is the proportion of profit of the early unwinding and rollover strategies over the buy and hold strategy. We find that difference between the profit levels from the naive trading strategies and the 'optimal' trading strategies, as defined parameters chosen from the previous 4 contracts, are not significant, implying that the parameter estimates are not consistent across contracts. At TC levels of 0.5% the ex-ante strategies earn about half of the ex-post maximum profits, with this ratio declining when we increase TC.

Simple regressions of absolute mispricing on time to maturity and the accumulated dividend effect confirms the longer the time to expiration the greater the level of mispricing. Tests to identify and estimate the process suggests that an AR2 process provides a reasonably good fit. An analysis of the estimated parameters suggests that the process followed by the mispricing variable is stable over time.

Finally, with a database of more contracts we hope to be able to gain an increased understanding of mispricing behaviour and to be able to paramaterise the arbitrage bounds for the London market. This will enable us to study the stochastic behaviour of the time series of mispricing and will help us to establish whether path dependency of the type described by MacKinlay and Ramaswamy exists for our data.

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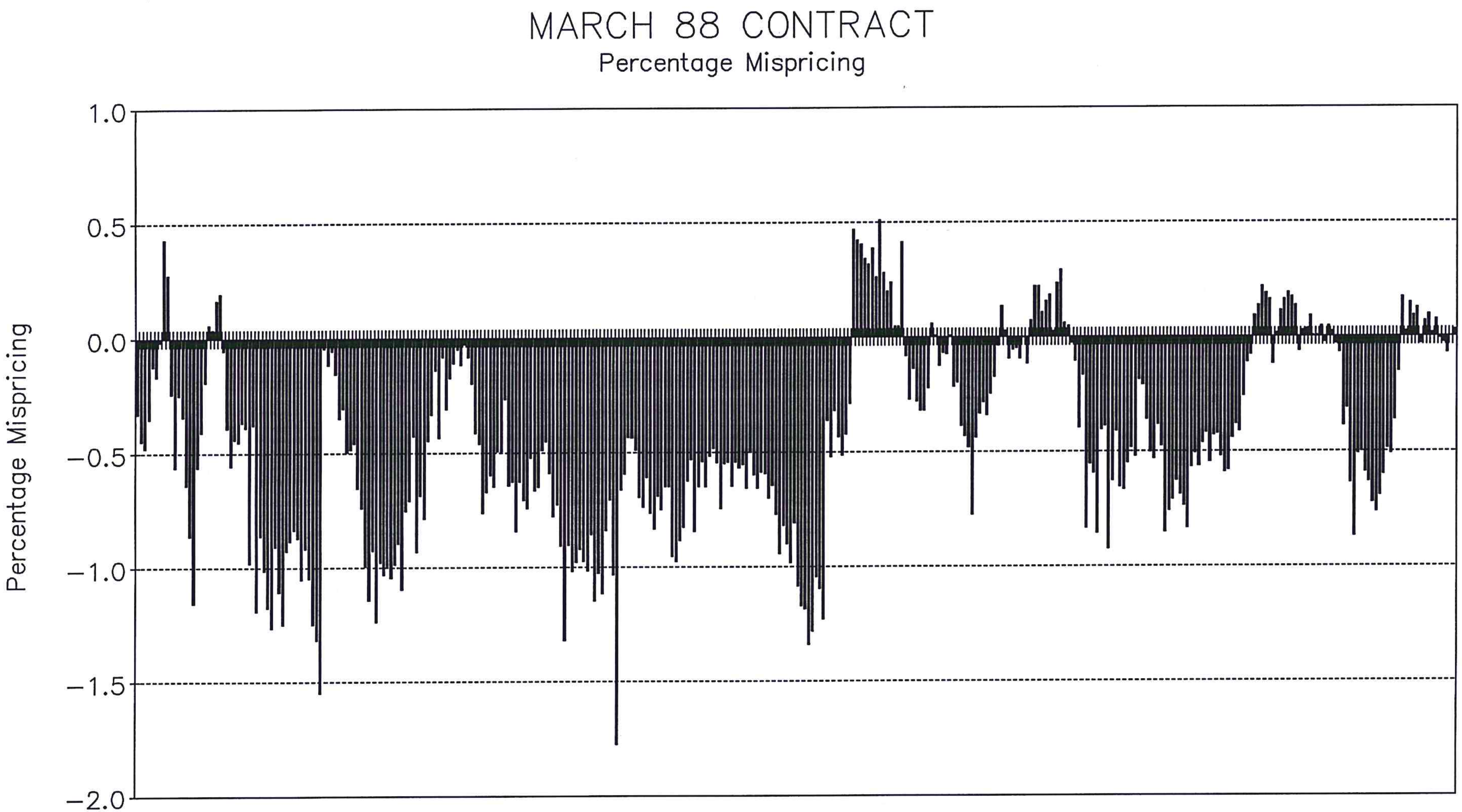
MARCH 88 CONTRACT
Percentage Mispricing
Percentage Mispricing
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0

Figure 1

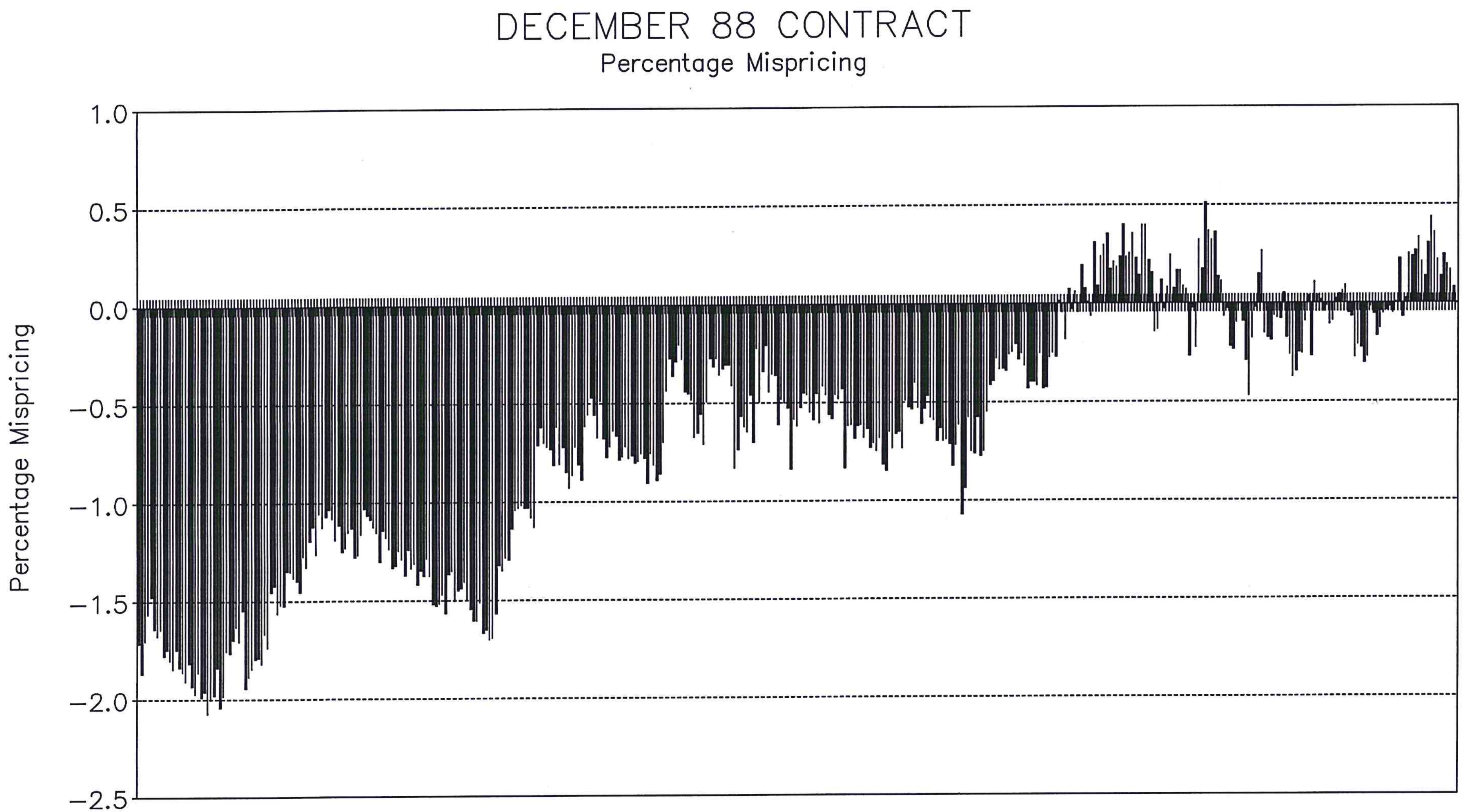
DECEMBER 88 CONTRACT
Percentage Mispricing
Percentage Mispricing
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5

Figure 2

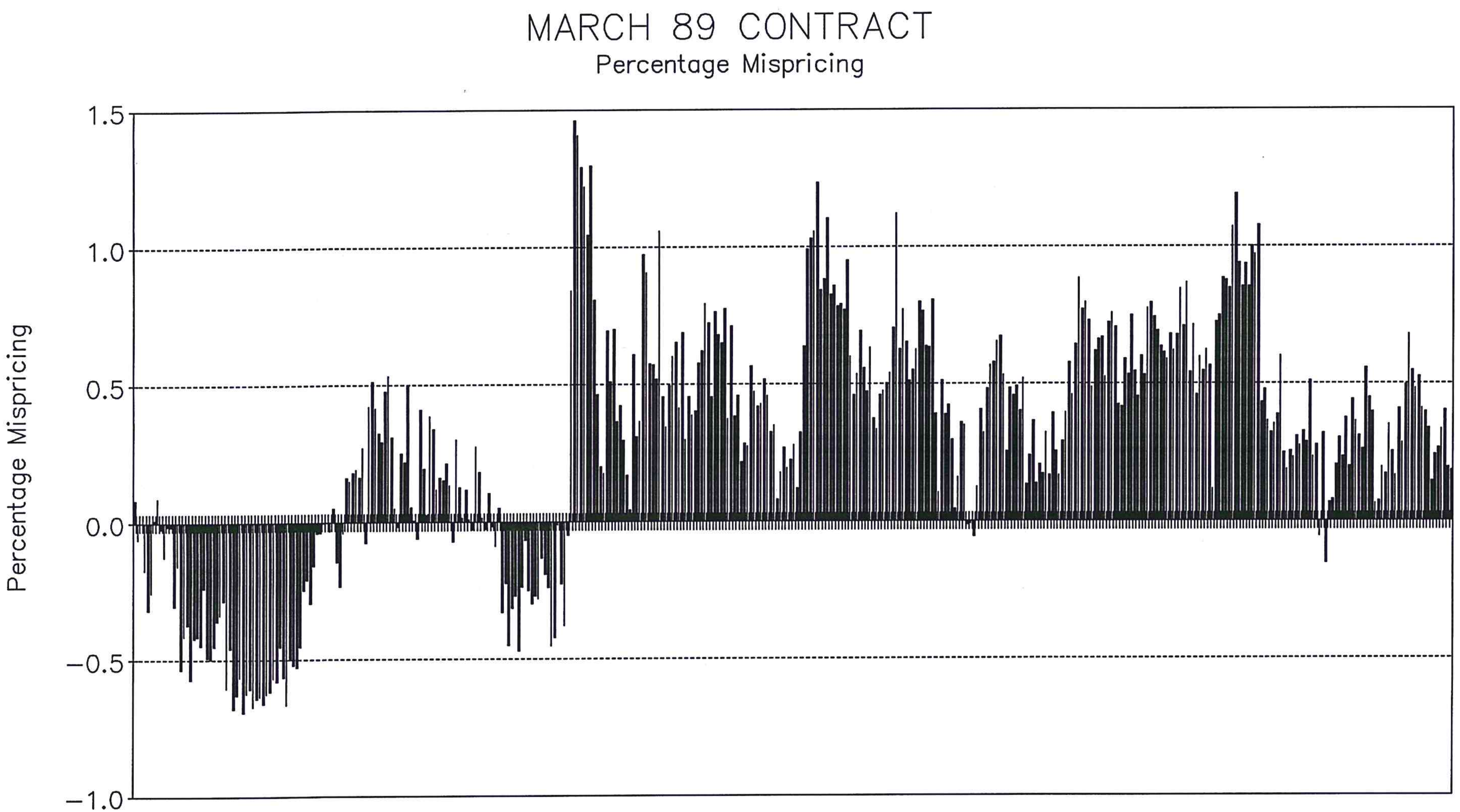
MARCH 89 CONTRACT
Percentage Mispricing
Percentage Mispricing
1.5
1.0
0.5
0.0
−0.5
−1.0

Figure 3