RETURN AND VOLATILITY DYNAMICS IN THE FT-SE 100 STOCK INDEX AND STOCK INDEX FUTURES MARKETS

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INTRODUCTION

The temporal relationship between the price of stock index futures contracts and the underlying cash market has attracted the attention of academics, practitioners, and regulators due to both the considerable volume of trading in these contracts and their role during periods of turbulence in financial markets. An important aspect of this relationship is the nature of the lead–lag in the returns between equivalent assets traded in different markets or the predictive power of price movements in one market for those in the other market. Stock index futures contracts are usually priced using the forward pricing model which, given perfect capital markets and non-stochastic interest rates and dividend yields, implies that the contemporaneous rates of returns of the futures contract and the underlying index portfolio should be contemporaneously cor-

I thank P.K. Yadav and P.F. Pope for use of the FT-SE 100 Index and Index Futures data set used in this study. I am also grateful to P.R. Draper, R.J. Limmack, Mark Powers, the Editor, two anonymous referees, and participants at the MidWest Finance Association Conference 1993 for helpful comments and suggestions. Financial assistance from the University of Strathclyde during the period this study was undertaken is also gratefully acknowledged. All errors and omissions are my sole responsibility.

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The Journal of Futures Markets, Vol. 15, No. 4, 457–488 (1995)

CCC 0270-7314/95/040457-32

related and not cross-autocorrelated. Hence, relevant new information should, theoretically, be impounded simultaneously into both the futures and cash market prices and, therefore, price movements in one market should not lead or lag movements of prices in the other market. In the presence of market imperfections however one market may react faster than the other leading to a lead–lag relationship. Empirical research[1] has tested for the presence of a lead–lag relationship between the index futures and the underlying cash market. The factors influencing this relationship as well as its behavior under varying market conditions have been studied as well. In addition, several recent studies,[2] have tested for a lead–lag in the volatility of returns between stock index futures and the underlying index. This relationship is of particular interest given the theoretical links between information and volatility [Ross (1989)] and the practical interest in the transmission of volatility between the index futures and cash markets.

The purpose of this article is fourfold. First, it seeks to investigate the lead–lag relationship between hourly returns in the FT-SE 100 stock index futures and the underlying cash index using hourly data for the period 1986–1990; this data set covers three sub-periods marked by distinct structural breaks which distinguish stages in the evolution of the U.K. stock index futures market. The data from the first two periods allow for a direct test of the role of transactions costs in the lead–lag relationship between the two markets. Second, the behavior of the lead–lag relationship is examined under varying market conditions: periods of "good" and "bad" news, episodes of low and high volatility and trading activity in the underlying equity market. Third, the article examines empirically the relationship between the volatility in one market and its predictive power for volatility in the other market using a conditional estimate of the return variance. Earlier studies used unconditional variance estimates. Finally, the relationship between the lead–lag in the volatility between the two markets is examined under varying market conditions (periods of "good" and "bad" news and low and high trading volume).

Research in this area is important for several reasons. First, existing research has concentrated largely on the U.S. index futures markets. It is of interest to extend this work to a different market environment.

[1]A selective list includes Herbst et al. (1987), Kawaller et al. (1987), Laatsch and Schwarz (1988), Ng (1987), Stoll and Whaley (1990), Schwarz and Laatsch (1991), Cheung and Ng (1991), Chan (1992), Grunbichler et al. (1994).

[2]Examples include Kawaller et al. (1990), Cheung and Ng (1989, 1991), Chan et al. (1991) and Chan (1992).

Second, since the data set covers periods separated by structural breaks with distinctly different transactions costs, it is possible to conduct a direct test of their role in the lead–lag relationship between the futures and the cash market returns. Third, as described in Sofianos (1993), the lead–lag relationship and its behavior are of particular relevance to arbitrageurs who are required to complete both legs of an index arbitrage transaction. The results of this study should therefore be of interest to practitioners. Finally, tests of the predictive power of volatility in the futures market on the underlying cash market is of concern to regulators who need to know the impact of index futures trading on the underlying market.

PREVIOUS RESEARCH, THEORETICAL BACKGROUND, AND METHODOLOGY

Previous Research

A number of studies have examined the temporal relationship between the index futures and cash index returns, based on tests for causality as defined in Granger (1969, 1988). For example, Ng (1987) tests for Granger causality between returns for cash and futures using a variety of stock indices, currencies, and agricultural commodities. Her results suggest that futures prices generally lead spot prices in revealing new information. Kawaller et al. (1987) find that the S&P 500 futures lead the S&P 500 index returns by 20 to 45 minutes, while the lead from cash to the futures rarely lasts beyond one minute. Stoll and Whaley (1990) report that the S&P 500 and the Major Market Index (MMI) futures tend to lead the stock index returns by about five minutes on average, but occasionally by as long as ten minutes or more. However, their results show some weak positive predictive effects of lagged stock index returns on current futures returns. Chan (1992) also finds that the futures leads the cash index and weaker evidence that the cash index leads the futures in the MMI (Major Market Index) futures and the S&P 500 futures markets. He also finds that the lead–lag relationship is largely robust to varying market conditions. Grunbichler et al. (1994) report evidence of a lead–lag in the DAX index futures market and its relationship to the trading mechanism there. Several studies have tested for a lead–lag relationship in the volatility of the index and the index futures returns based on the concept of causality in variance as in Granger et al. (1986). Kawaller et al. (1990) use intra-daily data on the S&P 500 Index and Index futures to examine the relationship between the futures price volatility and index volatility using unconditional variance estimators. They find no systematic pattern of futures volatility leading index volatility. Cheung and Ng (1991) report that no stable pattern emerges in the lead–lag between the S&P 500 index futures and the cash return volatilities. Chan et al. (1991), using a bivariate AR(1)-GARCH(1,3) model, study the S&P 500 index futures and cash returns. They find a much stronger bi-directional dependence, with past volatility of futures (cash) price changes identified as an important predictor of the future volatility of the cash (futures) price changes.

The general conclusion of previous research is that the returns in the futures market seem to lead the cash market returns. There is, however, some weak evidence of predictive ability from cash to futures. The tests for lead–lag in the volatility of the futures and the cash return series seem to suggest that this lead–lag relationship is variable over the sample period.

Theoretical Background

The forward pricing model, usually used for pricing stock index futures contracts, assumes perfect markets and non-stochastic interest rates and dividend yields. The model implies the following relationship between the price of an index futures contract and the price level of the underlying index:

$$F_t = C_t \exp(r - d)(T - t) \tag{1}$$

or alternately,

$$r_{c,t} = (r - d) + r_{f,t} \tag{2}$$

where, F_t = index futures price at time t; C_t = index price at time t; $r_{c,t} = \ln C_t/C_{t-1}$; $r_{f,t} = \ln F_t/F_{t-1}$; $r - d$ = net cost of carrying the underlying stocks in the index, i.e., the rate of interest less the rate at which the dividend yield on the stock index accrues to the holder; and $T - t$ = time remaining to the expiration date (T) of the futures contract. The relationship in eq. (2) implies, that: (i) the variance of the rate of return of the futures contract equals the variance of the rate of return of the underlying stock index and (ii) the contemporaneous rates of return of the futures and the cash are perfectly, positively correlated while the non-contemporaneous rates of return are uncorrelated and no lead–lag relationship would exist.

However, there are several reasons why, in the presence of market imperfections, there may be a lead–lag relationship between the index futures and cash market returns.

(1.) The lead–lag relationship between the two markets may be induced by infrequent trading of the stocks comprising the index. If, for example, 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. In other words, the index reflects "stale" prices. Therefore, if futures prices reflect information instantaneously, the "stale" cash index prices will lag the futures prices. It needs to be noted in this context that, unlike the S&P 500 Index which is based on the last recorded transaction price, the FT-SE 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 FT-SE 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,[3] 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 FT-SE 100 Index because the mid-point of the spread may not always reflect a "tradeable" price. In view of this, Stoll and Whaley (1990) suggest that the issue of drawing incorrect inferences about the lead–lag relationship in the presence of index autocorrelation can be reduced by using an ARMA model to filter out the effects of infrequent trading and bid–ask spreads on the index returns and then using the return innovations to proxy for the "true" index returns in the regression estimations.

(2.) Differences in liquidity between the spot and futures markets could also induce a lead–lag relationship. For example, if the average time between trades for the constituent firms in the index is longer than the average time between trades for the futures contract, information will be impounded in futures prices more rapidly on average than in spot prices, resulting in a lead–lag relationship between spot and futures prices. It is, however, important to note that it is the difference in the liquidity of the spot and futures markets that creates the lead–lag relationship—the lead–lag relationship is a function of the relative liquidity of the markets, rather than their absolute liquidity.

[3]A recent study by the London Stock Exchange (*Quality of Markets Review*, Spring 1992) suggests that some 50–60% of institutional trades occur inside the best prices or the "touch."

(3.) Anthony (1988), Stoll and Whaley (1990), Stephan and Whaley (1990), and Miller (1990) argue that market frictions such as transaction costs, capital requirements, and short-selling restrictions may make it optimal for some to trade in the derivatives market rather than the cash market. Furthermore, Grossman and Miller (1988) and Miller (1990) show that futures markets may provide more immediacy to traders than does the cash market. It is, therefore, likely that informed traders may find that they can act on their private information more rapidly and at a lower cost in the futures market than in the spot market, resulting in a lead–lag relationship between futures and cash prices.

(4.) In some situations informed traders may choose to trade in the spot market rather than in the futures market. For example, Subrahmanyam (1991) and Chan (1992) show that if an informed trader has firm-specific information, it may be optimal to trade the shares of the firm directly rather than trading the index futures. Thus, for some types of information, the transmission of information may run from the spot to the futures market. This implies, as discussed by Chan et al. (1991), the possibility of a bidirectional lead–lag relationship between the futures and the cash returns.

Methodology

To examine the nature of the lead–lag relationship between returns in the cash and the futures markets, following Stoll and Whaley (1990) Chan (1992), the following regression is estimated:

$$r_{c,t} = a + \sum_{j=-n}^{j=n} b_j r_{f,t-j} + \varepsilon_t \tag{3}$$

where $r_{c,t}$ and $r_{f,t}$ are the hourly futures and the cash returns at time t, n denotes the number of leads/lags used and ϵ_t denotes the error term. The regressions are estimated using Hansen's (1982) variance–covariance estimator, resulting in t-ratios which are consistent in the presence of serial correlation and heteroscedasticity. Further, a chi-square test that the coefficients $\{b_{-i}\}$ and $\{b_{+i}\}$ are jointly zero provides a test of the hypothesis that the cash leads the futures and that the cash lags the futures, or that futures leads the cash, respectively, in the mean returns.

As indicated earlier, a number of studies have examined the lead–lag relationship in the volatility of the cash index and the index futures returns. Pagan and Schwert (1990) and Kearns and Pagan (1990) outline a number of ways to obtain estimates of a time series of volatility from a time series of asset prices. One method involves the estimation of the unconditional volatility of long time interval using returns available from shorter periods, as in Kawaller et al. (1990). Other methods of estimating the conditional volatility include the two step iterative procedure of Davidian and Caroll (1987); the Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model of Bollerslev (1986); and the Exponential or EGARCH models of Nelson (1991) and other non-parametric models. Pagan and Schwert (1990) find that the non-parametric models are the best predictors in-sample but perform poorly out-of-sample. Among the parametric models, the EGARCH model performs better both in and out-of-sample. In addition, Nelson (1990) reports that conditional volatility estimates, using high frequency data generated even by a misspecified ARCH model, converge to the true conditional volatility and can be used to estimate the volatility very precisely. In this article therefore, EGARCH models are first estimated[4] for both the cash and the futures returns separately. Based on these estimations, two series of conditional variance estimates for the futures and the cash returns are generated and used to examine for lead–lag in the volatility of the futures and the cash returns based on the following regression:

$$h_{c,t} = \alpha + \sum_{j=-n}^{j=n} \beta_j h_{f,t-j} + \eta_t \tag{4}$$

where $h_{c,t}$ and $h_{f,t}$ are the hourly estimates of the conditional volatility of the cash and the futures returns respectively at time t; η_t is the error term; and n the number of leads/lags used in the regression. Again, the t-ratios and the χ^2-test statistics are based on Hansen's (1982) variance–covariance matrix.

THE DATA SET

The FT-SE 100 Index futures contract traded on the LIFFE is based on the FT-SE 100 Index, an arithmetic average, value-weighted index of the top 100 domestic stocks in terms of market capitalization, traded on the International Stock Exchange, London. The FT-SE 100 Index futures contract trades on a quarterly cycle maturing in March, June,

[4]The EGARCH model is estimated using the Berndt et al. (1974) algorithm by maximizing the log-likelihood function. In this case, a parsimonious AR(2)-EGARCH(1.1) model is selected based on the Akaike Information Criterion. The achievement of a global maximum is tested using a number of different starting values. The estimated regression is used to obtain a time series of values of h_t, the conditional volatility for the futures and cash return series. Detailed results are available from the author on request.

September, and December annually. The near contract is the most heavily traded. The index futures time series analyzed here uses data on the near contract shifting to the next near contract on the expiration day. During this sample period the cash market was open from 9:00 AM to 5:00 PM daily while the futures market was open from 9:05 AM to 4:05 PM. As a result, while the two series are based on coincident prices[5] at other times, the 9:00 AM cash prices are matched with the 9:06 AM futures prices. The entire data set consists of hourly cash and index futures data from 4/28/86 to 3/23/90 corresponding to 990 trading days and 7920 hourly observations. The return series for the index futures and the cash levels are constructed by taking the first difference of the natural logarithm of each price, resulting in eight hourly returns including the over-night or weekend return.

An important source of bias in tests for lead–lag relationships is the use of non-synchronous data, i.e., futures and cash prices which are not observed at the same point in time. In this data set, the opening cash price at 9:00 AM is matched to the futures price at 9:06 AM, whereas all the other prices are coincident. Following Stoll and Whaley (1990), the first observation for the day for the futures as well as the cash levels is deleted while constructing the return series to reduce this possible source of bias. The overnight return is also ignored because it is measured over a longer time period. The data set used in the estimations, therefore, has six returns per day for the index and the index futures series based on equally spaced (hourly), exactly coincident cash-futures prices. Since the first observation in both series is taken an hour after the market opens, this study reduces the effects of "stale" prices being reflected in the index values.

Finally, this study divides the entire sample period into three natural sub-periods. Period I, from 4/28/86 to 10/24/86, is the period prior to the introduction of the major structural reforms in the International Stock Exchange, London, known as the Big Bang. The second period extends from 10/27/86 to 9/30/87, i.e., post Big Bang to the Crash of 1987. The third sub-period of analysis includes the time following the 1987 Crash, 1/5/88 to 3/23/90. Periods I and II are separated by the Big Bang during which the International Stock Exchange (ISE) introduced several major reforms including: replacement of the single with a dual capacity system, opening up of dealerships to banks and other financial institutions, the liberalizing of commissions, halving the

[5]The futures price is extracted if it is posted less than 60 seconds before the corresponding hourly cash index price.

stamp duty, and the extension of the use of screen-based quotations to all stocks traded on the ISE. As a result, the competitiveness of the ISE increased considerably and on large deals transactions costs fell by about a third.[6] The inclusion of this period enables direct examination of the impact of a reduction in transactions costs on the nature of the lead–lag relationship.

EMPIRICAL RESULTS

Descriptive Statistics

Tables IA and IB provide summary statistics on the hourly futures and cash returns. The observed serial correlation and the heteroscedasticity in the data suggest the use of a robust variance–covariance matrix estimator which allows reliable inferences to be drawn from the test statistics. The FT-SE 100 Index autocorrelation, at lags 1 and 2 is significant and positive. It is between 0.25 and 0.08 in 1986, prior to the Big Bang, and falls to between 0.14 and −0.008 in 1990. This could imply, as in Froot and Perold (1990), that over the sample period there is less non-synchronous trading or that the cash market is more efficient in processing market-wide information. Next, Table IC describes the intraday cross-correlations between the hourly future and index returns for up to 10 leads and lags each sub-period. The average contemporaneous cross-correlation is about 0.49 in Period I, increases to 0.75 after the Big Bang and increases further to 0.82 in Period III. Lagged returns from both series seem to have forecast power for the other series. This can be seen from the significant correlation coefficients. Finally, Table ID describes the cross-correlation in the squared returns for each period. The squared cross-correlations can be taken as crude indicators of the volatility link between the two markets. Cross-correlation coefficients for the squared returns are also significant up to lag three in both directions. These preliminary results suggest that a lead–lag relationship may exist

[6]The total cost of a round trip of £500,000 before and after the Big Bang is as follows:

	Before Big Bang	After Big Bang
Stamp Duty	1.00%	0.50%
Commission	0.31%	0.25%
Average Touch	1.56%	1.24%
Total	2.87%	1.99%

These figures are from Pagano and Roell (1990).

between the index futures and the cash returns and also between the volatilities of these returns.

Lead–Lag Relationship between Cash and Futures Market Returns

The lead–lag relationship between the index and the index futures markets is first examined by estimating the regression:

$$r_{c,t} = a + \sum_{k=-3}^{k=3} b_k r_{f,t-k} + \varepsilon_{c,t} \tag{5}$$

where $r_{c,t}$ and $r_{f,t}$ are the hourly index and index futures returns at time t. The coefficients with negative subscripts are the lead coefficients and the positive subscripts are the lag coefficients. If the lead coefficients are significant then the cash leads the futures; and, if the lag coefficients are significant, the cash index lags the futures. The choice of lead/lag length (i.e., three) is based on the results reported in Table ID which suggest that cross-correlation coefficients at longer leads/lags are not significant.

TABLE IA
Summary Statistics for the Hourly Returns on the FT-SE 100 Index from April 28, 1986 to March 23, 1990

		Period I	*Period II*	*Period III*
Sample size		709	1318	3224
Mean		−0.0128	0.00002	0.0026
SD		0.2026	0.2463	0.2133
Skewness		0.8589	−1.1685	0.1759
Kurtosis		14.0739	5.2495	16.3913
	$\rho(r_t, r_{t-k})$			
	1	0.2473[a]	0.1215[a]	0.1397[a]
	2	0.0769[a]	−0.0006	−0.0081
	3	0.0665	−0.0353	−0.0564[a]
	4	−0.0049	0.0095	−0.0470[a]
	5	−0.0101	−0.0201	0.0161
	6	0.0719	0.0452	−0.0159
	7	0.0531	0.0172	−0.0087
	8	0.0475	0.0297	−0.0124
	9	0.0469	−0.0143	−0.0393[a]
	10	−0.0048	−0.0143	−0.0173

Note: The exact calendar days spanned by the four periods are, respectively, April 28, 1986 to October 24, 1986, October 27, 1986 to September 30, 1987. January 5, 1988 to March 23, 1990. The asymptotic standard errors for the autocorrelation coefficients under the null hypothesis of zero autocorrelation can be approximated at the 5% level by $\pm(2/\sqrt{T})$, where T is the sample size.

[a]Denotes significance at the 5% level. The kurtosis coefficient is computed in excess of three.

TABLE IB

Summary Statistics for the Hourly Returns on the FT-SE 100 Index Futures from April 28, 1986 to March 23, 1990

		Period I	*Period II*	*Period III*
Sample size		709	1318	3224
Mean		−0.0073	−0.0063	−0.00499
SD		0.2562	0.2835	0.2563
Skewness		0.0052	−1.3888	0.5083
Kurtosis		2.4929	12.285	20.3630
	$\rho(r_t, r_{t-k})$			
	1	0.1084[a]	−0.0164	0.0838[a]
	2	0.0569	−0.0266	−0.0018
	3	0.0012	−0.0466	−0.0332
	4	−0.0031	0.0058	−0.0169
	5	0.0122	0.0098	0.0108
	6	0.0369	0.0799[a]	−0.0126
	7	−0.0379	0.0124	−0.0091
	8	0.0339	−0.0119	−0.0137
	9	0.0574	−0.0284	−0.0361[a]
	10	−0.0353	−0.0122	−0.0153

Note: See footnote Table IA.

TABLE IC

Sample Cross-Correlation Coefficients between the Raw FT-SE 100 Stock Index Futures and Index Returns

$\rho(r^2_{c,t}, r_{f,t-k})$	*Period I*	*Period II*	*Period III*
−10	−0.0043	0.0521	−0.0077
−9	0.0898[a]	−0.0117	−0.0245
−8	−0.0466	0.0218	0.0006
−7	0.0599	0.0192	−0.0101
−6	0.0698	0.0223	−0.0115
−5	−0.0108	−0.0046	0.0183
−4	0.0602	0.0054	−0.0318
−3	0.0948[a]	−0.0419	−0.0538[a]
−2	0.1260[a]	−0.0108	0.0036
−1	0.4040[a]	0.2018[a]	0.2112[a]
0	0.4929[a]	0.7447[a]	0.8162[a]
1	0.0644	0.0289	0.0879[a]
2	0.0109	−0.0096	−0.0001
3	−0.0154	−0.0497	−0.0209
4	−0.0197	0.0175	−0.0380[a]
5	0.0627	−0.0062	0.0180
6	0.0018	0.0878[a]	−0.0163
7	−0.0086	0.0058	−0.0104
8	0.0525	−0.0011	−0.0165
9	0.0013	−0.0154	−0.0614[a]
10	−0.0320	−0.0448	−0.0148

Note: (a) indicates significance at the 5% level with the asymptotic standard errors given by $\mp(2/\sqrt{T})$.

TABLE ID
Sample Cross-Correlation Coefficients between the Squares of the Raw Hourly Returns on the FT-SE 100 Index Futures and Index

$\rho(r^2_{c,t}, r^2_{f,t-k})$	*Period I*	*Period II*	*Period III*
−10	0.0502	0.0202	−0.0063
−9	0.1233[a]	0.0086	0.0058
−8	−0.0199	0.0347	0.0366[a]
−7	0.0394	0.0074	0.0212
−6	0.0577	0.0409	0.0058
−5	0.0832[a]	0.0164	0.0269
−4	0.0167	0.1419[a]	0.1395[a]
−3	−0.0042	0.0702[a]	0.0532[a]
−2	0.0588	0.0278	0.0632[a]
−1	0.1203[a]	0.1326[a]	0.1227[a]
0	0.2987[a]	0.7655[a]	0.8309[a]
1	0.1349[a]	0.0746[a]	0.0879[a]
2	0.1378[a]	0.0309	0.0495[a]
3	0.0237	0.0336	0.0361[a]
4	0.0475	0.0388	0.1539[a]
5	0.0290	0.0311	0.0620[a]
6	0.0036	0.1734[a]	0.0061
7	−0.0262	0.0225	0.0390[a]
8	−0.0185	0.0323	0.0780[a]
9	−0.0096	0.0556[a]	0.0181
10	0.0264	−0.0162	0.0034

Note: See footnote to Table IC.

The regression results for each sub-period are presented in Table IIA. The contemporaneous coefficients (b_0) are 0.37, 0.65, and 0.67 in the three periods. This suggests that both markets largely react simultaneously to information arrival and that the contemporaneous relationship between the two markets grew stronger after the Big Bang and the Crash. χ_{LEAD} and χ_{LAG}, the chi-squared statistics, indicate that the cash index consistently lags the futures in all the sub-periods of the sample, i.e., the futures leads the cash, except for Period II where there is weak evidence that cash returns are predictive of futures returns. The estimates of the cash index lag coefficients (b_1, b_2, b_3) are 0.28, 0.05, and 0.05 in the pre-Big Bang period and 0.012, 0.004, and 0.02, respectively, in the most recent period. This suggests that the cash index may be reacting to the futures price movement faster over time.

It is likely that the results of the regression in eq. (5), using the raw cash and index futures returns, may be biased due to the autocorrelation induced in the stock index by the infrequent trading of component stocks. As discussed earlier and following Stoll and Whaley (1990),

TABLE IIA

Results of the Linear Regression of Coincident Hourly FT-SE 100 Index Returns on Leads and Lags of Hourly FT-SE 100 Futures Returns for Each Sample Period

$$r_{c,t} = a + \sum_{-3}^{3} b_k r_{f,t+k} + \varepsilon_t$$

	Period I	*Period II*	*Period III*
b_{-3}	−0.01264	−0.01315	0.0062
	(−0.44)	(1.56)	(0.55)
b_{-2}	−0.01571	0.01821	0.0028
	(−0.43)	(−0.82)	(0.26)
b_{-1}	−0.00654	0.04155[a]	0.0182
	(−0.18)	(2.23)	(1.93)
b_0	0.36965[a]	0.65224[a]	0.6681
	(10.35)	(30.49)	(36.86)
b_1	0.27738[a]	0.18861[a]	0.1211[a]
	(8.26)	(10.91)	(9.19)
b_2	0.04527[a]	0.01303	−0.0041
	(1.68)	(0.79)	(−0.42)
b_3	0.049799[a]	−0.000996	−0.0215
	(2.27)	(−0.052)	(−1.64)
χ_{LEAD}	0.833	7.9797[a]	4.4393
	($p = 0.8415$)	($p = 0.0464$)	($p = 0.2178$)
χ_{LAG}	116.901[a]	121.84[a]	86.63[a]
	($p = 0.0000$)	($p = 0.0000$)	($p = 0.0000$)

Note: Values in parentheses are t-ratios which are based on standard errors adjusted for autocorrelation and heteroscedasticity using Hansen's (1982) correction. χ_{LAG}/χ_{LEAD} is the χ^2 statistic that tests whether the cash lag (lead) coefficients are jointly zero.

[a]Denotes significance at the 5% level.

the regression is re-estimated by using the innovations[7] for the cash return series obtained by estimating an AR(2) process which is adequate to remove any serial correlation. The results of the regressions using the innovations, reported in Table IIB, are similar to those obtained from the raw return series. The lag coefficients (b_1, b_2, b_3) are now smaller in size, though the χ^2 tests indicate that the futures prices lead the cash index prices even after the infrequent trading component is taken into account.

[7]The FT-SE 100 Index returns are well described by an AR(2) process. The regressions are estimated, using the return innovations as the infrequent-trading and the bid–ask spread adjusted index return since it is orthogonal to previous index returns, and the futures returns. In view of the first-order serial correlation in the futures returns, the regressions are re-run using the futures return innovations from an AR model similar to that for the Stock index returns. The results from both these regressions are virtually the same. Only the latter are reported in this study. It is felt that the FT-SE 100 Index Futures returns do show some autocorrelation which may be due to thin trading since volumes were relatively low during the period of this study.

TABLE IIB

Results of the Linear Regression of the Innovations of the Coincident Hourly FT-SE 100 Index Returns on Leads and Lags of Hourly FT-SE 100 Futures Innovations for Each Sample Period

$$\varepsilon_{c,t} = a + \sum_{-3}^{3} b_k \varepsilon_{f,t+k} + e_t$$

	Period I	*Period II*	*Period III*
b_{-3}	−0.00802	−0.014798	0.01054
	(−0.18)	(−0.89)	(−0.08)
b_{-2}	−0.01132	0.01997	0.01054
	(−0.28)	(1.25)	(0.19)
b_{-1}	0.00097	0.03907[a]	0.00211
	(−0.03)	(2.04)	(0.19)
b_0	0.37199[a]	0.64745[a]	0.66835[a]
	(9.88)	(29.22)	(36.94)
b_1	0.22158[a]	0.10961[a]	0.08179[a]
	(7.07)	(6.25)	(5.93)
b_2	0.00995[a]	0.00028	−0.00284
	(0.34)	(0.02)	(−0.28)
b_3	0.04379[a]	−0.000515	−0.01865
	(1.97)	(−0.03)	(−1.43)
χ_{LEAD}	0.3106	7.6188[a]	4.9774
	($p = 0.9580$)	($p = 0.0546$)	($p = 0.1734$)
χ_{LAG}	77.0418[a]	40.153[a]	37.1075[a]
	($p = 0.0000$)	($p = 0.0000$)	($p = 0.0000$)

Values in parentheses are *t*-ratios which are based on standard errors adjusted for autocorrelation and heteroscedasticity using Hansen's (1982) correction. $\chi_{\text{LAG}}/\chi_{\text{LEAD}}$ is the χ^2 statistic that tests whether the cash lag (lead) coefficients are jointly zero.

[a]Denotes significance at the 5% level.

Lead–Lag Relationship between the Cash and Futures Returns under Varying Market Conditions

Period with Differential Transactions Costs

The post Big Bang period saw a substantial reduction in transactions costs in the London equity market. Pagano and Roell (1990) indicate that the total cost of a round trip transaction of £500,000 before and after the Big Bang fell from 2.87% to 1.99%. Therefore, if traders using market-wide information prefer the futures market should react faster (lag less) to market-wide information trading. To examine this hypothesis further, the returns from Periods I and II are pooled and the regression, in eq. (6), is re-run with an intercept dummy and a slope dummy for returns from the post Big Bang period:

$$r_{c,t} = a + a^* + \sum_{k=-3}^{k=3} b_k r_{f,t-k} + \sum_{k=-3}^{k=3} b_k^* D_t r_{f,t+k} + \varepsilon_{c,t} \qquad (6)$$

where $D_t = 0, 1$ for pre- and post-Big Bang period returns respectively. The results of this regression, presented in Table IIIA, suggest that the coefficient b^* is significantly negative which implies that there is a weaker tendency for the futures to lead the cash index returns when transactions costs in the cash market fall relative to those in the futures market after the Big Bang.

TABLE IIIA

Results of the Linear Regression of Hourly FT-SE 100 Index Returns on Leads and Lags of Hourly FT-SE 100 Futures Returns from Pre- and Post-Big Bang Periods Pooled Together

$$r_{s,t} = a + a^* D_t + \sum_{k=-3}^{k=3} b_k r_{f,t+k} + \sum_{k=-3}^{k=3} b^* D_t r_{f,t+k} + \varepsilon_t{}^{a}$$

	Periods I & II *Returns*	*t-ratio*	*Periods I & II* *Innovations*	*t-ratio*
b_{-3}	−0.0131	−0.46	−0.0101	−0.36
b_{-2}	−0.0118	−0.33	−0.1169	−0.31
b_{-1}	−0.0004	0.011	0.0016	0.04
b_0	0.3586[b]	9.79	0.3581	9.22
b_1	0.2756[b]	8.32	0.2271	7.24
b_2	0.0451[b]	1.71	0.0081	0.28
b_3	0.0532	2.49	0.0436	1.99
b'_{-3}	−0.0012	−0.035	−0.0060	−0.18
b'_{-2}	0.0296	0.76	0.0314	0.77
b'_{-1}	0.0425	1.04	0.0389	0.95
b'_0	0.2927	6.91	0.2872	6.43
b'_1	−0.0871[b]	−2.33	−0.1280	−3.56
b'_2	−0.0318	−1.02	−0.0211	−0.63
b'_3	−0.0534	−1.869	−0.0456	−1.56
χ_{LEAD}	0.6069	($p = 0.895$)	0.4419	($p = 0.931$)
χ_{LAG}	119.4127	($p = 0.000$)	81.5128	($p = 0.000$)
χ'_{LEAD}	1.8929	($p = 0.595$)	1.6560	($p = 0.647$)
χ'_{LAG}	13.4640	($p = 0.004$)	21.6456	($p = 0.000$)

Values in parentheses are t-ratios which are based on standard errors adjusted for autocorrelation and heteroscedasticity using Hansen's (1982) correction. χ_{LAG}/χ_{LEAD} is the χ^2 statistic that tests whether the cash lag (lead) coefficients are jointly zero.

[a]Where $D_t = 0, 1$ for pre- and post-Big Bang period returns respectively.

[b]Denotes significance at the 5% level.

Periods of "Good" and "Bad" News

The behavior of the lead–lag relationship is now examined by estimating eq. (5) during periods of "good," "bad," and "moderate" or "normal" news. This is done by stratifying the cash index and the futures returns into quartiles that are based on the size and sign of the cash index returns as done by Stephan and Whaley (1990). The cash index returns from the highest and the lowest quartiles are regarded as proxies for the arrival of "good" and "bad" news respectively. The results of the regressions, based on the observations sorted on the basis of "good," "moderate" or "normal," and "bad" periods, are presented in Tables IIIB–D. During periods of "good" news, neither the futures nor the cash market returns seem to indicate any predictive power for the other. In bullish markets it appears that economy-wide "good" news may be more symmetrically reflected in both the cash and the futures markets. In periods of "normal" news, as indicated in Table IIIC, the futures markets still consistently lead the cash. The evidence during periods of "bad" news (Table IIID) suggests that no clear pattern emerges; the futures returns lead the cash index in Period I, there is feedback effect in Period II, and neither market shows a lead or lag in Period III. In bearish markets during the sample period, neither market shows any consistent pattern in the predictive power of returns.

Periods of High and Low Volatility

Next, the nature of the lead–lag relationship is examined during periods, of high and low volatility by sorting the data according to an "index" of volatility. Two series of conditional volatility series for the futures and the cash returns obtained from the AR(2)-EGARCH(1,1) equations are estimated for the cash index return series. The linear regressions, based on eq. (6), are then re-run on the sub-samples sorted on the basis of high and low conditional volatility. The results of these estimations are presented in Tables IVA and IVB. Table IVA indicates that during episodes of high as well as low conditional volatility, the futures returns lead the cash returns in three sub-periods consistently. The predictive power of the futures market during periods of high volatility may be due to the increased use of index futures as risk management tools during periods of high volatility in the underlying equity market. However, during times of low volatility, there is some evidence of feedback from the cash to the futures in Period II, but no consistent picture emerges.

TABLE IIIB

Results of the Linear Regression of Hourly FT-SE 100 Index Returns from the Highest Quartile on Leads and Lags of Hourly FT-SE 100 Futures Returns for Each Sample Period

$$r^*_{c,t} = a + \sum_{k=-3}^{k=3} b_k r^*_{f,t+k,x} + \varepsilon_t{}^{a}$$

	Period I Returns	*Period I Innovations*	*Period II Returns*	*Period II Innovations*	*Period III Returns*	*Period III Innovations*
b_{-3}	−0.0309	−0.0453	0.0170	0.0136	−0.0172	−0.0144
	(−0.78)	(−0.92)	(1.02)	(0.077)	(−1.09)	(−0.86)
b_{-2}	−0.0724	−0.0851	−0.0206	0.0073	0.0010	−0.0061
	(−1.67)	(−1.74)	(−0.91)	(0.29)	(0.08)	(−0.45)
b_{-1}	−0.1098	−0.1358	0.01746	0.0025	0.0190	0.0229
	(−1.18)	(−1.73)	(0.78)	(0.09)	(0.83)	(0.89)
b_0	0.1708	0.1490	0.1995	0.2062	0.4672	0.4590
	(2.63)	(1.81)	(6.66)	(6.25)	(9.29)	(9.38)
b_1	0.0649	0.0518	0.0367	0.0121	0.06974	0.0453
	(1.70)	(1.54)	(1.92)	(0.68)	(3.43)	(2.25)
b_2	−0.0155	−0.0325	−0.0220	−0.0232	0.0018	0.0062
	(−0.34)	(−0.72)	(−1.47)	(−1.34)	(0.10)	(0.32)
b_3	−0.0206	0.0071	−0.0195	−0.0202	−0.0263	−0.0181
	(−0.69)	(0.21)	(−0.92)	(−0.98)	(−1.07)	(−0.76)
χ_{LEAD}	4.4833	5.3182	3.1645	0.9812	1.9912	2.0959
	(p = 0.2138)	(p = 0.1499)	(p = 0.3670)	(p = 0.8057)	(p = 0.5742)	(p = 0.5528)
χ_{LAG}	3.0199	2.9319	6.4717	2.8744	13.2807	5.4078
	(p = 0.3886)	(p = 0.4022)	(p = 0.0908)	(p = 0.4114)	(p = 0.0041)	(p = 0.1443)

Values in parentheses are t-ratios which are based on standard errors adjusted for autocorrelation and heteroscedasticity using Hansen's (1982) correction. $\chi_{\mathrm{LAG}}/\chi_{\mathrm{LEAD}}$ is the χ^2 statistic that tests whether the lag (lead) coefficients are jointly zero. Results of the linear regression of hourly FT-SE 100 index returns are from the highest quartile on leads and lags of hourly FT-SE 100 futures returns for each sample period.

[a]Where * ≡ returns from the highest quartile, i.e., proxy for good news.

TABLE IIIC

Results of the Linear Regression of Hourly FT-SE 100 Index Returns from the Highest Quartile on Leads and Lags of Hourly FT-SE 100 Futures Returns for Each Sample Period

$$r^{*}_{c,t} = a + \sum_{k=-3}^{k=3} b_k r^{*}_{f,t+k,x} + \varepsilon_t{}^{a}$$

	Period I Returns	*Period I Innovations*	*Period II Returns*	*Period II Innovations*	*Period III Returns*	*Period III Innovations*
b_{-3}	0.0052	0.0075	0.0210	0.0083	−0.0014	0.0038
	(0.61)	(0.98)	(0.88)	(0.87)	(−0.33)	(0.90)
b_{-2}	−0.0003	0.0042	0.0044	0.0071	0.0036	0.0001
	(−0.04)	(0.52)	(0.18)	(0.94)	(0.75)	(0.03)
b_{-1}	0.0164	0.0173	−0.0023	−0.0082	0.0028	0.0012
	(1.84)	(2.09)	(−0.11)	(−0.79)	(0.62)	(0.26)
b_0	0.0631	0.0523	0.5029	0.1342	0.1404	0.1430
	(4.40)	(4.34)	(14.61)	(8.75)	(14.52)	(14.53)
b_1	0.0222	0.0137	0.0933	0.0337	0.0325	0.0216
	(1.67)	(1.25)	(3.57)	(3.02)	(5.28)	(3.35)
b_2	0.0406	0.0229	0.0014	−0.0088	−0.0029	0.0067
	(4.37)	(2.64)	(0.70)	(−0.94)	(−0.52)	(1.13)
b_3	0.0213	−0.00004	−0.0207	−0.0018	0.0060	0.0031
	(2.45)	(−0.004)	(−1.06)	(−0.17)	(1.22)	(0.58)
χ_{LEAD}	4.1666	5.6432	0.9421	2.7292	1.2909	0.9346
	(p = 0.2440)	(p = 0.1303)	(p = 0.8152)	(p = 0.4353)	(p = 0.7313)	(p = 0.8171)
χ_{LAG}	30.2691	8.4327	16.0407	10.4565	30.6412	12.1636
	(p = 0.0000)	(p = 0.0379)	(p = 0.0011)	(p = 0.0151)	(p = 0.0000)	(p = 0.0068)

Values in parentheses are t-ratios which are based on standard errors adjusted for autocorrelation and heteroscedasticity using Hansen's (1982) correction. χ_{LAG}/χ_{LEAD} is the χ^2 statistic that tests whether the lag (lead) coefficients are jointly zero.

[a]Where * ≡ excluding returns from the highest and the lowest quartile, i.e., proxy for "normal/moderate" news.

TABLE IIID

Results of the Linear Regression of Hourly FT-SE 100 Index Returns from the Highest Quartile on Leads and Lags of Hourly FT-SE 100 Futures Returns for Each Sample Period

$$r^*_{c,t} = a + \sum_{k=-3}^{k=3} b_k r^*_{f,t+k,x} + \varepsilon_t{}^{a}$$

	Period I Returns	*Period I Innovations*	*Period II Returns*	*Period II Innovations*	*Period III Returns*	*Period III Innovations*
b_{-3}	−0.0035	0.0465	−0.0673	−0.0671	0.0210	0.0371
	(−0.61)	(0.96)	(−2.13)	(−2.26)	(0.88)	(1.40)
b_{-2}	−0.0641	−0.0682	0.0054	0.0035	0.0044	0.0110
	(−1.50)	(−1.55)	(0.21)	(0.14)	(0.18)	(0.47)
b_{-1}	−0.0245	−0.0175	0.0656	0.0711	−0.0023	−0.0021
	(−0.69)	(−0.50)	(2.67)	(3.01)	(−0.11)	(−0.09)
b_0	0.2386	0.2175	0.4899	0.4866	0.5029	0.4876
	(3.85)	(4.14)	(9.89)	(9.96)	(14.61)	(13.80)
b_1	0.1613	0.1590	0.1542	0.0849	0.0933	0.0507
	(3.00)	(4.79)	(5.53)	(2.99)	(3.57)	(1.82)
b_2	−0.0521	−0.0364	0.0281	0.0287	0.0014	0.0132
	(−1.26)	(−0.83)	(0.73)	(0.90)	(0.70)	(0.77)
b_3	0.0427	0.0397	0.0786	0.0775	−0.0207	−0.0111
	(1.01)	(0.94)	(2.26)	(2.25)	(−1.06)	(−0.57)
χ_{LEAD}	2.8421	2.7456	15.9207	18.6135	0.9421	2.4953
	($p = 0.4166$)	($p = 0.4325$)	($p = 0.0012$)	($p = 0.0003$)	($p = 0.8152$)	($p = 0.4762$)
χ_{LAG}	10.5592	23.4935	36.8788	15.5243	16.0407	4.8415
	($p = 0.0144$)	($p = 0.0000$)	($p = 0.0000$)	($p = 0.0014$)	($p = 0.0011$)	($p = 0.1838$)

Values in parentheses are t-ratios which are based on standard errors adjusted for autocorrelation and heteroscedasticity using Hansen's (1982) correction. χ_{LAG}/χ_{LEAD} is the χ^2 statistic that tests whether the lag (lead) coefficients are jointly zero.

[a]Where * ≡ returns from the lowest quartile, i.e., proxy for "bad" news.

TABLE IVA

Results of the Linear Regression of Hourly FT-SE 100 Index Returns from the Highest Quartile on Leads and Lags of Hourly FT-SE 100 Futures Returns for Each Sample Period

$$r^*_{c,t} = a + \sum_{k=-3}^{k=3} b_k r^*_{f,t+k,x} + \varepsilon_t{}^{a}$$

	Period I Returns	*Period I Innovations*	*Period II Returns*	*Period II Innovations*	*Period III Returns*	*Period III Innovations*
b_{-3}	−0.0476	−0.0360	0.0181	0.0167	0.0173	−0.0143
	(−1.01)	(−0.76)	(1.04)	(0.94)	(−1.13)	(−0.87)
b_{-2}	−0.0893	−0.0814	−0.0090	−0.0032	0.0008	−0.0062
	(−1.91)	(−1.60)	(−0.40)	(−0.13)	(0.06)	(−0.45)
b_{-1}	−0.1198	−0.1397	−0.0039	−0.0042	0.0240	0.0244
	(−1.32)	(−1.44)	(−0.15)	(−0.16)	(0.93)	(0.95)
b_0	0.2067	0.1512	0.2137	0.2010	0.4687	0.4599
	(2.65)	(1.93)	(6.62)	(6.11)	(9.77)	(9.46)
b_1	0.1694	0.0915	0.0846	0.0014	0.1012	0.0435
	(4.92)	(2.88)	(4.80)	(0.08)	(5.12)	(2.14)
b_2	0.06153	−0.0292	−0.0256	−0.0377	0.0102	0.0095
	(1.26)	(−0.63)	(−1.64)	(−2.49)	(0.60)	(0.50)
b_3	0.0217	0.0147	−0.0236	−0.0249	−0.0262	−0.0168
	(0.64)	(0.40)	(−1.13)	(−1.28)	(−1.01)	(−0.71)
χ_{LEAD}	5.8943	4.6925	1.2540	0.9669	2.3022	2.1718
	(p = 0.1169)	(p = 0.1958)	(p = 0.7401)	(p = 0.8093)	(p = 0.5121)	(p = 0.5375)
χ_{LAG}	29.9479	9.4307	27.4256	7.4016	30.9988	4.8888
	(p = 0.0000)	(p = 0.0241)	(p = 0.0000)	(p = 0.0601)	(p = 0.0000)	(p = 0.1801)

Values in parentheses are t-ratios which are based on standard errors adjusted for autocorrelation and heteroscedasticity using Hansen's (1982) correction. χ_{LAG}/χ_{LEAD} is the χ^2 statistic that tests whether the lag (lead) coefficients are jointly zero.

[a]Where * ≡ returns from the highest quartile of conditional volatility.

TABLE IVB

Results of the Linear Regression of Hourly FT-SE 100 Index Returns from the Highest Quartile on Leads and Lags of Hourly FT-SE 100 Futures Returns for Each Sample Period

$$r^*_{c,t} = a + \sum_{k=-3}^{k=3} b_k r^*_{f,t+k,x} + \varepsilon_t{}^{a}$$

	Period I Returns	*Period I Innovations*	*Period II Returns*	*Period II Innovations*	*Period III Returns*	*Period III Innovations*
b_{-3}	0.0164	0.0303	−0.0600	−0.0668	0.0286	0.0388
	(0.33)	(0.65)	(−1.95)	(−2.2)	(1.12)	(1.46)
b_{-2}	−0.1098	−0.0843	−0.0007	−0.00005	0.0017	0.0077
	(−2.46)	(−1.72)	(−0.03)	(−0.002)	(0.07)	(0.33)
b_{-1}	0.0006	−0.0096	0.0714	0.0713	0.0007	−0.0007
	(.01)	(−0.26)	(2.94)	(2.99)	(0.03)	(−0.03)
b_0	0.2085	0.2022	0.4953	0.4775	0.4949	0.4888
	(4.50)	(4.50)	(10.33)	(9.62)	(14.36)	(13.75)
b_1	0.2946	0.2014	0.1694	0.0783	0.1101	0.0491
	(6.85)	(5.78)	(5.69)	(2.77)	(4.21)	(1.76)
b_2	−0.0015	−0.0544	0.0387	0.0109	0.0187	0.0182
	(−0.04)	(−1.06)	(1.02)	(0.28)	(1.07)	(1.03)
b_3	0.0435	0.0363	0.0731	0.0808	−0.0105	−0.0094
	(0.96)	(0.85)	(2.16)	(2.36)	(−0.57)	(−0.49)
χ_{LEAD}	6.3276	3.1270	16.0894	17.7480	1.3629	2.4834
	($p = 0.0967$)	($p = 0.3725$)	($p = 0.0011$)	($p = 0.0006$)	($p = 0.7143$)	($p = 0.4783$)
χ_{LAG}	51.1806	33.7799	37.0811	13.8076	20.0142	4.8864
	($p = 0.0000$)	($p = 0.0000$)	($p = 0.0000$)	($p = 0.0032$)	($p = 0.0002$)	($p = 0.1803$)

Values in parentheses are t-ratios which are based on standard errors adjusted for autocorrelation and heteroscedasticity using Hansen's (1982) correction. χ_{LAG}/χ_{LEAD} is the χ^2 statistic that tests whether the lag (lead) coefficients are jointly zero.

[a]Where * ≡ returns from the lowest quartile of conditional volatility.

Periods of Different Trading Intensity

Next, the nature of the lead–lag relationship during periods of different trading intensity in the underlying equity market is examined using the volume of shares traded as a proxy prior to the Big Bang. Data on the total daily volume of trading in the FT-SE 100 Index constituents are not easily available. Therefore, the total trading volume on the exchange is used as a proxy for the level of trading activity before the Big Bang. The use of this proxy is justified since the FT-SE 100 index constituents comprise about 80% of the total market capitalization in the equity market. Subsequent to the Big Bang, daily volume data on all the alpha[8] stocks traded in the London Equity market are available. Daily volume data are used as the indicator of the level of trading activity in the market for the periods after the Big Bang. Since the return data have six observations per day, each return is allocated the trading volume for that day. The returns are then stratified on the basis of the daily volume into quartiles; the highest quartile corresponds to the top 25% days of trading volume during that period. In Tables VA–C the results of the linear regression test for lead–lag during periods of high, moderate, and low trading volume are presented. The results indicate that the futures returns lead the cash during periods of high, moderate, and low volume. In Period II, however, during the periods of low trading volume the return innovations indicate that neither futures nor cash leads.

The tests above suggest that the futures leads the cash during phases of high, moderate, and low trading activity in the cash market as well as during periods of high conditional volatility.

Lead–Lag Relationships between the Volatility of Cash and Futures Returns

The relationship in the lead–lag in the return volatility of cash and index futures returns is examined by estimating the following regression:

$$h_{c,t} = \alpha + \sum_{k=-3}^{k=3} \beta_k h_{f,t+k} + \eta_{c,t} \tag{7}$$

where $h_{c,t}$ and $h_{f,t}$ are the hourly index and index futures conditional volatility estimates at time t obtained from estimating univariate EGARCH models for both the cash and the futures return series. The

[8]Alpha stocks are the most actively traded equities on the London Stock Exchange. These securities make up the bulk of trading in U.K. equities and more than 60% of the equity market capitalization.

TABLE VA

Results of the Linear Regression of Hourly FT-SE 100 Index Returns from the Highest Trading Volume Quartile on Leads and Lags of Hourly FT-SE 100 Futures Returns for Each Sample Period

$$r^*_{c,t} = a + \sum_{k=-3}^{k=3} b_k r^*_{f,t+k} + \varepsilon_t{}^{a}$$

	Period I Returns	*Period I Innovations*	*Period II Returns*	*Period II Innovations*	*Period III Returns*	*Period III Innovations*
b_{-3}	0.0554	0.0562	−0.0232	−0.0253	0.0322	0.0393
	(1.32)	(−0.26)	(−0.68)	(−0.71)	(1.13)	(1.26)
b_{-2}	−0.0292	−0.0402	0.0076	−0.0102	0.0080	0.0029
	(−0.67)	(−0.8359)	(0.27)	(0.36)	(0.33)	(0.12)
b_{-1}	−0.0982	0.1190	0.0489	0.0498	0.0076	0.0118
	(−1.52)	(1.98)	(1.57)	(1.54)	(0.40)	(0.61)
b_0	0.4280	0.4431	0.6550	0.6471	0.7357	0.7433
	(6.91)	(6.98)	(17.97)	(16.79)	(19.65)	(20.15)
b_1	0.3171	0.2491	0.1775	0.0890	0.1073	0.0670
	(4.89)	(4.15)	(6.25)	(3.18)	(3.67)	(2.18)
b_2	0.0114	−0.0131	−0.0327	−0.622	−0.0112	−0.0094
	(0.20)	(−0.23)	(−1.24)	(−2.24)	(−0.58)	(−0.46)
b_3	0.0399	0.0211	−0.0260	−0.0622	−0.0564	−0.0537
	(0.90)	(0.48)	(−0.74)	(−0.55)	(−2.24)	(−2.18)
χ_{LEAD}	3.1530	4.9151	4.2509	4.2995	2.0853	2.5266
	(p = 0.3686)	(p = 0.1781)	(p = 0.2356)	(p = 0.2309)	(p = 0.5548)	(p = 0.4705)
χ_{LAG}	51.3449	34.3196	39.2702	11.9988	19.1843	10.2118
	(p = 0.000)	(p = 0.0000)	(p = 0.0000)	(p = 0.0074)	(p = 0.0003)	(p = 0.0168)

Values in parentheses are t-ratios which are based on standard errors adjusted for autocorrelation and heteroscedasticity using Hansen's (1982) correction. χ_{LAG}/χ_{LEAD} is the χ^2 statistic that tests whether the lag (lead) coefficients are jointly zero.

[a]Where * ≡ returns from the periods of highest trading volume in the equity market.

TABLE VB

Results of the Linear Regression of Hourly FT-SE 100 Index Returns from the Moderate Trading Volume Quartile on Leads and Lags of Hourly FT-SE 100 Futures Returns for Each Sample Period

$$r^*_{c,t} = a + \sum_{k=-3}^{k=3} b_k r^*_{f,t+k} + \varepsilon_t{}^{a}$$

	Period I Returns	*Period I Innovations*	*Period II Returns*	*Period II Innovations*	*Period III Returns*	*Period III Innovations*
b_{-3}	−0.0512	−0.0557	0.0036	0.0024	−0.0037	0.0003
	(−1.23)	(−1.30)	(0.18)	(0.12)	(−0.33)	(0.30)
b_{-2}	0.0007	0.0063	0.0195	0.0187	−0.0022	−0.0026
	(0.01)	(0.0925)	(0.85)	(0.77)	(−0.18)	(−0.21)
b_{-1}	0.0564	0.0715	0.0464	0.0415	0.0229	0.0225
	(1.49)	(1.77)	(1.72)	(1.49)	(2.12)	(2.03)
b_0	0.3496	0.3427	0.6813	0.6751	0.6349	0.6339
	(7.27)	(7.09)	(22.55)	(22.01)	(33.24)	(32.99)
b_1	0.2204	0.1648	0.2185	0.1234	0.1352	0.0939
	(5.26)	(4.07)	(8.09)	(4.36)	(8.66)	(5.91)
b_2	0.0595	0.0257	0.0558	0.0217	−0.0048	−0.0038
	(2.29)	(0.97)	(2.13)	(0.83)	(−0.37)	(−0.29)
b_3	0.0719	0.0659	0.0240	0.0188	−0.0015	0.0027
	(2.81)	(2.39)	(1.06)	(0.81)	(−0.99)	(0.17)
χ_{LEAD}	3.4740	4.1939	4.2810	3.6423	4.5250	4.1464
	(p = 0.3242)	(p = 0.2413)	(p = 0.2188)	(p = 0.3028)	(p = 0.2101)	(p = 0.2461)
χ_{LAG}	36.8348	22.7301	66.7286	19.6729	77.2031	36.3608
	(p = 0.0000)	(p = 0.0000)	(p = 0.0000)	(p = 0.0002)	(p = 0.0000)	(p = 0.0000)

Values in parentheses are t-ratios which are based on standard errors adjusted for autocorrelation and heteroscedasticity using Hansen's (1982) correction. χ_{LAG}/χ_{LEAD} is the χ^2 statistic that tests whether the lag (lead) coefficients are jointly zero.

[a] Where * ≡ returns from the periods of moderate trading volume in the equity market.

TABLE VC

Results of the Linear Regression of Hourly FT-SE 100 Index Returns from the Lowest Trading Volume Quartile on Leads and Lags of Hourly FT-SE 100 Futures Returns for Each Sample Period

$$r^*_{c,t} = a + \sum_{k=-3}^{k=3} b_k r^*_{f,t+k} + \varepsilon_t{}^{a}$$

	Period I Returns	*Period I Innovations*	*Period II Returns*	*Period II Innovations*	*Period III Returns*	*Period III Innovations*
b_{-3}	−0.0384	−0.0096	−0.0361	−0.0326	0.0092	0.0115
	(−1.23)	(−0.44)	(0.90)	(−0.77)	(0.57)	(0.69)
b_{-2}	0.0086	0.0141	0.0285	0.0338	0.0034	0.0012
	(0.22)	(0.36)	(0.79)	(0.87)	(0.23)	(0.08)
b_{-1}	0.0368	0.0357	0.0113	0.0096	0.0091	0.0080
	(0.94)	(0.85)	(0.25)	(0.21)	(0.44)	(0.38)
b_0	0.3060	0.2970	0.5709	0.5605	0.6173	0.6142
	(6.23)	(5.74)	(12.89)	(12.12)	(28.00)	(27.61)
b_1	0.3312	0.2911	0.1726	0.0927	0.0983	0.0667
	(5.26)	(4.77)	(4.13)	(2.00)	(4.94)	(3.26)
b_2	0.0706	0.0246	0.0192	−0.0088	0.0132	0.0121
	(1.53)	(0.50)	(0.63)	(−0.27)	(0.53)	(0.61)
b_3	0.0047	0.0003	0.0089	−0.0014	0.0087	0.0108
	(0.12)	(0.01)	(0.24)	(−0.04)	(0.51)	(0.63)
χ_{LEAD}	3.0144	1.6446	1.5013	1.2709	0.8365	0.8365
	($p = 0.3894$)	($p = 0.6493$)	($p = 0.6820$)	($p = 0.7360$)	($p = 0.8407$)	($p = 0.8407$)
χ_{LAG}	38.1318	28.9044	21.7964	4.4444	27.2366	12.7389
	($p = 0.0000$)	($p = 0.0000$)	($p = 0.0001$)	($p = 0.2173$)	($p = 0.0000$)	($p = 0.0052$)

Values in parentheses are t-ratios which are based on standard errors adjusted for autocorrelation and heteroscedasticity using Hansen's (1982) correction. χ_{LAG}/χ_{LEAD} is the χ^2 statistic that tests whether the lag (lead) coefficients are jointly zero.

[a]Where * ≡ returns from the periods of lowest trading volume in the equity market.

TABLE VIA

Results of the Linear Regression of Hourly Conditional Variance of the FT-SE 100 Index Returns on Leads and Lags of Hourly Conditional Variance of the FT-SE 100 Futures Returns

$$h_{c,t} = a + \sum_{k=-3}^{k\neq 3} b_k h_{f,t-k} + \eta$$

	Period I	*Period II*	*Period III*
b_{-3}	0.0517	0.0352	0.0236
	(0.32)	(1.36)	(0.46)
b_{-2}	0.0450	−0.0065	−0.0057
	(0.40)	(−0.23)	(−0.12)
b_{-1}	0.2190	0.0449	0.0138
	(0.58)	(1.58)	(0.39)
b_0	0.3741	0.4908	0.5691
	(1.92)	(5.18)	(13.96)
b_1	0.0984	0.0389	0.0030
	(0.60)	(0.48)	(0.10)
b_2	−0.1154	−0.0317	0.0113
	(−1.02)	(−0.52)	(0.40)
b_3	−0.1504	0.0174	−0.1656
	(−1.66)	(0.33)	(−5.17)
χ_{LEAD}	2.2307	7.7289	1.0383
	(0.5259)	(0.0520)	(0.7920)
χ_{LAG}	6.5111	0.5602	37.5340
	(0.0892)	(0.9055)	(0.0000)

Values in parentheses are *t*-ratios which are based on standard errors adjusted for autocorrelation and heteroscedasticity using Hansen's (1982) correction. χ_{LAG}/χ_{LEAD} is the χ^2 statistic that tests whether the lag (lead) coefficients are jointly zero.

results of the estimation of eq. (7) are indicated in Table VIA. They suggest that the futures volatility leads in Period I, the cash volatility leads in Period II, and the futures volatility leads in Period III. There is no evidence of any feedback effects. Thus, consistent with the results in Kawaller et al., the lead–lag in the volatility does not seem to indicate any systematic pattern.

Periods of Good and Bad News and Low and High Trading Volume

The nature of the lead–lag in the volatilities of the futures and the cash market returns is now examined during periods of "good" and "bad" news. The results in Table VIB and VIC indicate that there is no consistent pattern in the lead–lag relationship between the futures and cash return volatilities during those periods. Also, during periods of high and low trading volume in the cash market, the results in Tables VID and VIE suggest that there is no discernible pattern in the lead-lag in the volatility.

TABLE VIB

Results of the Linear Regression of Hourly Conditional Variance of the FT-SE 100 Index Returns on Leads and Lags of Hourly Conditional Variance of the FT-SE 100 Futures Returns during Phases of "Good" News

$$h_{c,t} = a + \sum_{k=-3}^{k\neq 3} b_k h_{f,t-k} + \eta$$

	Period I	*Period II*	*Period III*
b_{-3}	1.0105	0.0584	0.1243
	(0.92)	(0.69)	(1.29)
b_{-2}	−0.4536	0.2194	0.0453
	(−0.78)	(1.51)	(0.51)
b_{-1}	1.3312	−0.2807	−0.2028
	(2.22)	(−1.21)	(−1.01)
b_0	−1.3844	0.9706	0.6684
	(−1.57)	(4.43)	(3.59)
b_1	−0.2667	−0.3862	0.0081
	(−0.38)	(−3.50)	(0.10)
b_2	0.5635	0.0038	−0.0070
	(1.14)	(0.09)	(−0.14)
b_3	−0.2741	0.1592	−0.1638
	(−1.64)	(1.97)	(−3.53)
χ_{LEAD}	16.2987	4.8729	5.7348
	(0.0010)	(0.1813)	(0.1253)
χ_{LAG}	4.0428	13.8181	28.2878
	(0.2569)	(0.0032)	(0.0000)

Values in parentheses are *t*-ratios which are based on standard errors adjusted for autocorrelation and heteroscedasticity using Hansen's (1982) correction. $\chi_{\text{LAG}}/\chi_{\text{LEAD}}$ is the χ^2 statistic that tests whether the lag (lead) coefficients are jointly zero.

TABLE VIC

Results of the Linear Regression of Hourly Conditional Variance of the FT-SE 100 Index Returns on Leads and Lags of Hourly Conditional Variance of the FT-SE 100 Futures Returns during Periods of "Bad" News

$$h_{c,t} = a + \sum_{k=-3}^{k\neq 3} b_k h_{f,t-k} + \eta$$

	Period I	*Period II*	*Period III*
b_{-3}	0.2098	0.0075	−0.0728
	(1.20)	(0.32)	(−1.45)
b_{-2}	−0.1403	−0.0249	0.0574
	(−0.83)	(−0.94)	(0.91)
b_{-1}	−0.2205	0.1579	0.0678
	(−1.60)	(3.06)	(1.11)
b_0	0.9160	0.3355	0.5292
	(5.22)	(3.56)	(7.86)

continued

TABLE VIC (Continued)

	Period I	Period II	Period III
b_1	−0.1247	0.3458	−0.0055
	(−0.74)	(3.38)	(−0.77)
b_2	−0.4204	−0.1515	0.0323
	(−2.79)	(−1.06)	(0.40)
b_3	0.1148	−0.0488	−0.1114
	(0.85)	(−0.52)	(−1.96)
χ_{LEAD}	4.7999	11.3164	3.9985
	(0.1871)	(0.0101)	(0.2616)
χ_{LAG}	9.9329	13.2757	11.9142
	(0.0191)	(0.0041)	(0.0077)

Values in parentheses are t-ratios which are based on standard errors adjusted for autocorrelation and heteroscedasticity using Hansen's (1982) correction. χ_{LAG}/χ_{LEAD} is the χ^2 statistic that tests whether the lag (lead) coefficients are jointly zero.

TABLE VID

Results of the Linear Regression of Hourly Conditional Variance of the FT-SE 100 Index Returns on Leads and Lags of Hourly Conditional Variance of the FT-SE 100 Futures Returns during Periods of "High" Trading Volume

$$h_{c,t} = a + \sum_{k=-3}^{k\neq 3} b_k h_{f,t-k} + \eta$$

	Period I	Period II	Period III
b_{-3}	0.5220	0.0780	0.0827
	(1.20)	(1.25)	(0.86)
b_{-2}	−0.2296	−0.0538	−0.0448
	(−1.37)	(−0.94)	(−0.48)
b_{-1}	0.5768	0.0564	−0.0053
	(0.84)	(2.32)	(−0.08)
b_0	0.1533	0.4343	0.5902
	(0.51)	(5.66)	(9.06)
b_1	−0.6467	0.0469	0.0260
	(−1.52)	(0.69)	(0.49)
b_2	−0.2556	−0.0374	−0.0252
	(−1.21)	(0.66)	(−0.53)
b_3	0.0611	−0.0160	−0.1319
	(0.30)	(−0.37)	(−2.41)
χ_{LEAD}	3.3159	8.1455	0.9365
	(0.3454)	(0.0431)	(0.8166)
χ_{LAG}	3.3493	0.7959	12.3610
	(0.3408)	(0.8504)	(0.0062)

Values in parentheses are t-ratios which are based on standard errors adjusted for autocorrelation and heteroscedasticity using Hansen's (1982) correction. χ_{LAG}/χ_{LEAD} is the χ^2 statistic that tests whether the lag (lead) coefficients are jointly zero.

TABLE VIE

Results of the Linear Regression of Hourly Conditional Variance of the FT-SE 100 Index Returns on Leads and Lags of Hourly Conditional Variance of the FT-SE 100 Futures Returns during Periods of "Low" Trading Volume

$$h_{c,t} = a + \sum_{k=-3}^{k\neq 3} b_k h_{f,t-k} + \eta$$

	Period I	*Period II*	*Period III*
b_{-3}	−0.0819	−0.0038	−0.0703
	(0.47)	(−0.04)	(−1.90)
b_{-2}	−0.0940	0.1688	−0.0148
	(−0.54)	(1.01)	(−0.43)
b_{-1}	0.1664	0.2139	0.0350
	(0.68)	(0.97)	(0.94)
b_0	0.8043	0.5333	0.4846
	(3.26)	(3.41)	(10.11)
b_1	0.2847	−0.0742	0.0038
	(1.33)	(−0.58)	(0.09)
b_2	−0.2975	0.1502	0.0126
	(−1.41)	(1.33)	(0.37)
b_3	−0.2072	−0.1517	−0.1009
	(−1.18)	(−1.73)	(−2.74)
χ_{LEAD}	2.5316	2.4095	6.4402
	(0.4696)	(0.4919)	(0.0921)
χ_{LAG}	7.5452	3.6590	8.3000
	(0.0564)	(0.3001)	(0.0402)

Values in parentheses are *t*-ratios which are based on standard errors adjusted for autocorrelation and heteroscedasticity using Hansen's (1982) correction. χ_{LAG}/χ_{LEAD} is the χ^2 statistic that tests whether the lag (lead) coefficients are jointly zero.

CONCLUSIONS

The empirical results in this article suggest that, during the periods considered, there is a strong contemporaneous relationship between the FT-SE 100 futures and cash markets. There is also evidence that the futures market seems to lead the cash market in the mean in all three of the sub-periods, though there is a weaker effect of the cash returns having predictive power for the futures in Period II which is after the Big Bang. These results are plausible given that lower transaction and entry costs in the stock index futures market may lead to market-wide information being impounded in futures prices earlier than in the cash market as index arbitrageurs step in quickly to bring the cost-of-carry relationship into alignment. Support is also found for the hypothesis that lower transactions costs is one of the reasons why traders with market-wide information may prefer to use the futures markets. The evidence suggests that the sizeable reduction in transactions costs in the London equity market resulting from the Big Bang appears to have reduced both the size and the significance of the lead of the futures returns over the index returns series. In periods of "good" news, however, neither market seems to lead the other; whereas during times of "moderate" news, the futures leads the cash consistently. During periods of "bad" news, no consistent pattern in the lead–lag relationship emerges. It is shown also that the futures returns lead the cash during times of high volatility, but there is no clear pattern during periods of low volatility. In addition, the futures largely leads the cash during periods of high and low trading volume in the underlying equity market.

The tests for lead–lag in the conditional volatility suggest that there is no clear pattern of one market leading the other in terms of the volatility. This is consistent with earlier evidence in Kawaller et al. (1990) and Cheung and Ng (1991). During periods of "good" and "bad" news, neither market commands a consistent lead. Also, no discernible pattern in the predictive power of the volatilities of the two return series is seen during varying levels of market activity. Future research using a multivariate GARCH approach as in Chan et al. (1991), which may make more efficient use of the information in the variance–covariance matrix, might shed further light on the lead–lag relationship in the volatility in the FT-SE 100 index and index futures markets.

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