The Lead–Lag Relationship between Equities and Stock Index Futures Markets Around Information Releases

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This paper documents a strengthening in the lead of stock index futures returns over stock index returns around macroeconomic information releases. Some evidence of a strengthening in feedback from the equities market to the futures market and weakening in the lead of the futures market around major stock-specific information releases is also provided. This is consistent with the hypothesis that investors with better marketwide information prefer to trade in stock index futures while investors with stock-specific information prefer

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to trade in underlying stocks. A small weakening in the contemporaneous relationship between stock index futures returns and stock index returns around both types of releases is also documented. This is consistent with disintegration in the relationship between the two markets associated with noise induced volatility. One by-product of this study is new comparative evidence on the performance of adjustments for infrequent trading of index stocks based on a commonly used ARMA technique versus recalculation of the stock index using quote midpoints. The results suggest that the quote midpoint index performs at least as well as the ARMA adjusted index across the entire sample period, as well as around the different types of information releases. Jrl Fut Mark 20:467–487, 2000

INTRODUCTION

This paper analyzes the lead-lag relationship between returns on a stock index and stock index futures contract. Prior research has documented considerable variation in the statistical significance of this relationship both through time (e.g., Stoll & Whaley 1990; Abhyankar 1995) and across markets (Grunbichler, Longstaff, & Schwartz 1994). A number of possible explanations for this variation have been examined by prior literature including nonsynchronous trading (Shyy, Vijayraghavan, & Scott-Quinn 1996), market maturation (Stoll & Whaley 1990), transaction costs (Abhyankar 1995; Fleming, Ostdiek, & Whaley 1996), and market architecture (e.g., Grunbichler, Longstaff, & Schwartz 1994). The literature develops two other explanations for the variation in the lead-lag relation between equities and stock index futures markets. First, Chan (1992) argues that the lead of the futures market will be greater around *macroeconomic information* releases, as the leverage benefits of derivatives and lower cost futures environment attracts informed traders. Second, Grunbichler, Longstaff, and Schwartz (1994) recognize that the transmission of information may run from the spot to the futures market in the case of *firm-specific information*, and suggests that this explains the well-documented feedback from stock to stock index futures markets. This paper directly tests both of these propositions using data from the Australian Stock Exchange and Sydney Futures Exchange.

There is an absence of prior work that examines the lead-lag relationship between stock index and stock index futures returns in the presence of stock-specific information releases. However, there have been two prior papers that test the impact of macroeconomic information releases on the relationship between spot market and futures market returns. Chan (1992) was the first to examine the impact of marketwide information releases. An absence of macroeconomic data led him to develop a proxy that measures the extent to which the constituent stocks in an index move together (marketwide movement). He finds that the lead of the futures market appears to strengthen on days of apparent marketwide information releases. In a more direct test, Crain and Lee (1995) examine the lead-lag relationship in return volatility between spot and futures markets for the eurodollar and deutsche mark on days of known economic releases. Their results support Chan (1992) for the eurodollar contract; however, they conclude that there is no significant difference in lead-lag relationships on days of macroeconomic information releases relative to other days for the deutsche mark contract. This paper is primarily motivated by these conflicting findings.

Two methodological innovations are applied in testing whether the lead-lag relationship between returns on stock indices and stock index futures differs on days of macroeconomic news releases. First, Chan (1992) acknowledges that his proxy for marketwide information releases represents an approximation at best and is likely to be affected by considerable measurement error. The availability of a list of macroeconomic news releases for the present study allows us to directly test their impact on lead-lag relationships and mitigate any threats to the internal validity of our research design. Second, Shyy et al. (1996) argue that most of the lead-lag relation is explained by nonsynchronous trading. They demonstrate that when stock index and stock index futures returns are measured using quote midpoints of constituent stocks and futures rather than transaction prices, the lead of the futures market disappears, and, in fact, the reverse intermarket price transmission is much stronger. This study implements the methodological enhancement outlined by Shyy et al. (1996) in carrying out tests using quote data sourced from the ASX and SFE. One by-product of this study is a comparison of the use of midpoint returns in adjusting for nonsynchronous trading to other more commonly used techniques. This enables us to bring further evidence to bear on this issue.

DATA AND INSTITUTIONAL DETAIL

Trading in the Share Price Index (SPI) futures contract on the Sydney Futures Exchange (SFE) began in 1983. SPI futures are traded by open outcry on the floor of the exchange from 9:50 AM to 12:30 PM and 2:00 PM to 4:15 PM. The SPI futures contract is based on the All Ordinaries Index, which is comprised of approximately 280 stocks traded on the Australian Stock Exchange (ASX). The ASX was fully automated by 1991 through the introduction of SEATS. SEATS is an electronic open limit order book comprising a network of computer terminals.[1] SEATS allows brokers to submit orders and execute trades on a continuous basis from approximately 10:10 AM to 4:00 PM. The All Ordinaries Index is computed by SEATS once per minute throughout the trading day based on the last traded price of all stocks in the index.[2] The data used in this study covers the period from 1 August 1995 to 31 December 1996, during which the trading structures for the SPI and ASX listing stocks comprising the All Ordinaries Index remained essentially unchanged.

This study analyzes the relationship between the futures market and spot market around macroeconomic as well as price-sensitive stock-specific information releases.[3] While both the futures market and stock market trade continuously during the release of macroeconomic information, trading in stocks can be halted around the release of stock-specific information.[4] Market-sensitive information announcements typically result in trading halts of approximately 10 minutes.[5] During the halt, SEATS is placed in what is known as the *pre-opening* phase. During the pre-opening phase, bid and ask orders can be entered or amended, but overlapping bids and asks do not execute. The entire limit order book is visible during this phase. After pre-opening, the ASX executes overlapping bid and ask orders at a number of different prices in accordance with a prespecified algorithm (see Aitken, Frino, & Winn, 1997).

One of the distinguishing characteristics of this study is the availability of quote data for both the futures and equities market. Quote data for the SFE are captured by "price reporters"standing on the trading floor. Price reporters use microphones to communicate with price reporting system operators located on a catwalk above the trading floor. The operators then enter the trade information into computer terminals, which automatically assign a time stamp to each record accurate to the nearest second. This data collection system is referred to as the Price Reporting System (PRS), and the data are sold on-line in real time to quote vendors. Unlike U.S. "time and sales" data, PRS data include bid and ask quotes.

[1]See Glosten (1994) for a characterization of an electronic open limit order book.

[2]In the calculation of the index, bid and ask prices may be used instead of last-traded prices for individual stocks if either the bid price is higher or ask price lower than the last traded price, respectively.

[3]Information is classified as price-sensitive by the ASX if the company's department of the exchange believes the content of the announcement may significantly affect the share price. Such information is immediately released to the market, and trading in the stock is halted for a brief period.

[4]ASX Listing Rules dictate that all company announcements must be passed through the ASX to the market before they are released to any external parties such as information vendors.

[5]The main exception is takeover initiations. Stocks that are the subject of takeover initiations are halted for approximately 60 minutes, during which time no orders are accepted for the first 50 minutes.

Data for the ASX were captured on-line in real time from SEATS. The data include full details of all orders and trades including a time stamp to the nearest 100th of a second (see Aitken et al. 1997).

THEORY

Fleming, Ostdiek, and Whaley (1996) argue that informed traders are attracted to derivatives markets as a consequence of the leverage and transaction cost benefits offered by these markets. They demonstrate that the cost of taking a position in a stock index future is considerably lower than the cost of taking an equivalent position in stocks. This implies that better informed market agents can maximize profits from trading on the basis of a given piece of information by trading in stock index futures. Hence, on average, informed traders are more likely to trade in stock index futures markets, and price movements in stock index futures are likely to lead price movements on stocks. Chan (1992) recognizes that this is most likely to occur during periods of marketwide or macroeconomic information releases and argues that the lead of the futures market will consequently increase during such periods. These arguments lead to the following hypothesis:

H_1: The lead of SPI futures returns over All Ordinaries Index returns strengthens significantly around macroeconomic information releases.

Prior literature has also argued that the stock market may occasionally lead the futures market (Grunbichler, Longstaff, & Schwartz 1994). Traders informed of stock-specific information are more likely to trade in individual stocks than the futures market, as the information is likely to have a smaller impact on the index. By trading in individual stocks, these traders act to maximize profits from trading on the basis of a given piece of stock-specific information, which leads to the following hypothesis:

H_2: The feedback from All Ordinaries Index returns to SPI futures returns strengthens significantly around stock-specific information releases.

Despite this predicted relationship, the previously described trading halt that occurs during the release of stock-specific information is likely to influence the relationship between the stock index and stock index futures in two ways. First, while Amihud and Mendelson (1991) examine the relative volatility of the single price call market used to open the Tokyo Stock Exchange against continuous trading and find little difference between the two, Friedman and Rich (1997) carry out a laboratory experiment and find that multiple price call markets generate greater price variability than a single price call.[6] Together, these findings call into question the efficiency of multiple price call markets and imply that quotes are likely to be more volatile during a call than during continuous trading. Given that the ASX trading halt is essentially a multiple price call market, this implies that stock quotes are likely to be more volatile and are less likely to accurately reflect the impact of information released during the halt. Second, Harris (1989) argues that a reduction in the ability to arbitrage between the spot and futures market (because of the inability to execute trades in the spot market) may have resulted in a disintegration in the relationship between the S&P 500 Index and S&P 500 index futures contract in the market break of October 1987. ASX trading halts may similarly limit the ability of traders to properly arbitrage between the SPI and All Ordinaries Index, which could lead to a disintegration in the relationship between the two markets. Both of these factors are likely to obfuscate the relationship between prices quoted in the futures market and prices quoted in the equities market during the trading halt. However, the weakening in the relationship between SPI futures returns and All Ordinaries Index returns is not expected to be confined to the halt intervals. Lee, Ready, and Seguin (1994) provide evidence consistent with the notion that trading halts during periods of price-sensitive information releases are likely to impair price discovery around (but excluding) the period of the halt.

ADJUSTMENTS FOR INFREQUENT TRADING

In examining the lead-lag relationship between SPI futures and the All Ordinaries Index, this study follows prior research by regressing various measures of one minute returns on the All Ordinaries Index ($\hat{R}_{AOI,t}$) against lagged, contemporaneous and leading one minute returns on SPI futures ($\hat{R}_{SPI,t+j}$) as follows:[7,8]

$$\hat{R}_{AOI,t} = \alpha + \sum_{j=-n}^{+n} \alpha_j \hat{R}_{SPI,t+j} + \varepsilon_t \tag{1}$$

One significant issue in estimating (1) is the measurement of index re-

[6]Friedman and Rich (1997) argue that the variability of prices generated by the call result from strategic order placement by market participants. Because prices quoted during ASX trading halts are nonbinding, significant gaming in quote setting can occur over such intervals that bears little relationship to the market-clearing price of the stock. This gaming activity can introduce excessive volatility in quoted prices during halts.

[7]All analysis in the paper has also been carried out using 5-minute intervals. The results of the 5-minute analysis are consistent with those reported in this paper.

[8]Stoll and Whaley (1990); Chan (1992); Grunbichler, Longstaff, and Schwartz (1994); and Abhyankar (1995) also use this approach.

turns. Stoll and Whaley (1990) argue that observed index returns are a biased measure of "true" returns because revisions in investor price expectations are only reflected in the index after a trade. Infrequent trading of underlying stocks in an index implies that a marketwide return innovation in a given interval can be spread across a number of subsequent intervals until all constituent stocks trade. This problem can lead the researcher to invalidly conclude that the futures market leads the equities market on the basis of (1). Stoll and Whaley (1990) demonstrate that the effects of bid–ask bounce and infrequent trading of constituent stocks on index returns can be modelled as an ARMA (p,q) process. Hence the residuals from applying an ARMA model to observed index returns (herein "index innovations") proxy for "true" index returns.[9]

Another technique for avoiding the effects of infrequent trading is outlined in Shyy et al. (1996) and involves recalculating index returns using stock bid and ask quotes rather than trade prices. This mitigates the problem with transaction-based returns identified by Stoll and Whaley (1990). Shyy et al. (1996) demonstrate that index futures returns appear to lead index returns when index and futures transaction prices are used in the calculation of returns, but that the reverse occurs when returns are calculated using stock and futures quotes. Their evidence provides a justification for carrying out analysis using quote data. Hence, All Ordinaries Index returns ($R_{AOI,t}$) are recomputed using actual bid and ask prices for each of the component stocks as follows:[10]

$$R_{AOI,t} = \ln\left[\frac{\sum_{j=1}^{n}\{s_{j,t}\cdot(q_{j,t}^{b} + q_{j,t}^{a})/2\}}{\sum_{j=1}^{n}\{s_{j,t-1}\cdot(q_{j,t-1}^{b} + q_{j,t-1}^{a})/2\}}\right] \qquad (2)$$

where j is a component stock of the index, s_j is the number of ordinary shares outstanding for stock j, q_j^b, and q_j^a are the best bid and ask prices, respectively, for stock j, and n is the number of stocks in the index.

Table I reports estimates of eq. (1) after calculating SPI returns on the basis of SPI futures quotes and calculating All Ordinaries Index returns using (i) the reported index (AOI raw/SPI), (ii) return innovations

[9]Unfortunately, one of the limitations of the approach is that in purging the effects of infrequent trading and bid–ask bounce from observed index return, a portion of "true" returns can also be removed. Second, ARMA (p,q) estimation results in a loss of observations at the beginning of each day equivalent to the maximum number of lags included in the model.

[10]The bid and ask prices used in the recalculation of the index are captured in real time from SEATS for all stocks in the index. SEATS also gives monthly reports on the composition of the index, including the relative percentage of the index that each stock represents.

TABLE I

Parameter Estimates from Regressions of Stock Index Returns, Return Innovations and Midpoint Returns on Lagged, Contemporaneous, and Leading Nearby Futures Returns

	AOI raw/SPI		*AOI Innovations/SPI*		*AOI Midpoint/SPI*		*AOI Innovations/AOI Midpoint*	
	Coeff.	*White adj. t-stat*	*Coeff.*	*White adj. t-stat*	*Coeff.*	*White adj. t-stat*	*Coeff.*	*White adj. t-stat*
Intercept	0.0000	0.95	0.0000	−1.17	0.0000	0.67	0.0000	−2.44**
α_{+20}	−0.0008	−0.78	−0.0011	−1.06	−0.0016	−1.16	−0.0012	−0.48
α_{+19}	0.0004	0.35	0.0005	0.43	−0.0022	−1.48	0.0004	0.11
α_{+18}	−0.0012	−1.15	−0.0012	−1.22	−0.0003	−0.20	−0.0023	−0.99
α_{+17}	0.0001	0.07	0.0003	0.19	0.0019	1.20	−0.0047	−1.35
α_{+16}	−0.0010	−0.90	−0.0011	−0.93	−0.0023	−1.41	−0.0024	−0.70
α_{+15}	−0.0006	−0.51	−0.0005	−0.40	0.0010	0.66	0.0012	0.31
α_{+14}	0.0000	0.03	0.0001	0.13	−0.0001	−0.08	−0.0003	−0.12
α_{+13}	−0.0012	−1.07	−0.0012	−1.09	−0.0002	−0.16	−0.0009	−0.68
α_{+12}	−0.0006	−0.44	−0.0004	−0.30	−0.0013	−0.97	−0.0028	−1.19
α_{+11}	0.0000	0.01	0.0001	0.07	0.0009	0.69	0.0107	1.71
α_{+10}	−0.0020	−1.67	−0.0020	−1.66	−0.0006	−0.45	−0.0051	−1.59
α_{+9}	0.0013	1.19	−0.0020	−1.79	0.0003	0.25	−0.0050	−1.58
α_{+8}	−0.0007	−0.53	0.0012	1.29	0.0015	1.16	−0.0006	−0.27
α_{+7}	−0.0011	−1.00	−0.0007	−0.65	−0.0003	−0.24	−0.0041	−1.36
α_{+6}	−0.0003	−0.13	−0.0001	−0.06	0.0052	1.64	0.0076	0.97
α_{+5}	0.0005	0.48	0.0006	0.49	0.0044	3.10*	0.0001	0.04
α_{+4}	0.0037	3.16*	0.0036	3.14*	0.0053	3.57*	0.0051	1.61
α_{+3}	0.0046	4.13*	0.0041	3.74*	0.0089	5.67*	0.0154	3.72*
α_{+2}	0.0155	8.23*	0.0148	8.08*	0.0149	7.01*	0.0417	5.96*
α_{+1}	0.0395	10.83*	0.0372	10.76*	0.0317	9.27*	0.0339	2.88*
α_{0}	0.1141	2.68*	0.1084	2.53**	0.2574	7.30*	0.3755	4.67*
α_{-1}	0.0511	5.55*	0.0345	2.66*	0.0702	7.43*	0.0313	4.98*
α_{-2}	0.0331	10.63*	0.0257	9.10*	0.0404	13.06*	0.0290	3.13*
α_{-3}	0.0264	10.13*	0.0216	9.53*	0.0325	12.83*	0.0279	4.12*
α_{-4}	0.0268	8.06*	0.0230	7.35*	0.0283	13.85*	0.0242	2.80*
α_{-5}	0.0181	8.74*	0.0142	7.34*	0.0213	11.15*	0.0140	2.99*
α_{-6}	0.0179	4.18*	0.0153	3.65*	0.0281	3.17*	0.0152	2.94*
α_{-7}	0.0157	5.02*	0.0131	4.22*	0.0170	7.22*	0.0109	2.31**
α_{-8}	0.0123	5.64*	0.0100	5.14*	0.0203	9.61*	0.0063	1.01
α_{-9}	0.0151	3.78*	0.0133	3.35*	0.0254	7.92*	0.0051	0.84
α_{-10}	0.0618	8.74*	0.0596	8.42*	0.0082	4.72*	0.0093	1.37
α_{-11}	0.0335	7.58*	0.0245	4.86*	0.0146	6.98*	0.0127	1.65
α_{-12}	0.0277	8.15*	0.0228	6.23*	0.0150	7.36*	0.0103	1.39
α_{-13}	0.0241	7.81*	0.0201	6.11*	0.0103	6.42*	0.0090	0.99
α_{-14}	0.0172	8.66*	0.0137	6.48*	0.0112	5.98*	0.0022	0.70
α_{-15}	0.0198	7.90*	0.0173	6.94*	0.0085	3.61*	0.0092	1.05
α_{-16}	0.0259	5.87*	0.0230	5.17*	0.0125	5.64*	0.0021	0.54
α_{-17}	0.0259	7.03*	0.0221	5.97*	0.0072	2.42**	0.0100	1.22
α_{-18}	0.0227	4.34*	0.0189	3.49*	0.0050	2.24**	0.0194	1.39

TABLE I (Continued)

Parameter Estimates from Regressions of Stock Index Returns, Return Innovations and Midpoint Returns on Lagged, Contemporaneous, and Leading Nearby Futures Returns

	AOI raw/SPI		*AOI Innovations/SPI*		*AOI Midpoint/SPI*		*AOI Innovations/AOI Midpoint*	
	Coeff.	*White adj. t-stat*	*Coeff.*	*White adj. t-stat*	*Coeff.*	*White adj. t-stat*	*Coeff.*	*White adj. t-stat*
α_{-19}	0.0201	3.92*	0.0022	1.69	0.0012	1.19	0.0121	1.78
α_{-20}	0.0120	2.06**	0.0012	1.37	0.0019	1.34	0.0022	0.57
Adj. R^2	0.158		0.151		0.265		0.362	
No. Obs	59,230		59,230		59,230		59,230	
DW	2.06		2.04		2.08		2.09	
Coefficient tests: (F-stats in parenthesis)								
$(\alpha_{+1} + \ldots + \alpha_{+20})$	0.056	(122.23)*	0.052	(122.99)*	0.067	(111.27)*	0.087	(33.14)*
$(\alpha_{-1} + \ldots + \alpha_{-20})$	0.507	(753.20)*	0.396	(690.10)*	0.379	(617.44)*	0.263	(209.21)*
$(\alpha_{-1} + \ldots + \alpha_{-20}) - (\alpha_{+1} + \ldots + \alpha_{+20})$	0.451	(515.59)*	0.344	(282.31)*	0.312	(350.81)*	0.178	(64.12)*

*significant at the 0.01 level
**significant at the 0.05 level

from an ARMA (1,1) model (AOI Innovations/SPI),[11] and (iii) a recalculated index based on the midpoint of the stock quotes (AOI Midpoint/SPI).[12] Returns are calculated using a 1-minute observation interval, and the first 20 minutes prior to and following trading breaks (overnight and the lunchtime break) are excluded to avoid comparing returns across market breaks.[13] Consistent with prior research, the nearby futures contract

[11]A number of different ARMA (p,q) models were estimated; however, the Akaike Information Criterion was minimized for an ARMA(1,1) specification. The same specification was identified using the Schwartz Criteria.

[12]Whenever the underlying stock experienced a trading halt, the best nonoverlapping quotes were used in the calculation of the index. This is equivalent to choosing the best quotes after notionally applying the algorithm used by the ASX to execute overlapping quotes during a halt.

[13]It is unlikely that returns that are adjacent in calendar time will be associated in the same way as returns in trading time. Returns that cross-trading breaks are unlikely to be related primarily because of the possibility of (nontrading related) price discovery taking place during the trading halt. Consequently, index returns are calculated every minute from 10:30 AM to 12:10 PM and 2:20 PM to 3:40 PM. SPI futures returns, however, forming the leading and lagging variables in the regressions, are measured from 10:10 AM to 12:30 PM and 2:00 PM to 4:00 PM. In this way, only periods when both markets are open are examined, and all leading and lagging SPI futures returns involved in each regression are adjacent in calendar time.

is used to construct futures returns, and all t-statistics are adjusted for heteroskedasticity using the procedure outlined in White (1980).

Table I documents that when the lead-lag relationship in returns between the SPI and All Ordinaries index is calculated using the reported index, coefficients associated with 20 lagged SPI returns are significant at the 0.05 level. This implies that SPI returns lead index returns calculated on the basis of the *reported* All Ordinaries index by up to 20 minutes. Furthermore, coefficients on the first four leading SPI returns (α_{+1} to α_{+4}) are significant at the 0.05 level, implying a 4-minute feedback from the equities market to the futures market. When returns on the All Ordinaries Index are purged of infrequent trading using either the ARMA approach or recomputed index, coefficients α_{-19} and α_{-20} become insignificant, suggesting that the real lead of the futures market is only 18 minutes in duration. Hence, the evidence reported in Table I is consistent with most prior research, that generally, futures market returns lead stock market returns. F-statistics reported below the regression results test the null hypothesis that the sum of the lagging coefficients less the sum of the leading coefficients is equal to zero. For all regressions the null hypothesis is rejected at the 0.01 level.

The results in Table I also imply that both adjustments for infrequent trading work as expected, although there is some evidence that the midpoint index adjustment may perform better. When midpoint index returns are used in the analysis, observed feedback from the equities market to the futures market is longer by one minute and the lead of the futures market is statistically weaker at longer lags. Furthermore, the last two columns in Table I report the results of a regression of AOI return innovations on leading and lagging AOI midpoint returns (AOI Innovations/AOI Midpoint). This evidence suggests that the midpoint return series leads the innovation series by up to 7 minutes with a 3-minute feedback. Table I also demonstrates that the use of midpoint index returns is associated with a significantly higher R-squared for the lead-lag regressions than index return innovations (26.5% in the AOI Midpoint/SPI model versus only 15.1% for the AOI Innovations/SPI model).

THE IMPACT OF MACROECONOMIC RELEASES

To test the impact of macroeconomic releases on the lead-lag relationship between stock index and stock index futures returns (Hypothesis 1), dummy variables ($D_{m,t}$) are introduced into eq. 1 that take on a value of

1 if observation t lies within a half hour either side of a major macroeconomic release, otherwise 0:[14]

$$\hat{R}_{AOI,t} = \alpha + \sum_{j=-n}^{+n} \alpha_j \hat{R}_{SPI,t+j} + \sum_{j=-n}^{+n} \alpha_j' D_{m,t} \hat{R}_{SPI,t+j} + \varepsilon_t \quad (3)$$

The α_j' coefficients capture the incremental impact of the information release on the lead-lag relationship. A comprehensive list of scheduled macroeconomic information releases was provided by an investment bank over the sample period and used to construct the dummy variables. As it is not clear, however, that all scheduled macroeconomic information releases will have an impact on stock index futures prices, the announcements are prefiltered using a procedure developed by Ederington and Lee (1993). The procedure, which is described in Appendix A, determines which *categories* of releases have a statistically significant impact on stock index futures volatility. Table II reports our estimates of eq. 2 using both return innovations (AOI Innovations) and index returns based on quote midpoints (AOI Midpoint).

The results reported in Table II are generally consistent across both measures of stock index returns. The coefficients α_{-1} to α_{-4} on the dummy variables ($D_{m,t}$) for estimates based on the AOI Midpoint and α_{-1} to α_{-6} for estimates based on AOI Innovations are significantly positive (at the 0.01 level). This supports Hypothesis 1 and implies that the lead of the futures market strengthens surrounding major macroeconomic news releases. F-statistics testing the null hypothesis that the sum of the lagging coefficients on the dummy variables is equal to zero is rejected at the 0.01 level for both measures of index returns confirming this result. The coefficient on contemporaneous All Ordinaries Index and SPI returns is significantly lower in the half hour surrounding macroeconomic news releases. This implies that the relationship between the two markets disintegrates at these times, which may be driven by increased noise and price volatility (Ederington & Lee, 1993).

The results reported above also corroborate the findings of Chan (1992), which document that coefficients on lagged stock index futures returns increase significantly on days when there is a higher degree of comovement in returns of underlying stocks (probability of information releases higher).[15] Similarly, Chan (1992) finds no significant change in

[14]All major Australian macroeconomic information releases occur at 11:30 AM. Consequently, if a release occurs on a particular day, the dummy variable takes on a value of 1 for 60 intervals beginning at 11:00 AM and ending with the interval beginning at 11:59 AM.

[15]Chan (1992) proxied for the probability of an information release using a proxy "RATIO" measured as $|\Sigma 20\Delta s_i|/\Sigma|\Delta s_i|$, where Δs_i is the price change of MMI component stock i within a 30-minute interval. A higher RATIO is consistent with greater comovement in stock prices and is likely to be associated with marketwide information.

TABLE II

The Effect of Macroeconomic Releases on Estimates from Regressions of Stock Index Return Innovations and Midpoint Returns on Lagged, Contemporaneous, and Leading Futures Returns.

	AOI Midpoint				AOI Innovations			
SPI	Coeff.	White adj. t-stat	$D_{m,t}$ Coeff.	White adj. t-stat	Coeff.	White adj. t-stat	$D_{m,t}$ Coeff.	White adj. t-stat
Intercept	0.0000	0.67			0.0000	−1.18		
α_{+20}	−0.0022	−1.52	0.0091	1.66	−0.0014	−1.38	0.0028	0.58
α_{+19}	−0.0023	−1.48	0.0046	0.85	0.0006	0.51	−0.0022	−0.45
α_{+18}	−0.0003	−0.22	0.0003	0.05	−0.0015	−1.47	0.0058	1.23
α_{+17}	0.0019	1.18	−0.0034	−0.63	0.0004	0.31	−0.0044	−0.87
α_{+16}	−0.0026	−1.52	−0.0010	0.18	−0.0012	−1.01	0.0026	0.51
α_{+15}	0.0011	0.72	−0.0017	−0.31	−0.0004	−0.29	−0.0011	−0.23
α_{+14}	−0.0001	−0.04	0.0049	0.89	0.0001	0.10	0.0062	1.33
α_{+13}	−0.0002	−0.16	0.0021	0.34	−0.0010	−0.91	−0.0014	−0.25
α_{+12}	−0.0014	−1.06	0.0036	0.62	−0.0005	−0.40	0.0071	1.44
α_{+11}	0.0009	0.62	0.0003	0.04	0.0001	0.10	0.0013	0.24
α_{+10}	−0.0005	−0.40	−0.0011	−0.18	−0.0017	−1.36	−0.0054	−1.04
α_{+9}	0.0003	0.24	0.0030	0.50	−0.0019	−1.63	0.0035	0.69
α_{+8}	0.0013	1.02	0.0016	0.27	0.0011	1.32	0.0057	1.06
α_{+7}	−0.0004	−0.29	0.0030	0.49	−0.0003	−0.31	−0.0037	−0.73
α_{+6}	0.0055	1.64	−0.0075	−1.20	−0.0002	−0.07	0.0003	0.05
α_{+5}	0.0047	3.28*	−0.0026	−0.44	0.0007	0.59	0.0019	0.37
α_{+4}	0.0054	3.54*	−0.0018	−0.31	0.0040	3.42*	−0.0056	−1.13
α_{+3}	0.0088	5.49*	−0.0019	−0.30	0.0041	3.64*	−0.0005	−0.10
α_{+2}	0.0153	6.91*	−0.0065	−0.82	0.0151	7.87*	−0.0021	−0.36
α_{+1}	0.0307	8.79*	−0.0030	−0.53	0.0353	10.24*	−0.0038	−0.82
α_{0}	0.2634	7.23*	−0.1382	−3.66*	0.1099	2.46**	−0.0489	−2.17**
α_{-1}	0.0675	6.89*	0.0597	4.97*	0.0317	4.72*	0.0645	4.40*
α_{-2}	0.0386	12.32*	0.0442	6.69*	0.0241	8.55*	0.0383	6.52*
α_{-3}	0.0313	12.05*	0.0225	3.49*	0.0201	8.90*	0.0312	5.50*
α_{-4}	0.0277	13.24*	0.0164	2.59*	0.0226	6.97*	0.0172	4.21*
α_{-5}	0.0210	10.70*	0.0085	1.36	0.0139	6.99*	0.0107	2.42*
α_{-6}	0.0279	3.00*	−0.0007	−0.06	0.0143	3.29*	0.0204	3.28*
α_{-7}	0.0166	6.86*	0.0088	1.14	0.0129	3.98*	0.0042	0.67
α_{-8}	0.0204	9.28*	−0.0029	−0.47	0.0095	4.72*	0.0062	0.98
α_{-9}	0.0260	7.78*	−0.0090	−1.29	0.0134	3.25*	−0.0029	−0.42
α_{-10}	0.0083	4.59*	−0.0016	−0.31	0.0620	8.32*	−0.0112	−1.44
α_{-11}	0.0147	6.75*	−0.0026	−0.47	0.0247	4.70*	−0.0069	−0.98
α_{-12}	0.0152	7.15*	−0.0022	−0.40	0.0233	6.06*	−0.0089	−1.52
α_{-13}	0.0106	6.43*	−0.0089	−1.59	0.0204	5.98*	−0.0107	−1.86
α_{-14}	0.0113	5.79*	0.0010	0.19	0.0144	6.48*	−0.0012	−0.29
α_{-15}	0.0088	3.55*	−0.0074	−1.33	0.0180	6.90*	−0.0014	−0.37
α_{-16}	0.0125	5.44*	−0.0052	−0.96	0.0238	5.13*	0.0015	0.39
α_{-17}	0.0074	2.38**	−0.0067	−1.07	0.0229	5.88*	−0.0019	−0.45
α_{-18}	0.0049	2.12**	0.0041	0.74	0.0198	3.52*	0.0024	0.64

TABLE II (Continued)

The Effect of Macroeconomic Releases on Estimates from Regressions of Stock Index Return Innovations and Midpoint Returns on Lagged, Contemporaneous, and Leading Futures Returns.

	AOI Midpoint				*AOI Innovations*			
SPI	Coeff.	White adj. t-stat	$D_{m,t}$ *Coeff.*	*White adj. t-stat*	*Coeff.*	*White adj. t-stat*	$D_{m,t}$ *Coeff.*	*White adj. t-stat*
α_{-19}	0.0011	1.15	−0.0056	−0.93	0.0020	1.56	0.0026	0.72
α_{-20}	0.0011	1.32	−0.0081	−1.43	0.0017	1.18	−0.0010	−0.09
Adj. R^2	0.269				0.165			
No. Obs	59,230				59,230			
DW	2.07				2.04			
Coefficient tests: (F-stats in parenthesis)								
$(\alpha_{+1} + \ldots + \alpha_{+20})$			0.0039	(0.98)			0.0070	(1.06)
$(\alpha_{-1} + \ldots + \alpha_{-20})$			0.1043	(12.61)*			0.1430	(15.19)*

*significant at the 0.01 level
**significant at the 0.05 level

the coefficients associated with leading stock index futures returns on days where the probability of information releases is higher. In contrast to the findings documented in this study, however, Chan (1992) documents a significant increase in the coefficient associated with contemporaneous stock index and stock index futures returns on days when underlying stocks are moving together. One possible explanation for the difference in results is that partitioning on the degree of comovement in underlying stocks introduces a self-selection bias into the analysis (see Chan 1992, p. 145), which excludes information releases associated with a high degree of uncertainty and price volatility.

THE IMPACT OF STOCK-SPECIFIC INFORMATION RELEASES

To test the impact of stock-specific information releases on the lead-lag relationship between stock index and stock index futures returns (Hypothesis 2), eq. (4) was estimated as follows:

$$\hat{R}_{AOI,t} = \alpha + \sum_{j=-n}^{+n} \alpha_j \hat{R}_{SPI,t+j} + \sum_{j=-n}^{+n} \alpha_j'' D_{s,t} \hat{R}_{SPI,t+j} + \varepsilon_t \qquad (4)$$

The dummy variables ($D_{s,t}$) introduced in eq. 4 are computed using a list of all price-sensitive stock-specific information released by companies in the All Ordinaries Index over the sample period, provided by the ASX. However, many announcements are expected to have a trivial impact upon the overall index level because either the *announcement type* itself is insignificant, or because the *stock* to which the announcement relates is a very small fraction of the index. To account for this, the list of stock-specific announcements is also prefiltered using the approach developed by Ederington and Lee (1993), which identifies the categories of announcements with a statistically significant impact on the index price. This procedure is described in the appendix. Furthermore, to ensure that market behaviour around the *most* significant announcements is examined, announcements for stocks that compose less than 0.14% of the index were excluded from the analysis. This cutoff equates to the median proportion of the index made up by a constituent stock (by market capitalisation) across all stocks and days sampled.[16] The dummy variables ($D_{s,t}$) therefore take on a value of 1 if the following three criteria are all satisfied: (i) the interval t lies within 30 minutes either side of an announcement, (ii) the announcement is in a category that has a significant impact on index volatility, and (iii) where the announcement relates to a stock that composes more than 0.14% of the index.

Table III reports estimates of eq. (4) using both return innovations (AOI Innovations), and index returns based on quote midpoints (AOI Midpoint).

Table III documents that the first leading coefficient (α_{-1}) on the dummy variables is positive and significant at the 0.05 level for estimates of eq. 4 based on the AOI midpoint. This result implies that the reported feedback of the equities market to the futures market strengthens around stock-specific information releases. The evidence, however, is mixed as the F-test on the sum of the leading dummy variable coefficients is positive as expected but insignificant. It appears that the strengthening of the feedback at low leads becomes insignificant in the tests at the bottom of Table III due to the long lag structure used. Notably, however, the sum of the lagging dummy variable coefficients is highly negative and an F-test significantly rejects the null hypothesis that the sum of the lagging dummy variable coefficients is equal to zero at the 0.05 level. Despite the insignificance of the individual lagging coefficients, this provides some evidence of a weakening in the lead of the futures market around stock-specific information releases that is spread over a number of intervals. For estimates of eq. 4 based on AOI Innovations, in contrast to the pre-

[16]We thank the two anonymous referees for suggesting this partition. Other partitions of stock-specific information releases were examined but yielded similar results.

TABLE III

The Effect of Stock-Specific Releases on Estimates from Regressions of Stock Index Return Innovations and Midpoint Returns on Lagged, Contemporaneous, and Leading Futures Returns.

	AOI Midpoint				*AOI Innovations*			
SPI	*Coeff.*	*White adj. t-stat*	$D_{s,t}$ *Coeff.*	*White adj. t-stat*	*Coeff.*	*White adj. t-stat*	$D_{s,t}$ *Coeff.*	*White adj. t-stat*
Intercept	0.0000	1.77			0.0000	−0.41		
α_{+20}	−0.0047	−1.44	−0.0021	−0.26	0.0007	0.22	0.0035	0.47
α_{+19}	−0.0001	−0.02	−0.0102	−1.24	0.0005	0.16	−0.0155	−1.41
α_{+18}	0.0020	0.64	−0.0013	−0.18	0.0040	1.24	−0.0069	−0.89
α_{+17}	0.0029	0.97	0.0000	0.00	0.0008	0.23	0.0088	1.17
α_{+16}	−0.0038	−1.30	0.0002	0.03	−0.0004	−0.10	−0.0137	−1.78
α_{+15}	0.0017	0.55	0.0045	0.56	0.0014	0.37	−0.0098	−1.33
α_{+14}	−0.0007	−0.23	−0.0028	−0.40	−0.0007	−0.23	0.0139	1.92
α_{+13}	−0.0012	−0.38	0.0011	0.16	−0.0026	−0.63	0.0016	0.20
α_{+12}	−0.0002	−0.04	0.0111	1.53	0.0019	0.43	−0.0042	−0.53
α_{+11}	0.0062	1.77	0.0022	0.29	0.0028	0.61	0.0118	1.49
α_{+10}	0.0022	0.51	0.0062	0.76	−0.0029	−0.59	0.0099	1.21
α_{+9}	−0.0010	−0.30	−0.0020	−0.26	−0.0019	−0.45	0.0049	0.61
α_{+8}	0.0060	1.81	−0.0109	−1.53	−0.0006	−0.18	0.0026	0.35
α_{+7}	−0.0007	−0.21	0.0127	1.62	−0.0041	−1.27	0.0006	0.08
α_{+6}	0.0020	0.61	0.0040	0.54	0.0033	0.74	−0.0054	−0.64
α_{+5}	0.0039	1.29	−0.0067	−0.80	−0.0058	−1.67	0.0136	1.81
α_{+4}	0.0096	2.58*	−0.0062	−0.81	0.0001	0.04	0.0040	0.49
α_{+3}	0.0171	4.51*	−0.0125	−1.46	0.0074	2.16**	−0.0138	−1.72
α_{+2}	0.0256	5.44*	0.0010	0.12	0.0257	5.69*	0.0016	0.20
α_{+1}	0.0630	8.21*	0.0146	1.98**	0.0881	8.25*	−0.0045	−0.34
α_{0}	0.1475	4.45*	−0.0443	−2.35*	0.1368	2.05**	−0.0728	−3.12*
α_{-1}	0.1009	8.58*	0.0029	0.19	0.0592	2.92*	0.0194	0.89
α_{-2}	0.0641	8.07*	0.0015	0.14	0.0494	6.38*	0.0016	0.14
α_{-3}	0.0491	6.49*	0.0043	0.39	0.0430	7.32*	0.0020	0.20
α_{-4}	0.0346	7.31*	0.0117	1.16	0.0305	5.78*	0.0131	1.02
α_{-5}	0.0250	4.54*	0.0066	0.65	0.0228	5.74*	−0.0100	−1.05
α_{-6}	0.0238	5.52*	0.0021	0.23	0.0240	5.21*	−0.0145	−1.38
α_{-7}	0.0169	4.47*	−0.0121	−1.37	0.0224	5.26*	−0.0103	−0.85
α_{-8}	0.0191	5.08*	−0.0026	−0.35	0.0190	4.89*	−0.0082	−1.28
α_{-9}	0.0175	4.81*	−0.0116	−1.19	0.0184	4.24*	−0.0125	−1.55
α_{-10}	0.0113	2.79*	0.0005	0.05	0.0430	2.37*	−0.0372	−1.36
α_{-11}	0.0123	3.01*	−0.0003	−0.05	0.0117	2.29**	−0.0044	−0.45
α_{-12}	0.0112	2.57*	−0.0116	−1.77	0.0210	2.53*	−0.0072	−0.73
α_{-13}	0.0010	2.52*	0.0125	1.27	0.0101	2.30**	0.0085	1.12
α_{-14}	0.0115	2.88*	0.0016	0.23	0.0189	4.71*	−0.0148	−1.85
α_{-15}	0.0121	2.67*	0.0013	0.14	0.0232	4.10*	−0.0087	−0.85
α_{-16}	0.0127	4.07*	−0.0073	−1.08	0.0250	4.14*	−0.0139	−1.48
α_{-17}	0.0076	2.09**	0.0081	0.84	0.0248	3.81*	−0.0022	−0.11
α_{-18}	0.0085	2.57*	−0.0045	−0.67	0.0165	3.70*	−0.0015	−0.11

TABLE III (Continued)

The Effect of Stock-Specific Releases on Estimates from Regressions of Stock Index Return Innovations and Midpoint Returns on Lagged, Contemporaneous, and Leading Futures Returns.

	AOI Midpoint				*AOI Innovations*			
SPI	*Coeff.*	*White adj. t-stat*	$D_{s,t}$ *Coeff.*	*White adj. t-stat*	*Coeff.*	*White adj. t-stat*	$D_{s,t}$ *Coeff.*	*White adj. t-stat*
α_{-19}	0.0033	0.84	−0.0064	−0.66	0.0128	1.20	−0.0107	−1.15
α_{-20}	0.0004	0.13	−0.0058	−0.58	0.0080	1.50	−0.0054	−0.53
Adj. R^2	0.2671				0.1728			
No. Obs	59,230				59,230			
DW	2.06				2.03			
Coefficient tests: (F-stats in parenthesis)								
$(\alpha_{+1} + \ldots + \alpha_{+20})$			0.0030	(0.43)			−0.0029	(0.03)
$(\alpha_{-1} + \ldots + \alpha_{-20})$			−0.0191	(5.21)**			−0.1169	(10.75)*

*significant at the 0.01 level
**significant at the 0.05 level

vious results, there is no evidence of a significant change in leading or lagging dummy variable coefficients. However, many coefficients on the lagging dummy variables (α_{-1} to α_{20}) are negative and the sum of the coefficients is highly negative, consistent with the estimates of eq. 4 based on AOI midpoint returns. An *F*-test on the sum of the lagging dummy variable coefficients once again confirms that the effect is statistically significant at the 0.01 level. This result is similar yet stronger than that reported in Table III for results based on midpoint index returns. Overall, the results provide some support for Hypothesis 2 and the conjecture of Grunbichler, Longstaff, and Schwartz (1994). Furthermore, Table III provides evidence that the lead of the futures market may also weaken in the periods surrounding stock-specific information releases.

Table III also reports negative and statistically significant coefficients on the contemporaneous dummy variable coefficients. Similar to Table II, this result appears to indicate that some disintegration in the contemporaneous relationship between the markets occurs around stock-specific information releases. Three possible explanations for the disintegration in the relationship between the two markets are: (i) quotes sampled during trading halts are noisy and trade prices are not updated, (ii) trading halts impair price discovery around information releases, which in turn weakens the relationship between the markets, and (iii) the relationship between the markets may disintegrate because of the noise introduced by price discovery around information releases. The first two explanations are discussed in the theory section above, while the third is self-explanatory. In order to explore this issue further, the analysis of stock-specific information releases was repeated after excluding observations where one or more of the stocks underlying the index experienced a trading halt. The results of this analysis were almost identical to those reported in Table III.[17] Hence, it is unlikely that the results are being driven by quotes sampled during trading halts. Explanation (ii) can also be eliminated, because a similar disintegration in the relationship between the two markets is documented for macroeconomic information releases that are *not* accompanied by trading halts. Hence, it is concluded that the disintegration in the relationship between the two markets is driven by noise associated with trading activity around the information release.

CONCLUSION

This paper provides evidence that the lead-lag relationship between returns on stock index and stock index futures contracts is influenced by the release of macroeconomic and stock-specific information. Consistent with the hypothesis that investors with better marketwide information are more likely to trade in stock index futures, this paper finds that the lead of the futures market strengthens significantly around macroeconomic news releases. There is also some evidence that feedback from the equities market to the futures market strengthens around stock-specific information releases and that the lead of the futures market weakens. This is consistent with the hypothesis that investors with stock-specific information prefer to trade in individual stocks. For both macroeconomic and stock-specific information releases, there is evidence of disintegration in the contemporaneous relationship between the two markets, which appears consistent with the effects of noise associated with price discovery. These findings have a bearing on previous research that has attempted to compare the lead-lag relationship between stock index and stock index futures across markets and over different sample periods (e.g., Grunbichler, Longstaff, & Schwartz, 1994; Abhyankar 1995). The results suggest that this research needs to control for the effects of information releases in order to provide valid comparisons.

This paper also provides evidence relevant to evaluating the performance of the more commonly used ARMA approach to adjust for the

[17]This analysis is available from the authors on request.

effects of infrequent trading in index stocks against a technique outlined in Shyy etal. (1996) that involves recalculating the index on the basis of stock quotes. The evidence in this paper suggests that while both methods produce qualitatively similar results across the entire sample period, and around stock-specific as well as macroeconomic information releases, the midpoint index approach appears to perform slightly better in accounting for the effects of nonsynchronous trading.

APPENDIX A: DESCRIPTION OF INFORMATION RELEASE SAMPLES

This appendix provides descriptive statistics on the samples of stock-specific and macroeconomic information releases and outlines the procedure adapted from Ederington and Lee (1993), which is used to determine the categories of information releases that are considered "major." For macroeconomic and stock-specific information releases separately, a measure of return volatility is regressed on dummy variables corresponding to the different categories of information (as classified by the Australian Bureau of Statistics [ABS] and Australian Stock Exchange, respectively). For macroeconomic information releases, 23 dummy variables are constructed for the categories of information outlined in panel A of Table A.1. For stock-specific information releases, 16 dummy variables are constructed covering the categories outlined in panel B of Table A.1. Each dummy variable takes on a value of 1 if the observation relates to an interval with an announcement in the corresponding information category and 0 otherwise. In addition, as a trading halt occurs in the equities market upon the release of stock-specific information, the dummy variables also take on a value of 1 for the half hour either side of stock-specific announcements.[18]

Panel A of Table A.1 reports the types, number, and frequency of scheduled macroeconomic information releases in Australia over the sample period in addition to the results of the regression analysis. Since ABS releases occur at 11:30 AM, the dependent variable in the regression is the absolute value of SPI futures returns in the 1-minute interval beginning at 11:30 AM.[19] Panel B of the same table reports the types and number of stock-specific information releases that occurred over the sample period as well as the number of unique stocks that released such

[18]Aitken, Frino, and Winn (1997) demonstrate that the bulk of price discovery occurs within a half hour of a stock-specific information release on the ASX.

[19]The regression analysis is run using all days in the sample. The use of the announcement interval (11:30 AM) alone in the regression analysis of panel A is consistent with Ederington and Lee (1993).

TABLE A.1

Panel A: Macroeconomic information releases	*Regression*			
Announcement	*Coeff* * 10^2	*White adj. t-stat*	*n*	*Frequency*
ANZ Job Vacancies	0.0072	3.966*	17	Monthly
Australian Business Expectations	0.0047	1.16	1	Quarterly
Average Weekly Overtime Earnings	0.0135	6.766*	10	Quarterly
Balance of Payments	0.0031	2.689*	21	Monthly & Qtrly
Building Approvals	0.0041	2.753*	16	Monthly
Company Profits	0.0101	2.344**	6	Quarterly
Consumer Price Index	0.0131	5.8*	5	Quarterly
Dwelling Unit Commencements	0.0070	3.504*	5	Quarterly
Employment	0.0097	6.849*	17	Monthly
Housing Finance	0.0078	5.269*	18	Monthly
Job Vacancies & Overtime	0.0088	3.199*	4	Quarterly
Merchandise Imports	0.0019	1.577	16	Monthly
Motor Vehicle Registrations	0.0032	2.978*	18	Monthly
NAB Business Survey	0.0015	0.77	7	Quarterly
National Accounts	0.0016	0.507	1	Quarterly
Net External Debt	0.0009	0.469	7	Quarterly
Price Index of Articles Produced in Manufacturing	0.0028	2.426**	15	Monthly
Price Index of Articles Used in Manufacturing	0.0044	3.835*	18	Monthly
Private New Capital Expenditure	0.0020	1.266	6	Quarterly
RBA Credit Aggregates	0.0040	3.178*	16	Monthly
Real GDP	0.0047	1.718	5	Quarterly
Retail Trade	0.0059	4.637*	20	Monthly & Qtrly
Stocks and Sales, Selected Industries	0.0008	0.456	7	Quarterly

Panel B: Stock-specific Information Releases	*Regression*			
Announcement	*Coeff* * 10^2	*White adj. t-stat*	*n*	*Stocks*
Takeover Announcement	0.0007	2.412**	175	54
Shareholder Details	0.0017	2.598*	15	12
Periodic Reports	0.0006	3.827*	463	261
Quarterly Activities Report	0.0002	0.779	140	71
Issued Capital	0.0007	2.262**	87	65
Asset Acquisition & Disposal	0.0004	2.297**	199	125
Notice Of Meeting	0.0014	1.296	10	10
Stock Exchange Announcement	−0.0005	−0.788	33	28
Dividend Announcement	0.0012	2.837*	59	39
Progress Report	0.0005	3.602*	425	71
Company Administration	0.0020	1.876	8	8
Other	0.0006	4.126*	385	147
Chairman's Address	0.0020	3.467*	5	5
Letter to Shareholders	0.0026	0.873	2	2
ASX Query	0.0009	1.641	28	19
Missing Classification	0.0006	2.209**	119	81

*significant at the 0.01 level
**significant at the 0.05 level

information. The results of the regression analysis are reported with the dependent variable measured as the absolute value of All Ordinaries Midpoint Index returns sampled at one-minute intervals during each day.[20] For macroeconomic information releases in panel A, estimates of the coefficients on the dummy variables imply that only 15 categories of information are significantly related to SPI futures return volatility (at the 0.05 level). Consequently, the dummy variables used in eq. (3) take on a value of 1 if the announcement relates to these 15 types. Panel B of the table demonstrates that of the 16 possible stock-specific information categories, coefficients on only 10 dummy variables are significantly related to index return volatility (at the 0.05 level). Only these 10 categories are considered in the construction of dummy variables for eq. (4).

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[20]Unlike macroeconomic information releases, stock-specific information can be released at any time of the day. Consequently, all intervals on all days are included in the regression analysis in panel B of Table A.1.

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