Asymmetric Dynamics of Quoted Prices and Trades in the Information Dissemination Process

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This article documents the asymmetric responses of bid and ask prices to informed trades by observing the information transmission process between the KOSPI 200 futures market and its underlying stock market, using the 10-second quote and trade data from July 2004 to February 2005. The vector error correction system analysis shows that the futures market tends to lead the stock market in terms of returns and order imbalances, even though the other direction is also weakly observable. More importantly, in the vector error correction system analysis with bid and ask returns, we observe that the lagged ask (bid) returns in one market have greater positive impact on contemporaneous bid (ask) returns in the other market. By categorizing the whole samples into two groups according to the KOSPI index daily returns, positive and negative, we figure out this asymmetric cross-market impact of ask and bid results from informed trades.

JEL classification: G12; G13; G14
Key words: Asymmetric responses; bid and ask prices; KOSPI 200 index; Information transmission; VEC

I. Introduction

When informed traders try to exploit positive (negative) information, it is likely that the revision of ask (bid) quote may be faster than that of bid (ask) because informed traders' buyer- (seller-) initiated trades quickly deplete the best ask (bid) depth. These asymmetric responses of quote prices to informed trades are mentioned in Biais, Hillion, and Spatt (1995), and Hasbrouck (1999). Jang and Venkatesh (1991) also find that the responses of bid and ask prices to trades can be asymmetric because quotes represent interests of many heterogeneous investor groups as well as those of specialists and because the limit order book can respond sluggish to trades. However, except Engle and Patton (2004), there are no empirical studies to examine asymmetric responses of bid and ask quotes to trades. They observe that buys have greater impacts on asks while sells have greater impacts on bids in the New York Stock Exchange. Additionally, they find that the asymmetric responses of quoted prices to trades are not due to informed trades because the trades cause increase in uncertainty about the information, so their bid-ask spreads widen.

This paper examines whether the asymmetric responses of bid and ask prices to trades can be caused by informed trades, especially by observing the information transmission process between the KOSPI 200 index futures and its underlying stocks. This research can contribute the market microstructure literature by showing more explicitly the process in which information can be reflected on prices. In addition, by comparing the dynamics of the bid and ask quotes with that of the mid-quotes, we will show studies with bids and asks can provide richer and more precise explanations about the market dynamics than those with the mid-quotes. To our knowledge, there has been no empirical study that examines the detailed dynamics of bids and asks when information is released into markets. In this paper, after examining the information transmission process between these two markets, we will look at quote responses to information in more detail.

Many studies have been made on the information dissemination process between a futures market and its cash market by using the mid-quote returns and several trading variables, such as trading volumes or order imbalances. The existing literature documents that a futures market lead its cash market in general, though there is a weak evidence that the cash index returns lead futures returns. For example, Kawaller, Koch, and Koch (1987) and De Jong and Nijman (1997) show that S&P 500 futures lead the cash index by beyond 10 minutes, whereas the cash index leads the futures by at most two minutes. Stoll and Whaley (1990) find that the S&P 500 and Major Market Index cash markets have symmetric lead-lag relations with their futures markets. Chan (1992) shows that the futures returns lead the MMI index return by 15 minutes and also tends to lead individual stock returns. The existing literature shows that market-wide information seems to be processed especially fast in the futures market. In the German DAX Index market, Booth, So, and Tse (1999) study information sharing and find that futures prices lead spot prices. Also, in the same market, Schlag and Stoll (2005) provide some supporting evidence that the futures market is superior to their underlying market in regards to being informative. So and Tse (2004) show that the Hang Seng Index futures market leads the index market. On the other hand, Chiang and Fong (2001) show derivative markets do not seem to lead the cash index market in the Hang Seng index market, and attribute it to the relative market immaturity and low liquidity of derivative markets. Kang, Lee, and Lee (2006) and Kang and Park (2007), however, document that the KOSPI 200 index futures leads the KOSPI 200 stock index in terms of returns, volatility and order imbalance.

We start by examining information transmission process between the KOSPI 200 index futures and its underlying stocks in a vector error correction (hereafter VEC) system in terms of returns and order imbalances. The model is a revised version of Engle and Patton (2004), but we regard order imbalances as an endogenous variable. This is because trades can be trigged by quote changes. We conduct two VEC systems: one uses the mid-quote returns as a return measure and the other uses bid and ask quote returns. Through the comparison of the results of VEC systems, we examine if analysis using the two quote returns gives additional information about the market dynamics and whether bid and ask returns are responding asymmetrically to information arrived in the markets. Furthermore, we investigate whether responses of bid and ask returns are different depending on the type of information, negative or positive, by classifying the whole sample into two subsamples based on the KOSPI 200 index daily return.

We are using 10-second quote and trade data from July 2004 to February 2005. We examine the quote and order imbalance movements of individual stocks consisting of the KOSPI 200 index rather than those of the KOSPI 200 index. Since some of the stocks the index consists of are sparsely quoted, we examine 13 stocks that are traded heavily and quoted almost continuously in the Korea Stock Exchange rather than the KOSPI 200 index that contains many stocks traded and quoted infrequently.

In our results, the VEC analysis with mid-quote returns indicates that the futures market tends to lead the stock market in terms of quote revisions and trades, while the other direction is weakly observable. In addition, quote revisions through limit orders in general, lead trades through market orders. These two results are identically shown in the VEC analysis with bid and ask quote returns. In cash-market-only and futures-market-only analyses of both bid and ask VEC systems, we cannot observe asymmetric responses of the bid and ask quotes to informed trades. This is because, in the analysis, we do not choose the specific time period when information is released through a market. However, in the cross market VEC analysis with the two quote returns, we find that the lagged ask (bid) returns in one market have a greater positive impact on the current bid (ask) returns in the other market. From the VEC examination conducted by classifying the whole samples into two subsamples depending on the KOSPI 200 index daily returns, we can interpret these cross asymmetric responses of quote returns as the results of informed trades in the leading market. In more detail, in a positive return day of the KOSPI 200 index when positive information seem to be disseminated across markets, buyers in the futures market are more active so that buyer-initiated trades are quickly consuming the best futures ask orders. Therefore, even though both bid and ask quotes moves to the direction of the information, the asks appear to be faster in responding to the information than the bids. Thus, the impact of lagged futures ask returns on the stock quote returns is greater than that of lagged futures bid quote returns. Simultaneously, in the stock market, ask quotes move faster than bid quotes for the same reason. Therefore, the stock bid returns are more affected by the lagged futures ask quote returns than the stock ask returns. The reverse is true when negative information is disseminated in markets. Additionally, in this analysis with two subsamples, we observe asymmetric responses of bids and asks to informed trades in the futures market.

This article is organized as follows: section II briefly describes the data used in this article. Section III presents the VEC model and examines the information transmission process using the VEC analysis. In section IV, empirical results are shown. Finally, section V summarizes the results and concludes the article.

II. Data

A. the KOSPI200 futures and the Korean stock markets

This article uses the KOSPI 200 index futures and a synthetic stock market index that consists of thirteen actively traded companies on the Korean Stock market from the period of July 22, 2004 to February 15, 2005.

The KOSPI 200 index consists of 200 blue-chip stocks representing the Korean stock market and industry groups. The KOPSI 200 index at January 3, 1990 is set as 100 and its value has been calculated since June 15, 1994. Since the index is designated only for the KOSPI 200 futures and options, the index itself is not tradable. Even though the two hundred stocks included in the index are large and actively traded companies, we may still face the infrequent trading problem if we use 10-second return and order imbalance data. To mitigate this infrequent trading problem, we construct an artificial index, called the stock index or SI in this paper, using the top thirteen companies among the two hundred companies in terms of market capitalization at the end of December 2004. The market capitalizations of these companies are provided in Panel A of Table 1. The total market capitalization of the thirteen companies comprises more than 50% of the value of the KOSPI 200 index.

The KOSPI200 index futures contracts are cash settled and have March-cycle delivery months. The last trading day of the futures is the second Thursday of the contract month. In this article, we use only the nearby futures since the nearby futures contracts are most liquid. However, when the maturity of nearby futures is less than five days remaining, we use the next nearby futures since the nearby futures prices are known to behave abnormally during this near-maturity period. The minimum tick size of KOSPI200 futures is 0.05 points, regardless of the futures price[1]. On the other hand, in the Korean stock markets, the minimum tick size depends on stock prices[2].

Transaction costs for the KOSPI200 futures and Korean stocks depend on intermediaries to trade. If investors use home trading system[3], on average, the transaction fee is 0.003 % of the total trading amount for the futures and 0.025% for stocks. When investors liquidate their positions of stocks, they have to pay 0.3% of the total amount of liquidation for transaction tax as well as 0.025% for transaction fee. However, investors only need to pay transaction fee of 0.03% of the total liquidation amount of the futures. There is no transaction tax on trading the KOSPI 200 index futures.

B. Specification of the data

[1] The multiplying unit for one transaction is KRW 500,000 and then the price of futures per one transaction is calculated as KRW 500,000 * KOSPI200 futures index. Thus, the price change per one tick change is 0.05 * KRW 500,000 = KRW 25,000.

[2] Minimum tick sizes of Korean stocks are KRW 5, if a stock price is less than KRW 5,000; KRW 10, if a stock price is less than KRW 10,000; KRW 50, if a stock price is less than KRW 50,000; KRW 100, if a stock price is less than KRW 100,000; KRW 500, if a stock price is less than KRW 500,000; KRW 1000 if a price is more than KRW 500,000.

[3] If investors use cell phones or ARS, the transaction fee per trade for stocks is 0.12 % or 0.15%, respectively.

This article uses the 10-second quote returns and order imbalances of the KOSPI 200 futures and thirteen stocks traded on the Korea Stock Exchange. The 10-second quote return at time t is calculated as log P(t) – log P (t – 10 seconds), where P(t) is the quote at time t. We calculate three kinds of quote revisions by using ask, bid, and mid quote prices. The order imbalance at time t is estimated as the number of buyer-initiated contracts minus seller-initiated contracts over the interval of (t-10 seconds, t][4]. Because all of the quotes are posted by traders through limit orders in this market and all of the orders, including market orders, are fed into the Automated Trading System in KSE, we easily identify whether a trade is buyer-initiated or seller-initiated by looking at the sequence of orders placed. For example, if a buyer for the trade submits the purchase order before a seller, then this trade becomes a seller-initiated trade. Thus the order imbalance of the trade is calculated by multiplying minus one by the number of contracts of the trade. The return and order imbalance of the stock index constructed from the thirteen stocks are calculated as the market value-weighted average return and order imbalance of these thirteen stocks. To make sure that overnight periods are not contained in our tests, we examine the data only from 09:20:00 to 14:40:00 over our sample period. Our sample contains the total of 265,098 10-second intervals.

[4] Thus, order imbalances at time t precede returns at time t in this paper. We are following the convention used in Hasbrouck (1991), and Chan, Chung and Fung (2002).

Panel B of Table 1 shows the summary statistics of the mid-quote return, trading volume, and order imbalance for the KOSPI 200 index futures and SI. Not surprisingly, the average 10-second returns and their standard deviations of the futures and SI are close to zero. The average order imbalances of the stock index and the futures over 10-second intervals in our dataset are very small. Thus, in our analyses, we regard the average returns and order imbalances as zero.

III. The model

This paper examines the asymmetric responses of bid and ask prices to informed trades, using the KOSPI 200 futures and its underlying stock market data. To do this, we adopt a VEC model, which consists of two equations, returns and order imbalances. This specification can be thought of an extension of Engle and Patton (2004). Unlike theirs, we regard order imbalances as an endogenous variable and focus on how information is being reflected in quote prices. Additionally, we examine quote dynamics between the two markets because it can be difficult to specify a particular time period when information is disseminated into a one market. Since a futures market and its underlying asset market are close substitutes for investors, informed investors can choose one of the markets to exploit their private information and the information will flow one market to another. Thus, we examine the interrelation between the KOPSI 200 index futures market and its stock market to see the quote dynamics when information is released into markets.

In the VEC model in terms of the mid-quote returns and order imbalances, we first examine the information transmission process between the futures and its cash market by investigating which effect, information or liquidity, is dominating in an own market and cross markets analyses. Next, we conduct a VEC analysis with bid and ask returns in return equations of the system, instead of the mid-quote returns. The reason of examining two VEC analyses is to find out whether we can get additional information in the analysis with bid and ask prices. In both cases, order imbalance equations of the VEC system are given as the same ones.

The remaining of this section is as follows. First, we will elaborate on our VEC system. Then, we will describe how variables in the VEC system can be interpreted given that information and liquidity effects are applied separately in markets. Finally, we will explain how asymmetric responses of bid and ask prices to informed trades can be observed in the VEC system. The empirical results will be provide in the next section.

A. A VEC system

Our model for the dynamic relations of returns and order imbalances between the Korean stock market and the KOSPI 200 futures market is specified as follows:

$$r_t = \alpha_0 + \sum_{k=1}^{q} \alpha_k r_{t-k} + \sum_{k=0}^{q} \beta_k OI_{t-k} + \chi\ Cost\_of\_carry_{t-1} + \delta\ Depth\_diff_{t-1} + \varepsilon_{1,t} \tag{1}$$

$$OI_t = \gamma_0 + \sum_{k=1}^{q} \gamma_k r_{t-k} + \sum_{k=1}^{q} \theta_k OI_{t-k} + \phi\ \ Depth\_diff_{t-1} + \varepsilon_{2,t} \tag{2}$$

where $r_t = [r_{SI,t}, r_{F,t}]$, $OI_t = [OI_{SI,t}, OI_{F,t}]$, $Cost\_of\_carry_{t-1} = I_{t-1} - F_{t-1}$ and $Depth\_diff_{t-1} = [Depth\_diff_{SI,t-1}, Depth\_diff_{F,t-1}]$. $r_{SI,t}$ and $r_{F,t}$ denote ten-second log mid-quote returns on SI and the KOSPI 200 futures, at time t, respectively, while $OI_{SI,t}$ and $OI_{F,t}$ denote order imbalances of the thirteen stocks consisting of SI and the KOSPI 200 futures, respectively, over the interval of (t-10 seconds, t]. F_{t-1} and I_{t-1} are log prices of futures and the KOSPI index at time t-1. $Depth\_diff_{t-1}$ is the log difference between the sum of the best five ask depths and the sum of the best five bid depths at time t-1. $\varepsilon_{1,t}$ and $\varepsilon_{2,t}$ are 2×1 vectors of disturbance terms.

Because we examine the two highly co-integrated markets, we use a 'cost-of-carry' for error correction term in Equation (1), in lieu of the spread in Engle and Patton (2004). Furthermore, we regard order imbalance, which proxies for trading activity, as an endogenous variable because investors can trade based on the information from quote revisions as in Chan, Chung and Fung (2002).

In addition to equations (1) and (2), we estimate the following equations, using both of the bid and ask returns in return equations, instead of mid-quote returns.

$$r_t = \alpha_0 + \sum_{k=1}^{q} \alpha_k r_{t-k} + \sum_{k=0}^{q} \beta_k OI_{t-k} + \chi\ Cost\_of\_carry_{t-1} + \delta SPR_{t-1} + \phi Depth\_diff_{t-1} + \varepsilon_{1,t} \tag{3}$$

$$OI_t = \gamma_0 + \sum_{k=1}^{q} \gamma_k r_{t-k} + \sum_{k=1}^{q} \theta_k OI_{t-k} + \varphi\, Depth\_diff_{t-1} + \varepsilon_{2,t} \quad (4)$$

where $r_t = [r_{SI,t}^{ask}, r_{SI,t}^{bid}, r_{F,t}^{ask}, r_{F,t}^{bid}]$, $OI_t = [OI_{SI,t}, OI_{F,t}]$ and $SPR_{t-1} = [SPR_{SI,t-1}, SPR_{F,t-1}]$. $r_{SI,t}^{ask}, r_{SI,t}^{bid}, r_{F,t}^{ask}$ and $r_{F,t}^{bid}$ denote ten-second bid and ask quote log-returns on SI and the KOSPI 200 futures, at time t, respectively. SPR_{t-1} is the spread, which is the difference between the log prices of the best bid and best ask at time t-1. In equations (3) and (4), we use the bid-ask spread as an error-correction term in addition to the 'cost-of-carry' because the bid and ask returns of an asset can be regarded as cointegrated.

B. Information and liquidity effects in VEC equations

1. Returns and order imbalance

There are many reasons that informed investors may prefer one market over the other. Both markets have different market microstructures, transaction costs, and securities with different features[5]. Some investors might be more comfortable in one market than the other. Informed investors will place orders in market A rather than market B if they believe their private information can be more easily exploited in market A. In this case, the information is first revealed in quotes and order imbalances in market A, and then transmitted to market B. The pooling equilibrium of Easley, O'Hara, and Srinivas (1998) explains

[5] These are explained in the previous section.

this process.

The information transmission between markets will be revealed in cross-market coefficients of the VEC equations. If market A leads market B, then the lagged coefficients of returns and order imbalances of market A will be positive in the regressions of market B. Thus, the lead-lag relations between the two markets can be tested by examining the cross-market lagged coefficients of returns and order imbalances in our VEC equations.

The own-market lagged coefficients of returns and order imbalances in our VEC equations are affected by information and liquidity effects. The information dissemination process in a market will cause own-market lagged coefficients to be positive. If investors learn the information revealed in quote revisions and order imbalances, their reaction to the information will move the quotes and order imbalances further in the direction consistent with the information content revealed. This learning and reacting process will result in positive own-market lagged coefficients. In addition, informed investors may split their orders over time to minimize the price impact of their trading activity, as suggested by Kyle (1985), Hasbrouck and Ho (1987), and Admati and Pfleiderer (1988). This order splitting behavior causes positive own-market lagged coefficients. On the other hand, the liquidity effect will cause own-market lagged coefficients to be negative. Ho and Stoll (1983) and Stoll (1978, 1989) suggest that order imbalances should be reversed over time due to the market makers' inventory control problem. If sell (buy) orders exceed buy (sell) orders temporarily, market makers will have excessive (insufficient) inventory. To reduce this temporary inventory imbalance, they will quote lower (higher) prices, which causes more buy (sell) orders. Thus, negative (positive) order imbalances tend to result in positive (negative) order imbalances afterwards. Chordia, Roll, and Subrahamanyam (2002) also argue similarly that return reversals can be observed due to the liquidity effect. To sum up, the signs of own-market lagged coefficients are ambiguous, because the effect of liquidity is opposite to that of information.

2. Depth difference

Huang and Stoll (1994) develop a two-equation model to test market microstructure theories and examie the predictive power of microstructure variables for future stock price movements. One of the microstructure variables in their model, the log depth difference, which is the sum of the five best ask depths less the sum of the five best bid depths, was able to account for whether quote revisions are from the information effect or the inventory effect. Thus, as in Engle and Patton (2004), we include this variable in our VEC equations (1) and (3). If the information effect is applied, the positive (negative) log depth difference at time t-1 implies that informed investors are more in the ask (buy) side, thinking that the price is overvalued (undervalued). This will cause downward (upward) quote changes at time t, so the impact of log depth difference at time t-1 on return at time t is negative. On the other hand, the inventory effect or liquidity effect causes the influence of the log depth difference on return to be positive, because market makers want to balance the inventory. If inventory is too high (low) at time t-1, market markets try to induce buyers (sellers) by undercutting (raising) the ask (bid) quote. After the inventory problem is resolved at time t, the quote prices reverse to the previous level. Therefore, positive relationship between the log depth difference at time t-1 and return at time t will appear in the case of the liquidity.

Since we presume that order imbalances, like returns, can be affected by information or liquidity effects, we construct order imbalance equations (2) and (4) in the same way as return equations (1) and (3). In a similar fashion, if the information effect is applied, the log depth difference at time t-1 will negatively affect the order imbalance at time t. This is because seller (buyer) -initiated trades will outnumber buyer (seller) –initiated trades as negative (positive) information is disseminated to investors. On the other hand, considering the inventory effect, trade initiators at time t-1 are more likely to be buyers (sellers) when market makers induce traders by lowering (raising) ask (bid) prices to mitigate the inventory problem. Thus, a positive relationship between the log depth difference at time t-1 and order imbalance at time t appears.

C. Asymmetric responses of bid and ask returns

Huang and Stoll (1994) show the probability that a buyer-initiated trade is not equal to 0.5 when three microstructure effects are considered: the adverse information effect, the inventory effect, and the order processing costs. Additionally, Habrouck (2007) points out that the bid and ask prices may not be quoted symmetrically around the efficient price when the probability that the following initiated trade is buy or sell is not 0.5 in a framework of Glosten and Milgrom (1985). These things suggest that the responses of bid and ask prices to informed trades may be different.

The mid-quote prices, rather than transaction prices, have been used in many financial studies to eliminate or reduce the market microstructure effects such as spurious volatility due to bid-ask bounces. In addition, the impact of trades on prices has been studied by using the mid-quote prices as a proxy for the efficient prices in the literature, since the efficient prices are not observable. However, if bid and ask prices respond asymmetrically to information, analyses with the mid-quote prices may bias the results since they miss the asymmetric dynamics of quoted prices and trades in the information dissemination process.

Suppose that there is positive (negative) information and that it is known to some investors. These informed investors will try to exploit the information in one of the financial markets by placing buy (sell) orders. If market-makers or other investors respond to these orders asymmetrically when they revise their bid and ask quotes, then the revision of ask (bid) prices will precede the revisions of bid (ask) prices. This implies that ask (bid) returns reflect positive (negative) information earlier than bid (ask) returns, which causes lagged ask (bid) returns to have more ability to predict the current bid and ask returns than lagged bid (ask) returns. We will call this hypothesis the *asymmetric response hypothesis*. On the other hand, if market-makers or other investors respond to the orders from informed investors symmetrically, then we will not observe any difference of prediction power of bid and ask lagged returns on the current bid and ask returns.

This asymmetric response hypothesis has an implication on the information transmission process between two financial markets. Under the asymmetric response hypothesis, the lagged ask (bid) returns in the leading market should have more prediction power on the current bid and ask returns in the lagged market as well as in its own market than the lagged bid (ask) returns when there is positive (negative) information. That is, the lagged ask (bid) return in the leading market should have more positive relations with the current bid and ask returns in the cross market than the lagged bid (ask) returns in the leading market when there is positive (negative) information.

IV. Empirical results

A. Information and liquidity effects in VEC equations

Table 2 provides the estimation results of the VEC equations (1) and (2). We will examine return equations first. If we look at lagged coefficients of own-market returns in both return equations, almost all of them are negative and statistically significant at the 1% significance level. These negative lagged coefficients of own-market returns are consistent with the liquidity effect, but not with the information effect. However, if we look at lagged returns of cross-market returns, almost all of them are positive and statistically significant at 1% significance level, which is consistent with the information effect. This shows that information impounded in the mid-quote revisions is transmitted in both ways: from the stock market to the futures market and from the futures market to the stock market as well. Thus, there is the information effect as well as the liquidity effect in returns.

If we look at the contemporaneous and lagged coefficients of futures order imbalances in return equations, they are positive and statistically significant at the 1% significance level up to the 4^{th} lag. Surprisingly, in the stock return equation, the coefficients of futures order imbalances are bigger and more statistically significant than the contemporaneous coefficient of futures order imbalances. This shows that the changes in futures order imbalances precede the mid-quote revisions in the stock market. In general, those coefficients of futures order imbalances imply that the information contained in futures order imbalances is disseminated in the market over 40 seconds and affects the mid-quote revisions in both stock and futures markets. If we look at the contemporaneous and lagged coefficients of stock order imbalances in return equations, they are positive and statistically significant at the 1% significance level up to the second lag in the futures return and the stock return equations.

Next, we examine order imbalance equations. The lagged coefficients of futures order imbalances are almost positive and statistically significant at the 1% significance level in the futures order imbalance equation, and they are also positive and statistically significant at the 1% significance level up to the fourth lag in the stock order imbalance equation. Those coefficients are consistent with the information effect and they show that information is transmitted from the futures market to the stock market. If we look at the lagged coefficients of stock order imbalances, they are in general positive and statistically significant at the 1% significance level up to the sixth leg in the stock market and only at the first lag in the futures markets. This statistically significant first lag in the futures market shows that information is also transmitted from the stock market to the futures market. However, the degree of the transmission from the stock market to the futures market seems weaker than the degree of transmission from the futures market to the stock market in the futures order imbalance equation.

The lagged coefficients of futures returns are all positive in the futures and stock order imbalance equations. The positive return coefficients show that the mid-quote revisions in the futures lead trades in the futures market and in the stock market. The lagged coefficients of stock returns in the futures order imbalance regressions are positive and significant only up to the first lag, while they are generally negative in the stock order imbalance equation. The negative lagged coefficient of returns in the stock order imbalance equation is consistent with the liquidity effect. Thus, the mid-quote revisions in the futures market lead trades or order imbalances in both the stock and futures markets. This shows that limit orders in the stock and futures markets lead market orders in both markets.

The coefficients of the futures log depth difference in return and order imbalance equations are all negative and statistically significant. Additionally, the coefficients of the stock index log depth difference are negative and significant in all equations, except in the stock index order imbalance equation. This is mostly consistent with the information effect.

To summarize, information seems to be transmitted in two ways: from the stock market to the futures market, and also from the futures market to the stock market. However, it should be noted that the degree of information transmission from the stock market to the futures market is weaker than that from the futures market to the stock market. In addition, the mid-quote revisions from limit orders seem to precede order imbalances from trades in both markets. In particular, the mid-quote revisions in the futures market lead trades in both markets.

B. Different responses between quote prices and mid-quote price

The previous section documents that information is transmitted from the futures market to the stock market more strongly than from the stock market to the futures market, using the VEC analysis in terms of the mid-quote returns and order imbalances. The VEC analysis with the mid-quote returns is appropriate to examine the general tendency of dynamics of returns when information is transmitted. However, since the analysis with mid-quote revisions assumes that the mid quotes are the efficient prices and bid and ask quoted prices always move symmetrically, there is a possibility that this analysis may miss the asymmetric responses of two quoted prices when information is reflected in prices. To ascertain asymmetric dynamics of two quoted prices in informed trades, we examine the VEC analysis in terms of bid and ask returns and order imbalances in this section.

Table 3 shows the estimation results of the VEC equations (3) and (4). Let us examine return equations first. As in Table 2, all coefficients of own-market lagged ask (bid) returns in both ask (bid) return equations are negative and statistically significant at the 1% significance level. These results are consistent with the liquidity effect, but coefficients of own-market lagged bid (ask) returns in ask (bid) equations are positive and significant. This shows that one of the bid and ask prices moves first, and then the information contained in the first mover is reflected in the other. Thus, it suggests that the information adjustment speed of bid and ask prices might be different, and is consistent with the asymmetric response hypothesis.

If we look at the coefficients of cross-market lagged returns, almost all of them are positive and statistically significant at the 1% significance level in both futures and stock markets. However, the impacts of lagged bid (ask) returns of futures on contemporaneous ask (bid) returns of stocks are twice as large as those of lagged ask (bid) of futures. Also in futures return equations, lagged bid (ask) stock returns have greater impacts on contemporaneous futures ask (bid) returns than lagged ask (bid) stock returns, even if they are not twice as large. These are worth noting, and consistent with the asymmetric response hypothesis.

When positive information is released, investors try to consume the best ask quotes as soon as possible to exploit information. In this case, the revisions at the ask side will be speedier than those of the bid side. The information content of the revised ask quote will be disseminated to the lagged market as well as the bid side of the leading market. As a consequence, lagged ask returns will have greater explanation power of the contemporaneous bid returns in the lagged market when positive information is released. In a similar fashion, when negative information is disseminated, lagged bid returns in the leading market have a greater impact on contemporaneous ask returns in the lagged market than lagged ask returns in the leading market do. Biais et al (1995) mention that quote revisions occur first at the side where informed investors trade by showing examples of bid and ask quotes and transient price sequences of a specific firm. To our knowledge, our study is the first to provide the evidence of the asymmetric responses of bid and ask quotes described in Biais, et al. To check the asymmetric response hypothesis more in detail, we will divide our sample into two subsamples depending on whether the daily KOSPI200 index returns are positive, and examine the VEC equation (3) in the two subsamples in the next section.

As shown in the transition process from the VEC with mid-quote returns to the VEC with bid and ask returns in Engle and Patton (2004), coefficients of lagged returns in the VEC analysis using the mid-quote returns can be calculated by summing the coefficients of lagged bid and ask returns in both bid and ask return equations and then dividing by four. However, we cannot infer the coefficients of bid and ask returns from the results of the VEC with mid-quote returns.

Back to the return equations of Table 3, the coefficients of contemporaneous and lagged order imbalances are positive and mostly significant, and the logs of depth differences between bid and ask are all negative and significant. Furthermore, in order imbalance equations, except the coefficients of lagged stock bid and ask returns in the stock index order imbalance equation, most of the coefficients of lagged returns and order imbalances are positive in both of the order imbalance equations. Those results imply that information effect dominates in the dynamics of returns and order imbalances in the KOSPI 200 index futures and Korean stock markets, as in the results in the previous section. In addition, the signs of the coefficients of the log-spread and the cost of carry are shown as we expect. If log-spread, i.e., the difference between log bid and ask prices, widens, then the ask price goes down and the bid price goes up and so the log-spread becomes narrower.

C. Asymmetric responses of bid and ask quotes according to information type

Informed trades driven by positive (negative) information makes ask (bid) quotes move upward (downward) speedier than bid (ask) quotes, as stated above. In this section, we will examine this asymmetric response hypothesis more in detail, using two subsamples. One subsample is a "positive information" sample, and the other is a "negative information" sample. The positive (negative) information sample consists of 10-second trade and quote data when the day's return is positive (negative).

Table 4 reports the estimation results of the VEC equation (3) for the two subsamples. If we look at the coefficients of own-market lagged bid and ask returns in ask return equations in the futures market, regardless of the type of information, the signs and statistical significances of the variables are the same as those in Table 3 discussed in the previous section. However, the magnitude of the coefficients of own-market lagged bid returns in futures ask return equation are bigger by 0.05 on average for the negative information sample than those in the futures ask return equation for the positive information sample. In addition, the coefficients of own-market lagged ask returns in the futures bid return equation for the positive information sample are bigger by around 0.03 than those in the futures bid return equation for the negative information sample. We can see the same phenomena in the stock index case: The coefficients of own-market lagged bid returns for the negative information sample are bigger than those for the positive information sample in the ask return equation, while the coefficients of own-market lagged ask returns for the positive information sample are bigger than those for the negative information sample in the bid return equation. Thus, we can observe the asymmetric response of bid and ask quotes to informed trades even in an own market. Lagged bid (ask) returns are positively related to the contemporaneous ask (bid) return in general, because bid and ask quotes tend to move together and so if one quote moves, the other quote moves in the same direction. Lagged bid (ask) returns are more strongly positively related to the contemporaneous ask (bid) return for the negative (positive) information sample in an own market, because sell (buy) orders consume the depth of the bid (ask) side first in the negative (positive) information case and then the information content of the sell (buy) orders is spread to the ask (bid) side, as mentioned in the previous section.

Next, let's examine the cross-market coefficients in Table 4. Our concern here is whether we can observe asymmetric impacts of lagged bid and ask returns in the leading market on contemporaneous returns in the lagged market. If we look at the coefficients of lagged futures bid returns in the stock return equation for the negative information sample, the coefficients are clearly much greater and significant than coefficients of the variables. The same is said of coefficients of lagged futures bid returns in the stock return equations, in positive return days. The impact of lagged futures ask returns on contemporaneous stock returns are greater. On the other hand, in futures return equations, this asymmetric impact of cross-market lagged returns on contemporaneous returns are not obvious. This may be because the futures market leads the stock market as shown in the previous VEC analyses. Those results correspond to our hypothesis about the asymmetric impact of lagged bid and ask returns on contemporaneous returns in the lagging market and explain clearly the results in the previous section.

V. Conclusion

This article examines the asymmetric responses of bid and ask prices to informed trades by observing the information transmission process between the KOSPI 200 futures market and its underlying stock market using the 10-second quote and trade data from July 2004 to February 2005.

Using the VEC analysis in terms of the mid-quote returns and order imbalances, the futures market tends to lead the stock market in terms of quote revisions and trade, while the other direction is weakly observable. In addition, quote revisions through limit orders in general, lead trades through market orders. In the VEC analysis with bid and ask returns instead of the mid-quote returns, we find out informed trades make two quote prices asymmetrically respond. Informed trades driven by positive information consume quickly the best ask quotes, so the revision of ask prices becomes faster than that of bid prices. For negative information, informed investors do same work at bid side. Therefore, we can observe asymmetric impacts of lagged bid and ask returns on contemporaneous bid and ask returns. We also observe that these asymmetric responses of bid and ask prices are applied in cross-market return dynamics between the futures and the stock markets. Although asymmetric responses of stock bid and ask returns to informed trades are observed, because the futures market leads the stock markets, information transmitted by lagged futures bid and ask returns affect asymmetrically contemporaneous stock returns. Thus, when there is positive information, lagged futures ask return affects more contemporaneous stock bid returns, while lagged futures bid returns have greater impact on contemporaneous stock ask returns when negative information is transmitted.

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Table 1. Descriptive statistics

Panel A shows the thirteen stocks consisting of the stock index used in this paper and their market capitalization in December 2004. Panel B shows the summary statistics of mid-quote log returns, trading volumes, and order imbalances for the KOSPI 200 index futures and the stock index. Returns are calculated from the log differences of the mid-quote prices over 10-second interval. Trading volumes and order imbalances of the futures and the stock index are the summed values during 10-second intervals. The sample period is from July 2, 2004 to February 15, 2005.

Panel A. Market Capitalizations of Companies Consisting of the Stock Index

Company	Market Capitalization (Won)	% of the total value of the KOSPI 200
Samsung Electronics	60,834,626,181,000	17.798
KEPCO	17,043,912,041,800	4.986
POSCO	16,042,377,640,000	4.693
SK Telecom	15,920,543,578,500	4.658
Kookmin Bank	13,354,250,905,200	3.907
KT	12,447,918,780,000	3.642
LG Philips LCD	11,597,504,705,000	3.393
Hyundae Motors	11,019,024,351,000	3.224
LG Electronics	8,892,918,953,100	2.602
S-Oil	7,272,848,363,200	2.128
Shinhan Group	6,598,941,051,500	1.931
Woori Finance	6,552,599,649,550	1.917
Hynix Semiconductor	4,693,332,470,350	1.373
Totals		56.252

Panel B. Summary statistics

	The KOSPI 200 index futures			The stock index		
	Return	Trading Vol.	Order imbalance	Return	Trading Vol.	Order imbalance
Mean	0.000	87.874	-1.129	0.000	7,702.5	-70
Std.	0.000	142.489	112.108	0.000	13,585	12,815
Max	0.005	5388	1623	0.008	2,106,170	543,320
Min	-0.004	0	-2399	-0.007	0	-2,093,910
% of zeros	66.364	9.184	10.722	38.933	2.765	3.530

Table 2. VECM with the mid-quote returns and order imbalances

Dependent Variables		lag	return futures	return S.I.	order imbalance futures	order imbalance S.I.
	constant		-0.136**	0.028**	-0.040**	-0.039**
Futures	return	1	-0.139**	0.038**	0.297**	4.479**
		2	-0.066**	0.079**	0.077**	3.576**
		3	-0.042**	0.091**	0.039	2.681**
		4	-0.030**	0.087**	0.024**	2.287**
		5	-0.018**	0.077**	0.017**	1.963**
		6	-0.010**	0.062**	0.013**	1.613**
	Order imbalance	0	0.227**	0.059**		
		1	0.039**	0.101**	0.008**	1.818**
		2	0.027**	0.025**	-0.007**	0.992**
		3	0.016**	0.000	0.005*	0.870**
		4	0.014*	0.004	0.006**	0.601*
		5	0.009	0.006	0.005*	0.400
		6	-0.004	0.009	0.015**	-0.062
	Depth diff.		-0.011**	-0.001**	-0.002**	-0.219**
Stock Index	return	1	0.024**	-0.083**	0.001*	-0.828**
		2	0.015**	-0.057**	0.000	-0.446**
		3	0.016**	-0.039**	0.002	-0.114
		4	0.010**	-0.021**	0.001	-0.038
		5	0.009**	-0.014**	0.001	0.021
		6	0.009**	-0.009**	0.003	0.013
	Order imbalance	0	0.000**	0.000**		
		1	0.000**	0.004**	0.000**	0.156**
		2	-0.000**	0.001**	0.000	0.071**
		3	0.000	0.000	0.000	0.047**
		4	0.000	0.000**	0.000	0.026**
		5	0.000	0.000	0.000	0.022**
		6	0.000	0.000	0.000	0.019**
	Depth diff.		-0.000**	-0.000**	-0.000**	0.000**
Cost-of-carry			0.041**	-0.013*		
Adj. R^2			0.019	0.132	0.446	0.101

Table 3. VEC with the bid and ask returns and order imbalances

Dependent variables		lag	return: futures ask	return: futures bid	return: Stock index ask	return: Stock index bid	order imbalance: futures	order imbalance: stock index
	constant		0.798**	-1.540**	0.543**	-0.741**	0.000**	-0.039**
Futures	ask return	1	-0.319**	0.084**	0.004**	0.034**	0.150**	2.235**
		2	-0.256**	0.093**	0.025**	0.051**	0.038**	1.906**
		3	-0.216**	0.090**	0.031**	0.056**	0.019**	1.593**
		4	-0.186**	0.082**	0.034**	0.052**	0.011**	1.196**
	bid return	1	0.179**	-0.223**	0.033**	0.005**	0.147**	2.247**
		2	0.189**	-0.158**	0.053**	0.027**	0.039**	1.674**
		3	0.173**	-0.132**	0.058**	0.037**	0.020**	1.097**
		4	0.156**	-0.112**	0.056**	0.033**	0.013**	1.098**
	order imbalance	0	0.226**	0.227**	0.062**	0.056**		
		1	0.041**	0.037**	0.099**	0.104**	0.008**	1.822**
		2	0.029**	0.025**	0.031**	0.020**	-0.007**	0.995**
		3	0.016**	0.015**	-0.001	0.002	0.005*	0.883**
		4	0.010	0.017**	0.001	0.006	0.007**	0.603*
	spread		-0.195**	0.290**	0.019*	-0.012		
	Depth diff.		-0.010**	-0.012**	-0.001**	-0.001**	-0.002**	-0.219**
stock index	ask return	1	0.008*	0.011**	-0.124**	-0.032**	0.001	-0.736**
		2	0.014**	0.015**	-0.055**	0.008*	-0.001	-0.497**
		3	0.007*	0.011**	-0.035**	0.012**	0.000	-0.206
		4	0.007*	0.011**	-0.020**	0.016**	0.000	-0.156
	bid return	1	0.016**	0.013**	0.036**	-0.046**	0.000	-0.147
		2	0.001	0.000	-0.007*	-0.061**	0.001	0.011
		3	0.009**	0.006	-0.005	-0.051**	0.002	0.062
		4	0.002	-0.001	0.000	-0.037**	0.000	0.106
	order imbalance	0	0.001**	0.001**	0.001**	0.001**		
		1	0.001*	0.001**	0.004**	0.004**	0.001**	0.156**
		2	0.001**	-0.001**	0.001**	0.001**	-0.000	0.071**
		3	0.000**	0.000	0.000**	0.000**	0.000	0.047**
		4	0.000	0.000	0.000**	0.000**	0.000	0.026**
	spread		0.002	-0.003	-0.030**	0.040**		
	Depth diff.		-0.001**	-0.001**	-0.001**	-0.000**	-0.000**	0.000
cost of carry			0.056**	0.018**	-0.010*	-0.018**		
Adj. R^2			0.074	0.074	0.127	0.123	0.446	0.101

Table 4. VEC with bid and ask returns and order imbalances in two subsamples according to daily index return

Dependent variable		lag	Futures Negative ask	Futures Negative bid	Futures Positive ask	Futures Positive bid	Stock Index Negative ask	Stock Index Negative bid	Stock Index Positive ask	Stock Index Positive bid
	constant		0.812**	-1.440**	0.814**	-1.630**	0.485**	-0.698**	0.612**	-0.762**
Futures	ask return	1	-0.339**	0.070**	-0.302**	0.090**	-0.021	0.012*	0.024**	0.052**
		2	-0.280**	0.077**	-0.234**	0.103**	-0.002	0.027*	0.048**	0.073**
		3	-0.245**	0.065**	-0.190**	0.109**	0.007	0.031**	0.052**	0.076**
		4	-0.213**	0.059**	-0.162**	0.099**	0.010	0.028**	0.053**	0.072
	bid return	1	0.205**	-0.201**	0.157**	-0.235**	0.059**	0.028**	0.009	-0.016
		2	0.215**	-0.136**	0.169**	-0.171**	0.078**	0.052**	0.032**	0.006
		3	0.201**	-0.106**	0.151**	-0.149**	0.078**	0.060**	0.041**	0.018
		4	0.175**	-0.094**	0.140**	-0.124**	0.076**	0.056**	0.038**	0.014
	order imbal-ance	0	0.217**	0.219**	0.239**	0.239**	0.058**	0.051**	0.066**	0.059**
		1	0.031**	0.020*	0.050**	0.050**	0.097**	0.088**	0.099**	0.113**
		2	0.036**	0.031**	0.022**	0.021**	0.023**	0.011	0.037**	0.028**
		3	0.025**	0.023**	0.009	0.009	-0.002	-0.003	-0.002	0.005
		4	0.003	0.001	0.016	0.030	0.005	0.009	-0.002	0.002
	spread		-0.181**	0.296**	-0.207**	0.292**	0.045**	0.010**	-0.003	-0.031**
	Depth diff.		-0.012**	-0.015**	-0.010**	-0.011**	-0.001**	-0.001**	-0.002**	-0.001*
Stock Index	ask return	1	0.007	0.014**	0.007	0.007	-0.128**	-0.030**	-0.122**	-0.024**
		2	0.015**	0.016**	0.012**	0.013**	-0.075**	0.008	-0.038**	0.009*
		3	0.010*	0.014**	0.006	0.008	-0.035**	0.034**	-0.034**	-0.004
		4	0.013*	0.019**	0.005	0.006	-0.029**	0.008	-0.014**	0.018
	bid return	1	0.011**	0.005	0.020**	0.021**	0.033**	-0.055**	0.037**	-0.050**
		2	-0.003	-0.004	0.004	0.004	0.018**	-0.063**	-0.026**	-0.060**
		3	0.010	0.007	0.006	0.004	0.000	-0.080**	-0.010*	-0.029**
		4	-0.003	-0.006	0.004	0.002	0.016**	-0.019**	-0.011**	-0.048**
	order imbal-ance	0	0.001**	0.001**	0.143**	0.148**	0.005**	0.005**	0.004**	0.004**
		1	-0.000	-0.069	-0.079	-0.106	0.001**	0.001**	0.001**	0.001**
		2	0.001	0.087	0.046	0.041	0.001**	0.000**	0.000**	0.000**
		3	0.001	0.010	-0.049	0.006	0.000**	0.000**	0.000**	0.000**
		4	-0.000	-0.078	-0.058	-0.097	0.000**	0.000	0.000**	0.000**
	spread		-0.002**	-0.009**	0.004**	0.001	-0.033*	0.033**	-0.028**	0.046**
	Depth diff.		-0.001*	-0.001**	-0.001**	-0.000	-0.000**	-0.000**	-0.000**	-0.000*
cost of carry			0.022**	0.005*	0.079**	0.031**	-0.025*	-0.025*	-0.001**	-0.015**
Adj. R2			0.075	0.069	0.074	0.079	0.129	0.129	0.120	0.119