The Lead-Lag Relations of Returns and Volatilities among Spot, Futures, and Options Markets: A Case of the KOSPI200 Index Markets

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This paper empirically examines the lead-lag relations among the KOSPI200 spot market, the KOSPI200 futures market, and the KOSPI200 options market. In general, the KOSPI200 futures and options markets lead the KOSPI200 spot market by up to 10 minutes in terms of returns and by 5 minutes in terms of volatilities, even after purging the infrequent trading effect as well as the bid-ask spread effect. The KOSPI200 options market leads and lags the KOSPI200 futures market by 5 minutes only in terms of returns. However, these lead-lag relations don't seem to generate any profit opportunities after taking transaction costs into account.

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1. Introduction

In a perfectly-functioning ideal world, every derivative price is determined simultaneously with its underlying asset price. That is, neither derivative prices nor the underlying asset prices lead the others. New information disseminated in the market should be reflected immediately and simultaneously in the prices of derivatives as well as its underlying asset. In reality, these simultaneous price movements among the financial markets may not be observed due to the differences in transaction costs and institutional settings of the financial markets. Since transaction costs are in general lower in derivatives markets, derivative prices may lead underlying asset prices. For example, Longstaff (1995) shows that the S&P100 index values can be significantly different from the index value implied in the S&P100 index options.

This paper empirically investigates the intraday price change relations in the KOSPI200 index market, the KOSPI200 futures market, and the KOSPI200 Options market. Especially, we examine the lead-lag relations among the spot index price, the futures price, and the forward price implied by the option prices. The implied forward prices are calculated from the put-call parity relation.

The KOSPI200 futures and options contracts are two of the most actively traded derivatives in the world. The KOSPI200 futures contracts are more actively traded than the S&P500 futures contracts. In 2002, the trading volume of the KOSPI200 futures contracts is around 42.8 million, while that of the S&P500 futures contracts is around 2.4 million. The KOSPI200 options contracts are even more actively traded. Actually, it is the most actively traded index options in the world. In 2002, the trading volume of the KOSPI200 options contracts is around 1.89 billion, which is much bigger than 29.9 million for the S&P500 index options contracts. Since the KOSPI200 futures and options markets are so active, we expect that they are informationally efficient markets. We want to test whether these derivatives markets lead the underlying KOSPI200 stock market.

There are many papers examining the lead-lag relations among a spot, a futures and an options prices. For example, Stoll and Whaley (1990) document that futures returns tend to lead stock returns by about 5 minutes even after taking non-synchronous trading effects into account. Chan (1992) also documents that the futures index return leads the spot index return, but finds weak evidence that the spot index return leads the futures return. Manaster and Lendleman (1982) document that it may take up to 1 day for stock prices to adjust to the information contained in options prices, using closing price data. On the other hand, Bhattacharya (1987) doesn't find any evidence supporting that option prices may lead stock prices. Moreover, Stephan and

Whaley (1990) document that stock returns lead options returns by up to 20 minutes.

This paper can be distinguished from the others in the following ways. Firstly, this paper examines relations together among a stock market, its futures market and its options market, unlike the other papers. The other papers examine either between a stock market and its futures market or between a stock market and its options market. We examine not only both relations investigated in the literature but also the relation between a futures market and an options market with the same underlying asset. Secondly, this paper examines the lead-lag relations of volatilities as well as those of returns among the markets. Since trading options can be regarded as trading volatilities of the underlying asset returns, information regarding volatilities may be reflected more speedily in options market. Thirdly, our approach is relatively model-free. Since we extract the implied forward or stock prices from the put-call parity relation, our estimated stock index values implied in the options market are model-free unlike the estimated values in the other papers. The other papers, such as Stephan and Whaley (1990) and Longstaff (1995), frequently assume the Black and Scholes model to extract the implied stock index prices in options market. Lastly, we look at the KOSPI200 index, which has the most actively traded derivatives markets in the world.

We document that futures returns and options returns lead stock returns by up to 10 minutes, and that futures returns lead and lag options returns by around 5 minutes. We document that this lead-lag relation holds even after taking non-synchronous trading effects into account. Also, we document that the KSOPI200 futures and the KOSPI200 options markets lead the KSOPI200 stock market in terms of volatilities, but that the KSOPI200 options market does not lead or lag the KOSPI200 futures market in terms of volatilities.

The remainder of this paper is organized as follows. Section 2 describes the theoretical background for lead-lag relations among a spot and its derivative markets. Section 3 describes the data used in this paper. Section 4 presents the main empirical results for this paper. Section 5 considers the bid-ask spread and the infrequent trading effects, and examines the lead-lag relations among the markets after purging the bid-ask spread and the infrequent trading effects. Section 6 examines trading strategies using the lead-lag relations documented in this paper. Section 7 summarizes the paper and discusses the results.

2. Relations among Spot Prices, Futures Prices and Options Prices

In theory, the price of a futures contract on a tradable asset at time t, F_t, is determined as follows:

$$F_t = S_t e^{(r-q)(T-t)} \ , \tag{1}$$

where S_t is the underlying asset price at time t, r is the risk-free rate, q is the dividend yield of the underlying asset, and T is the maturity date of the futures contract[1]. Thus, the change in (log) futures prices, ΔF_t, can be expressed as:

$$\Delta F_t \equiv \ln F_t - \ln F_{t-\delta} = \ln S_t - \ln S_{t-\delta} + (r-q)\delta$$

$$\equiv \Delta S_t + (r-q)\delta \,. \tag{2}$$

If we assume that (r−q) is constant, we can see in the above equation that the regression coefficient of ΔS_t should be 1 if we regress ΔF_t against a constant and ΔS_t.

Since we can synthesize a forward contract using the options contracts, there is also a relation between the options prices and the futures prices. The put-call parity relation implies that the implied forward price, G(t) should satisfy:

$$G_t = (C_t - P_t)e^{r(T-t)} + K \ , \tag{3}$$

where C_t and P_t are the time-t prices of a call and a put with an exercise price, K and a maturity date T, respectively. Thus, the change in implied forward prices may be expressed as:

$$\Delta G_t = \Delta S_t + (r-q)\delta \,. \tag{4}$$

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[1] Rigorously speaking, this relation holds only when the underlying asset price is uncorrelated with the risk-free rate under the risk-neutral probability measure.

If the spot, the futures, and the options markets are perfectly functioning so that new information disseminated in the financial markets are simultaneously reflected in the prices of the underlying asset and the derivatives contracts, then equation (2) and (4) should hold. In this ideal world, if we examine the following regression coefficients, all the regression coefficients except the one representing the contemporaneous relation should be zero:

$$\Delta S_t = \alpha + \sum_{k=-K}^{K} \beta_k \Delta F_{t-k} + \varepsilon_t , \tag{5}$$

$$\Delta S_t = \alpha + \sum_{k=-K}^{K} \beta_k \Delta G_{t-k} + \varepsilon_t , \tag{6}$$

$$\Delta F_t = \alpha + \sum_{k=-K}^{K} \beta_k \Delta G_{t-k} + \varepsilon_t . \tag{7}$$

Leading and lagged effects will be revealed in these regression equations through nonzero non-contemporaneous regression coefficients. These regressions are the ones examined in Stoll and Whaley (1990) and Stephan and Whaley (1990). The difference of our study from the previous literature is the way that the implied forward (or spot) prices are extracted from options prices. For example, Stephan and Whaley extract the implied spot prices from an American option pricing model that is exposed to modeling errors, while we extract the implied forward prices from the put-call parity relation that should hold if there is no arbitrage opportunity in the market. Also, Stephan and Whaley assume that the implied volatility at time t is the same as the one at time t-1, which is not likely to hold. We do not make any assumption regarding the stationarity of implied volatilities. Since the put-call parity relation always holds unless there exist arbitrage opportunities in the market, our method is not exposed to the model misspecification problem Stephan and Whaley may have.

We examine the relation between the options market and the futures market as well as the relations between the options market and the spot market or between the futures market and the spot market.

We also examine the lead-lag relations of the volatility changes among the spot, the futures, and the options markets. These relations are investigated through the following equations:

$$\Delta Vol_t^{spot} = \alpha + \sum_{k=-K}^{K} \beta_k \Delta Vol_{t-k}^{futures} + \varepsilon_t \,, \tag{8}$$

$$\Delta Vol_t^{spot} = \alpha + \sum_{k=-K}^{K} \beta_k \Delta Vol_{t-k}^{options} + \varepsilon_t \,, \tag{9}$$

$$\Delta Vol_t^{futures} = \alpha + \sum_{k=-K}^{K} \beta_k \Delta Vol_{t-k}^{options} + \varepsilon_t \,. \tag{10}$$

where Vol_t means the volatility at time t in each market. The volatility in each market is measured by the square of the return or the absolute value of the return. These volatility measures represent the variance or the standard deviation. Since these measures use a single point of the realized squared return, they may not be efficient volatility measures, but unbiased measures. In addition to these measures, in case of the options market, the Black-Scholes implied volatility is also used as a proxy for the volatility. If the market is perfectly integrated and so the information regarding the volatility changes is reflected simultaneously in the KOSPI200 index, the KOSPI200 futures, and the KOSPI200 options prices, then all the non-contemporaneous regression coefficients in equations (8), (9), and (10) should be zero, while the contemporaneous regression coefficients should be 1.

3. Data

In this study, we use the transaction price data for the KSOPI200 futures and options contracts, the 5-minute KOSPI200 index data, and the 90-day CD rate data for the riskless interest rates. The KSOPI200 price data are obtained from the Korea Stock Exchange (KSE), and the CD rates are obtained from the Korea Bond Pricing and Korea Rating Co (KBP).

The sample period used in this paper is from September 1, 2001 to December 30, 2002. Table 1 shows the descriptive statistics for the 5-minute data of the KOSPI200 index values, KOSPI200 futures prices, and the implied forward prices calculated from the put-call parity as in section 2. When we calculate the implied forward prices, we need prices of a put-call pair with the same exercise price. For the time-t implied forward price, we scan all the nearby put-call pairs with the same exercise price for the period of (t-5 minutes, t] and select the put-call pair with the closest transaction time from t among the ones the difference of which the recorded transaction times between the call and the put is less than 30 seconds. In this scanning procedure, we only look at the ATM options. Since the ITM or the OTM option prices may have more noise than the ATM option prices as shown in Hentschel (2003), options are included in the scanning procedure only when $0.95 \leq F/K \leq 1.05$, where F is the nearby futures price and K is the exercise price of the option. [Table 1-(1)] shows that the average recorded transaction time for the put-call pair used to calculate the time-t implied forward price is around t – 5 seconds and the recorded transaction time difference between the call and the put is around 4 seconds.

For futures prices, we use only nearby futures contracts, since nearby futures contracts are much more liquid than the other futures contracts. We regard the last transaction price before time t as the time-t futures price. Thus, all the futures and implied forward prices at time t are actually prices before time t, even though the transactions occur very near at time t.

Table 1 (2) and (3) show that the three KOSPI200 related prices are very close to each other, unlike in Longstaff (1995). Longstaff documents that the stock index values implied in options are larger than the stock index values for 442 of the 444 observations in his sample. Our sample doesn't have that kind of a problem. This might be due to the different method to estimate the implied stock index values we adopt in this paper or due to the sample difference. Longstaff extract the implied stock index values under the assumption of the Black-Scholes model.

Even though the three KOSPI200 related prices are close, they are not exactly the same. For example, the KOSPI200 futures price and implied forward price are more volatile than the KOSPI200 index itself. Also, as we can see in Figure 1, the difference between the two prices of them can be significant, even though the average differences among them are close to zero. This suggests that there might exist some lead-lag relations among the KOSPI200 spot, the KOSPI200 futures, and the KOSPI200 options markets.

[Table 2] shows the descriptive statistics for return data used in this paper. This table shows that stock returns are much more negatively skewed and leptokurtic than the others. This may be due to the fact that our sample period includes September 11, 2002. However, even excluding this day, our results reported in this paper don't change qualitatively. The autocorrelation structure of stock index returns is also different from that of the others. Stock index returns are more negatively serially correlated than the others.

4. Main Empirical Results

In this paper, we investigate the information transmission process among the KSOPI200 related markets by looking at the lead-lag relations of return and volatility processes among the markets. The first subsection examines the lead-lag relations of returns, and the second subsection examines the lead-lag relations of volatilities. The last subsection looks at the implications of transaction costs in these relations.

4.1. The Lead-Lag Relations of Returns

[Table 3] reports the estimation results for equations (5), (6), and (7).[2] All the contemporaneous coefficients are much bigger than the non-contemporaneous coefficients, and statistically significantly different from 0 at any reasonable significance level. However, since all the contemporaneous coefficients are statistically

[2] The intercept coefficients are included in the regressions of the paper, but not reported in the tables of this paper, as in [Table 3].

different from 1 at a 1% significance level, the three markets don't move together perfectly.

Non-contemporaneous coefficients show that the futures and the options returns lead the spot returns and that the futures returns lead options returns. If we look at β_{-1} and β_{-2} in the regressions of spot returns against futures returns and against implied forward returns, respectively, they are 0.0839 and -0.0241 for the futures return case, and 0.0658 and -0.0211 for the implied forward return case. All those values are statistically significant at a 1% significance level. One thing peculiar is that β_{-1} and β_{-2} have opposite signs for both cases. This may come from some market inefficiencies. Or this may also result from the bid-ask spread effect, since we use transactions prices as in Stoll and Whaley (1990), Stephan and Whaley (1990), and others. We will look more closely at this issue later. In these regressions, β_1's are also statistically significant, but its magnitude is around 1%, which is much smaller than β_{-1}. This shows that options and futures markets lead the spot market by around 5 minutes, while the spot market also leads the derivatives markets to a much weaker degree by around 5 minutes. But the latter effect might be due to the fact that the derivative returns at time t in our data set are actually the returns at time slightly before t.

If we look at β_{-1} and β_{+1} in the regressions of futures returns against implied forward returns, they are 0.0074 and 0.0193, respectively, and they are statistically significant at a 1% significance level. Since β_{+1} is much bigger than β_{-1}, the extent that the options market leads the futures market seems bigger than that of the other case.

To summarize, the KSOPI200 futures and options markets lead the KOSPI200 spot market by around 5 minutes, and the KOSPI200 options market leads and also lags the KOSPI200 futures market.

4.2. The Lead-Lag Relations of Volatilities

Since trading options is heavily involved in volatility, information about volatilities may be reflected in options market earlier than in the other markets. [Table 4] examines this possibility and reports the estimation results for equations (8), (9) and (10). Since the results from the absolute return regressions are qualitatively the same as those from the squared return regressions, we only report the results from the squared return regressions. As in the return regressions shown in section 4.1, contemporaneous regression coefficients are much bigger than non-contemporaneous regression coefficients. In these regressions, squared spot returns seem much more sensitive to a shock than squared futures or implied forward returns. β_0's in the regressions of changes in squared spot returns against changes in squared futures returns and against squared changes in implied forward returns are around 1.9. However, this huge coefficient values can be attributed mainly to the turmoil of September 11, 2002. When we exclude the observations in September, 2002, these values decrease to around 0.94.

Non-contemporaneous coefficients show that volatilities of futures and options returns lead volatilities of spot returns by around 5 minutes. If we look at β_{-1} in the regressions of squared spot returns against squared futures returns and against squared implied forward returns, respectively, they are 0.1285 for the squared futures return case, and 0.1135 for the squared implied forward return case. Those two values are statistically significant at a 1% significance level, and the other coefficients in the regressions are all insignificant even at a 10% significance level.

If we look at the regression of squared futures returns against squared implied forward returns, all the non-contemporaneous coefficients are very small, and statistically insignificant in general. Thus, in terms of volatilities, neither the KOSPI200 options market nor the KOSPI200 futures market leads the other market.

So far, we regard the square of a return as the proxy of the volatility. However, in options markets, the Black-Scholes implied volatility is a more prevalent measure of the volatility. The Black-Scholes implied volatility is a volatility measure fitting the observed option price to the model price assumed in the Black-Scholes model. This measure shows the future volatility of the underlying asset's return under the assumptions of the Black-Scholes model. If a volatility shock arrives and is reflected in an options market, this effect will be reasonably revealed in the Black-Scholes implied volatility. One thing we should note is, however, that the Black-Scholes implied volatility at time t is a volatility measure showing the expected value of the future volatilities for the period from time t to the expiration date of the option, while the other volatility measures in this paper are the measures showing the realized volatility at time t in the market.

There are some debates regarding whether the Black-Scholes implied volatility can be an unbiased estimator of the future realized volatility. For example, Canina and Figlewsky (1993) documents that the implied volatility has little prediction power, if any, on the future realized volatility in their sample. On the other hand, Lamoureux and Lastrapes (1993), Jorion (1995), Christensen and Prabhala (1998), and Hwang and Kang (2004) found some prediction power of the Black-Scholes implied volatility on the future realized volatilities.

Our approach is a little different from the previous literature mentioned in the above.

We look at the effects of the changes in the implied volatilities on the changes in the volatilities in stock returns, implied forward returns and futures returns; we do not examine the relation between the levels of implied volatilities and stock volatilities. Since the volatility process is very persistent, it is more convenient to look at the changes instead of levels. Also, our main focus is to examine which market reflects the information regarding volatility shocks, i.e., volatility changes more speedily.

The call options used to estimate the implied forward prices are used to estimate the Black-Scholes implied volatilities. [Table 5] reports the estimation results of equations (8), (9), and (10). For comparisons with the other volatility measures in this paper, we use the squared implied volatility as the volatility in the KOSPI200 options market. We also look at the lead-lag relations between the squared implied forward returns and the squared implied volatilities. In all the regressions shown in [Table 5], only the coefficient, β_{-1}, is statistically significant at a 1% significance level.[3] This shows that changes in the Black-Scholes implied volatilities lead changes in the realized volatilities of the spot, the futures, or the implied forward index by up to 5 minutes. This means that the information regarding the volatilities is reflected in the options earlier than the spot index, the futures index or the implied forward index.

[3] The regression coefficients in [Table 5] are not comparable to those in [Table 4], since the Black-Scholes implied volatility is an annualized value, unlike the other volatility measures in this paper.

To summarize, the realized volatilities of the KOSPI200 futures and options lead and lag the KOSPI200 stock index volatilities by around five minutes, while there is no evidence that the realized volatilities of the implied forward returns lead or lag the KOSPI200 realized futures volatilities. However, the Black-Scholes implied volatilities lead the realized volatilities in the markets by up to 5 minutes.

4.3. Transaction Costs

We have documented so far that the KOSPI200 futures and the KOSPI200 options markets lead the KOSPI200 spot market in general. This lead and lag relationship among the markets may result from the differences in the structure of markets, the infrequent trading effect, or the inefficiency of the markets.

One of the differences among these markets, probably the most important difference, is the difference in transaction costs. [Table 6] reports the transaction costs of the three markets. As we can see in this table, trading the KOSPI200 futures contracts costs much less than trading the stocks included in KSOPI200 index. Trading the KOSPI200 options contracts also costs much less than trading the stocks included in KSOPI200 index, since the former costs only 0.5% of the options premium, while the latter costs 0.25% of the price of the traded stock. Moreover, 0.3% of transaction tax is charged on the trades of the stocks in Korea Stock Exchange, while no transaction tax is charged on the trades of the KOSPI200 futures or options contracts. This difference in transaction costs may result in the observed lead-lag relations among the markets.

It is also possible that the observed lead-lag relations are caused by the infrequent trades in the KOSPI200 spot market, which will be examined in the next section.

5. Nonsynchronous Trading, Bid-Ask Spreads, and Lead-Lag Relations

Since we use transaction price data, our return data may be contaminated due to a bid-ask spread effect. Many authors, including Stephan and Whaley (1990), and Stoll and Whaley (1990), model this bid-ask spread effect as a moving average process. Also, there is a nonsynchronous trading effect, especially in stock index return case. Since some of the stocks in the KSOPI200 index may not have any trading activities in some intervals, new information generated in the intervals may not be fully reflected in the stock index, which may cause lead-lag relations between the stock market and its derivatives markets. Dimson (1979), Lo and MacKinlay (1988), Scholes and Williams

(1977), Stephan and Whaley (1990), and Stoll and Whaley (1990) suggest that this effect can be modeled as an ARMA process.

We model stock index returns, futures returns and implied forward returns as MA(2) processes, because we do not find any additional AR terms. That is, we model a return, R(t) as follows:

$$R(t) = \mu + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} \,. \tag{11}$$

We will call ε_t as an innovation at time t, and regard it as the return after eliminating the bid-ask spread and the infrequent trading effects.

[Table 7-(1)] shows the estimation results of equation (11), and [Table 7-(2)] shows the descriptive statistics for innovation processes. If we look at [Table 7-(2)], the autocorrelations of each innovation are almost zero for all cases, which achieves our intention of purging the bid-ask spread and the infrequent trading effects.

[Table 8] replicates [Table 3] except for replacing returns by innovations. The results in this table are almost the same as those in [Table 3]. However, β_{-1} and β_{-2} in the regressions of spot return innovations against futures return innovations or against implied forward return innovations have the same signs; They are positive and statistically significant at a 1% significance level. This confirms our guess that the bid-ask spread effect may cause the negative sign of β_{-2} in [Table 3]. [Table 8] shows that futures returns and options returns lead stock index returns by around 10 minutes after purging the bid-ask spread and the infrequent trading effects. If we look at β_{-1} and β_{+1} in the regressions of futures return innovations against implied forward return innovations, they are 0.0186 and 0.0192, respectively, and they are statistically significant at a 1% significance level. Unlike [Table 3], the magnitude of β_{+1} is almost the same as that of β_{-1}. Thus, we can say that futures returns lead and lag options returns after purging the bid-ask spread and the infrequent trading effects.

[Table 9] replicates [Table 4] except for replacing squared returns by squared innovations. The results in this table are qualitatively the same as those in [Table 4]. Non-contemporaneous coefficients show that volatilities of the futures and options markets lead volatilities of spot returns by around 5 minutes, but that neither the KOSPI200 options market nor the KOSPI200 futures market leads the other market.

[Table 10] replicates [Table 5], except for replacing squared returns by squared innovations. All the qualitative results remain after these changes.

To summarize, after purging the bid-ask spread and the infrequent trading effects, the options and the futures market lead the spot market by up to 10 minutes in terms of returns and by 5 minutes in terms of volatility. However, the options market leads and also lags the futures market only in terms of returns, not in terms of realized volatilities.

In addition, the Black-Scholes implied volatilities lead the realized volatilities in the markets by up to 5 minutes.

6. Trading Results Using the Lead-Lag Relations of Returns

In this section, we examine whether the information transmitted from the other markets can generate trading profits. In the previous sections, we document that the KOSPI200 futures and the KOSPI200 options markets lead the KOSPI200 stock markets. If the information content of a new shock is known in advance to the KOSPI200 derivatives markets, we may get trading profits in the KSOPI200 spot market designing a trading strategy by using the information reflected in the KOSPI200 derivatives prices.

The most straightforward trading strategy to exploit the lead-lag relations among the markets is to take a long [short] position in one market at time t and to clear the position by taking a short [long] position in the same market at $t+\Delta t$, if the return of an asset in another market is positive[negative] from time t-5 minutes to t. We examine the cases of Δt=5 minutes and 10 minutes. [Table 11] shows the results of the trading strategy. If we look at [Table 11], we can clearly see that the trading strategy to buy or sell stocks at time t and to clear the position at time t+5 minutes, using the futures returns or the implied forward returns at time t as a signal to trade, is very profitable. The 5-minute returns on those trading strategies are on average 0.02% to 0.03%, which is statistically significant at any reasonable significance level. Also, even if we use the innovations of returns, instead of returns themselves, as trading signals, the results don't change.

The above trading strategies do not guarantee profit opportunities in the real world. First, it is difficult to buy or sell the KOSPI200 index. Since we have buy 200 different stocks to buy the stock index, it may take more than 5 minutes to implement the trading strategies. As [Table 11] shows, it is not profitable to trade 10 minutes after we receive trading signals in the KOSPI200 futures or options markets. Second, the magnitude of the profit is not large enough to offset the transaction costs. To implement the trading strategies, investors need to bear bid-ask spread as well as brokerage fees. Even if 0.02% to 0.03% is huge as a 5-minute return, it is much less than the transaction costs reported in [Table 6].

[Table 11] shows, however, that the KOSPI200 futures and the KOSPI200 options prices reflect and disseminate new information more speedily than the KOSPI200 stock prices. [Table 11] confirms again that the KOSPI200 futures and the KOSPI200 options markets lead the KOSPI200 stock market by around 5 minutes.

7. Conclusions

In a perfectly functioning world, every piece of information should be reflected simultaneously in the underlying spot market and their derivatives markets. However, in reality, information can be disseminated in one market first, and then transmitted to other markets due to market imperfections. This paper examines whether there exist lead-lag relations of returns and volatilities among the KOSPI200 stock market, the KOSPI200 futures market and the KOSPI200 options market. We document the following things:

(1) The KOSPI200 futures and options returns lead the KOSPI200 stock index returns by up to ten minutes. This relation still holds after purging the bid-ask spread effect and the infrequent trading effect.

(2) The KOSPI200 futures returns lead and lag the KOSPI200 options returns by around five minutes. This relation still holds after purging the bid-ask spread effect and the infrequent trading effect.

(3) The KOSPI200 futures and options volatilities lead and lag the KOSPI200 stock index volatilities by around five minutes.

(4) There is no evidence that the changes in the realized volatilities of the KOSPI200 implied forwards lead or lag the changes in the realized volatilities of the KOSPI200 futures returns.

(5) The changes in the Black-Scholes implied volatilities lead the changes in the realized volatilities in the markets by up to 5 minutes.

(6) When the 5-minute-before returns in the KOSPI200 futures or options markets are used as a signal to buy or sell the KOSPI200 stocks, there seem statistically significant trading profits. However, the trading profits are not large enough to offset the transaction costs of the trading.

The lead-lag relations documented in this paper may be due to the difference in transaction costs. Much lower transaction costs in the derivatives markets may facilitate the trades in those markets, which disseminates information more efficiently and speedily than the spot market.

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[Table 1] Descriptive Statistics for the KOSPI200 Index, Futures, and Options Prices

This table provides the summary statistics for the KOSPI200 stock index, futures, and options prices used in this paper. (1) shows the information about the recorded transaction times of option prices used to construct the implied forward prices. (2) shows the summary statistics for the prices used in this paper. The implied forward prices are constructed from the put-call parity relation using near-the-money options. (3) shows the correlation matrix among spot, futures, and implied forward prices.

(1) Summary Statistics for the Transaction Time

(unit: second)

	transaction time gap between the call and the put	transaction time difference from t
average	4	5
median	2	3
max	30	298
min	0	1

(2) KOSPI200 Index, Futures and Implied Forward Prices

	spot	futures	implied forward
# of obs.	22,592	22,592	22,592
averge	89.60	89.47	89.56
std	13.84	14.13	14.03
skewness	-0.25	-0.25	-0.24
kurtosis	2.59	2.59	2.59
max	118.53	119.25	119.17
min	57.25	56.85	56.79
median	90.12	89.85	89.95
autocorr.			
1	0.9998	0.9998	0.9998
2	0.9996	0.9996	0.9996
3	0.9994	0.9994	0.9994
4	0.9992	0.9992	0.9992
5	0.9991	0.9991	0.9990

(3) Correlation matrix among spot prices, futures prices and implied forward prices

	spot	futures	implied forward
spot	1.0000		
futures	0.9997	1.0000	
implied forward	0.9997	0.9999	1.0000

[Table 2] Descriptive Statistics for the KOSPI200 Index, Futures, and Options Returns

This table provides the summary statistics for the returns on the KOSPI200 stock index, futures, and implied forward contracts used in this paper. (1) shows the summary statistics for the returns used in this paper. The implied forward prices are constructed from the put-call parity relation using near-the-money options. (2) shows the correlation matrix among spot, futures, and implied forward returns.

(1) Summary statistic for returns

	spot	futures	implied forward
# of obs.	22591.00	22591.00	22591.00
averge	0.00	0.00	0.00
std	0.00	0.00	0.00
skewness	-4.89	-0.85	-0.10
kurtosis	319.28	85.08	70.88
max	0.04	0.04	0.05
min	-0.13	-0.08	-0.07
median	0.00	0.00	0.00
autocorr.			
1	-0.0559	-0.0181	-0.0062
2	-0.0272	0.0207	0.0162
3	-0.0055	-0.0037	-0.0065
4	-0.0045	-0.0066	-0.0049
5	-0.0008	-0.0024	-0.0034

(2) correlations among returns

	spot	futures	implied forward
spot	1.0000		
futures	0.8298	1.0000	
implied forward	0.8384	0.9471	1.0000

[Table 3] Lead-Lag Relations among Spot, Futures, and Implied Forward Returns

This table shows the estimation results of the following regressions:

$$\Delta S_t = \alpha + \sum_{k=-6}^{6} \beta_k \Delta F_{t-k} + \varepsilon_t ,$$

$$\Delta S_t = \alpha + \sum_{k=-6}^{6} \beta_k \Delta G_{t-k} + \varepsilon_t ,$$

$$\Delta F_t = \alpha + \sum_{k=-6}^{6} \beta_k \Delta G_{t-k} + \varepsilon_t ,$$

where S_t, F_t, and G_t indicate time-t log prices of the KOSPI200 spot index, futures, and options. In parentheses, t-statistics are reported.

		Dependent Variable			
Indep.		Spot		Futures	
Futures	-6	-0.0032	(-0.854)		
	-5	-0.0009	(-0.251)		
	-4	-0.0024	(-0.64)		
	-3	-0.0078	(-2.048)		
	-2	-0.0241	(-6.377)		
	-1	0.0839	(22.158)		
	0	0.8574	(226.559)		
	1	0.0102	(2.684)		
	2	-0.0067	(-1.762)		
	3	0.0008	(0.209)		
	4	0.0097	(2.576)		
	5	0.0014	(0.364)		
	6	-0.0052	(-1.376)		
Implied forward	-6	-0.0026	(-0.702)	-0.0015	(-0.687)
	-5	0.0011	(0.299)	0.0022	(1.021)
	-4	-0.0044	(-1.18)	0.0006	(0.286)
	-3	-0.0059	(-1.567)	0.0013	(0.611)
	-2	-0.0211	(-5.617)	0.0034	(1.552)
	-1	0.0658	(17.491)	0.0074	(3.404)
	0	0.8761	(233.02)	0.9596	(444.077)
	1	0.0094	(2.488)	0.0193	(8.929)
	2	-0.0021	(-0.553)	0.0038	(1.764)
	3	0.0011	(0.284)	0.0024	(1.108)
	4	0.0078	(2.075)	-0.0011	(-0.519)
	5	0.0016	(0.418)	0.0017	(0.789)
	6	-0.0047	(-1.255)	0.0011	(0.511)

[Table 4] Lead-Lag Relations among Spot, Futures, and Implied Forward Volatilities

This table shows the estimation results of the following regressions:

$$\Delta Vol_t^{spot} = \alpha + \sum_{k=-6}^{6} \beta_k \Delta Vol_{t-k}^{futures} + \varepsilon_t \quad (8)$$

$$\Delta Vol_t^{spot} = \alpha + \sum_{k=-6}^{6} \beta_k \Delta Vol_{t-k}^{options} + \varepsilon_t \quad (9)$$

$$\Delta Vol_t^{futures} = \alpha + \sum_{k=-6}^{6} \beta_k \Delta Vol_{t-k}^{options} + \varepsilon_t \quad (10)$$

where Vol_t means the volatility at time t in each market. The volatility in each market is measured by the square of the return. In parentheses, t-statistics are reported.

		dependent variables			
indep.		Spot		Futures	
Futures	-6	-0.0023	(-0.394)		
	-5	-0.0068	(-1.146)		
	-4	-0.0010	(-0.17)		
	-3	-0.0031	(-0.522)		
	-2	0.0002	(0.042)		
	-1	0.1285	(21.564)		
	0	1.8571	(311.77)		
	1	-0.0040	(-0.668)		
	2	-0.0016	(-0.267)		
	3	-0.0017	(-0.292)		
	4	-0.0022	(-0.363)		
	5	0.0000	(0.003)		
	6	-0.0056	(-0.936)		
implied forward	-6	-0.0047	(-0.512)	-0.0005	(-0.16)
	-5	-0.0102	(-1.123)	-0.0029	(-0.967)
	-4	-0.0079	(-0.87)	-0.0033	(-1.113)
	-3	-0.0066	(-0.723)	-0.0011	(-0.373)
	-2	0.0012	(0.131)	0.0008	(0.278)
	-1	0.1135	(12.451)	-0.0019	(-0.635)
	0	1.8762	(205.83)	1.0349	(350.47)
	1	-0.0027	(-0.295)	-0.0004	(-0.132)
	2	-0.0073	(-0.796)	-0.0014	(-0.467)
	3	-0.0100	(-1.1)	-0.0046	(-1.561)
	4	-0.0125	(-1.376)	-0.0063	(-2.124)
	5	-0.0080	(-0.88)	-0.0053	(-1.807)
	6	-0.0070	(-0.763)	-0.0004	(-0.143)

[Table 5] Regressions of Changes in Variances of Returns against Changes in the Squared Black-Scholes Implied Volatilities

This table shows the estimation results of the following regressions:

$$\Delta Vol_t^{spot} = \alpha + \sum_{k=-6}^{6} \beta_k \Delta BSVol_{t-k}^2 + \varepsilon_t$$

$$\Delta Vol_t^{futures} = \alpha + \sum_{k=-6}^{6} \beta_k \Delta BSVol_{t-k}^2 + \varepsilon_t$$

$$\Delta Vol_t^{implied\ forward} = \alpha + \sum_{k=-6}^{6} \beta_k \Delta BSVol_{t-k}^2 + \varepsilon_t$$

where Vol_t means the volatility at time t in each market. The volatility in each market is measured by the square of the return. $BSVol_t^2$ means the square of the Black-Scholes implied volatility. All the coefficients are multiplied by 1,000. In parentheses, t-statistics are reported.

		Dependent variable(단위:X1000)					
indep.		futures		spot		implied forward	
Changes in the square of implied vol.	-6	-0.0104	(-1.69)	-0.0058	(-0.93)	-0.0089	(-1.5)
	-5	-0.0112	(-1.36)	-0.0065	(-0.78)	-0.0101	(-1.27)
	-4	-0.0108	(-1.12)	-0.0065	(-0.68)	-0.0105	(-1.14)
	-3	-0.0040	(-0.39)	-0.0057	(-0.54)	-0.0052	(-0.52)
	-2	-0.0093	(-0.84)	-0.0064	(-0.58)	-0.0094	(-0.89)
	-1	0.0582	(5.14)	0.0728	(6.41)	0.0825	(7.56)
	0	0.0049	(0.43)	0.0050	(0.44)	0.0039	(0.36)
	1	0.0047	(0.42)	0.0065	(0.57)	0.0041	(0.38)
	2	0.0039	(0.36)	0.0083	(0.75)	0.0055	(0.52)
	3	0.0105	(1)	0.0095	(0.9)	0.0094	(0.94)
	4	0.0051	(0.53)	0.0054	(0.56)	0.0049	(0.53)
	5	0.0032	(0.39)	0.0033	(0.4)	0.0031	(0.39)
	6	0.0011	(0.17)	0.0018	(0.28)	0.0016	(0.26)

[Table 6] Transaction Costs

This table shows the average brokerage fees charged by securities companies and futures companies in 2002.

(unit: %)

	brokerage fees	
	institutions	individuals
stocks	0.25	0.11
futures	0.02	0.01
options	0.50	0.30

[Table 7] Time-Series Estimation of Returns

In (1), the estimation results of the following MA(2) specifications are provided:

$$R(t) = \mu + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2}\,, \tag{11}$$

where the KOSPI200 index return, the futures return, and the implied forward return are used in place of R(t). In parentheses, t-statistics are reported. In (2), the summary statistics for ε_t's for the index return, the futures return, and the implied forward return are provided.

(1) MA(2)

	Spot		Futures		Implied forward	
Parameter	estimate	t	estimate	t	estimate	t
const.	0.0000	(0.5)	0.0000	(0.45)	0.0000	(0.47)
q1	-0.0582	(-8.76)	-0.0168	(-2.54)	-0.0052	(-0.78)
q2	-0.0283	(-4.26)	0.0210	(3.16)	0.0163	(2.46)

(2) Summary Statistics for Innovation Processes

	spot	futures	implied forward
average	0.0000	0.0389	0.0000
median	0.0000	0.0000	0.0000
standard dev.	0.0026	0.0025	0.0025
skewness	-4.9804	-0.8471	-0.0889
kurtosis	319.2100	85.2270	71.0430
max	0.0417	0.0389	0.0523
min	-0.1309	-0.0815	-0.0687
autocorr.			
1	0.0033	-0.0001	-0.0001
2	-0.0084	-0.0003	-0.0001
3	-0.0071	-0.0028	-0.0059
4	-0.0045	-0.0069	-0.0050
5	-0.0024	-0.0031	-0.0041

[Table 8] Lead-Lag Relations among Spot, Futures, and Implied Forward Innovations

This table shows the estimation results of the following regressions:

$$\varepsilon_t^{spot} = \alpha + \sum_{k=-6}^{6} \beta_k \varepsilon_{t-k}^{futures} + e_t \,,$$

$$\varepsilon_t^{spot} = \alpha + \sum_{k=-6}^{6} \beta_k \varepsilon_{t-k}^{implied\ \ forward} + e_t \,,$$

$$\varepsilon_t^{futures} = \alpha + \sum_{k=-6}^{6} \beta_k \varepsilon_{t-k}^{implied\ \ forward} + e_t \,,$$

where $\varepsilon^{spot}{}_t$, $\varepsilon^{futures}{}_t$ and $\varepsilon^{implied\ forward}{}_t$ indicate time-t innovation values of the KOSPI200 spot index, futures, and options. Innovations are estimated from returns using the MA(2) specifications. In parentheses, t-statistics are reported.

		dependent variables			
indep.		Spot		Futures	
Futures	-6	-0.0033	(0.9)		
	-5	-0.0015	(0.4)		
	-4	-0.0023	(0.7)		
	-3	-0.0071	(2)		
	-2	0.0249	(6.8)		
	-1	0.1196	(32.4)		
	0	0.8583	(231.9)		
	1	0.0094	(2.6)		
	2	-0.0066	(1.8)		
	3	0.0013	(0.4)		
	4	0.0098	(2.7)		
	5	0.0008	(0.3)		
	6	-0.0055	(1.5)		
implied forward	-6	-0.0026	(0.7)	-0.0015	(0.8)
	-5	0.0006	(0.2)	0.0023	(1.1)
	-4	-0.0043	(1.2)	0.0006	(0.3)
	-3	-0.0052	(1.5)	0.0014	(0.7)
	-2	0.0234	(6.4)	-0.0010	(0.5)
	-1	0.1132	(30.8)	0.0186	(8.7)
	0	0.8774	(238.5)	0.9600	(447)
	1	0.0084	(2.3)	0.0192	(9)
	2	-0.0019	(0.6)	0.0039	(1.9)
	3	0.0015	(0.5)	0.0022	(1.1)
	4	0.0081	(2.2)	-0.0010	(0.5)
	5	0.0007	(0.2)	0.0016	(0.8)
	6	-0.0048	(1.3)	0.0009	(0.5)

[Table 9] Lead-Lag Relations among the Squared Spot, Futures, and Implied Forward Innovations

This table shows the estimation results of the following regressions:

$$\Delta\left(\varepsilon_t^{spot}\right)^2 = \alpha + \sum_{k=-6}^{6} \beta_k \Delta\left(\varepsilon_{t-k}^{futures}\right)^2 + e_t ,$$

$$\Delta\left(\varepsilon_t^{spot}\right)^2 = \alpha + \sum_{k=-6}^{6} \beta_k \Delta\left(\varepsilon_{t-k}^{implied\ forward}\right)^2 + e_t ,$$

$$\Delta\left(\varepsilon_t^{futures}\right)^2 = \alpha + \sum_{k=-6}^{6} \beta_k \Delta\left(\varepsilon_{t-k}^{implied\ forward}\right)^2 + e_t ,$$

where ε^{spot}_t, $\varepsilon^{futures}_t$ and $\varepsilon^{implied\ forward}_t$ indicate time-t innovation values of the KOSPI200 spot index, futures, and options. Innovations are estimated from returns using the MA(2) specifications. In parentheses, t-statistics are reported.

		dependent variables			
indep.		Spot		Futures	
Futures	-6	-0.0020	(0.4)		
	-5	-0.0070	(1.2)		
	-4	-0.0009	(0.2)		
	-3	-0.0030	(0.6)		
	-2	-0.0021	(0.4)		
	-1	0.0851	(14.4)		
	0	1.8586	(313.7)		
	1	-0.0040	(0.7)		
	2	0.0004	(0.1)		
	3	-0.0014	(0.3)		
	4	-0.0021	(0.4)		
	5	0.0003	(0.1)		
	6	-0.0056	(1)		
implied forward	-6	-0.0044	(0.5)	-0.0005	(0.2)
	-5	-0.0100	(1.2)	-0.0027	(1)
	-4	-0.0079	(0.9)	-0.0034	(1.2)
	-3	-0.0064	(0.8)	-0.0011	(0.4)
	-2	0.0013	(0.2)	0.0018	(0.7)
	-1	0.0709	(7.9)	-0.0028	(1)
	0	1.8768	(206.7)	1.0345	(350.4)
	1	-0.0014	(0.2)	-0.0001	(0.1)
	2	-0.0056	(0.7)	-0.0012	(0.5)
	3	-0.0092	(1.1)	-0.0045	(1.6)
	4	-0.0123	(1.4)	-0.0063	(2.2)
	5	-0.0079	(0.9)	-0.0054	(1.9)
	6	-0.0071	(0.8)	-0.0005	(0.2)

[Table 10] Regressions of Changes in Variances of Innovations against Changes in the Squared Black-Scholes Implied Volatilities

This table shows the estimation results of the following regressions:

$$\Delta\left(\varepsilon_t^{spot}\right)^2 = \alpha + \sum_{k=-6}^{6}\beta_k \Delta BSVol_{t-k}^2 + e_t$$

$$\Delta\left(\varepsilon_t^{futures}\right)^2 = \alpha + \sum_{k=-6}^{6}\beta_k \Delta BSVol_{t-k}^2 + e_t \Delta$$

$$\Delta\left(\varepsilon_t^{implied\ \ forward}\right)^2 = \alpha + \sum_{k=-6}^{6}\beta_k \Delta BSVol_{t-k}^2 + e_t$$

where ε^{spot}_t, $\varepsilon^{futures}_t$ and $\varepsilon^{implied\ forward}_t$ indicate time-t innovation values of the KOSPI200 spot index, futures, and options. Innovations are estimated from returns using the MA(2) specifications. $BSVol_t^2$ means the square of the Black-Scholes implied volatility. All the coefficients are multiplied by 1,000. In parentheses, t-statistics are reported.

indep.		innovation_futures		innovation_spot		ınovation_implied forwar	
Changes in the squa:	-6	-0.0105	(-1.7)	-0.0058	(-0.93)	-0.0089	(-1.49)
of the implied vol.	-5	-0.0113	(-1.37)	-0.0066	(-0.79)	-0.0101	(-1.27)
	-4	-0.0109	(-1.13)	-0.0066	(-0.68)	-0.0105	(-1.14)
	-3	-0.0034	(-0.32)	-0.0060	(-0.57)	-0.0046	(-0.45)
	-2	-0.0092	(-0.83)	-0.0067	(-0.6)	-0.0093	(-0.88)
	-1	0.0585	(5.16)	0.0724	(6.35)	0.0827	(7.57)
	0	0.0049	(0.43)	0.0050	(0.44)	0.0039	(0.35)
	1	0.0047	(0.41)	0.0066	(0.58)	0.0041	(0.38)
	2	0.0038	(0.34)	0.0085	(0.77)	0.0055	(0.52)
	3	0.0104	(1)	0.0095	(0.9)	0.0094	(0.93)
	4	0.0051	(0.53)	0.0054	(0.56)	0.0049	(0.53)
	5	0.0032	(0.38)	0.0033	(0.4)	0.0031	(0.38)
	6	0.0010	(0.17)	0.0017	(0.28)	0.0016	(0.26)

[Table 11] Trading Profits of the Investment Strategies Using the Lead-Lag Relations of Returns

This table shows the performance of the trading strategies exploiting the lead-lag relations among the markets. In (1), we take a long[short] position in the KSOPI200 index and in the KOSPI200 implied forward contracts at time t and clear the position by taking a short [long] position at time t+Δt if the return of the futures contract from time t-5 minutes to t is positive[negative]. In (2), we take a long[short] position in the KSOPI200 futures and in the KOSPI200 implied forward contracts at time t and clear the position by taking a short [long] position at time t+Δt if the return of the KOSPI200 index from time t-5 minutes to t is positive[negative]. We examine the cases of Δt=5 minutes and 10 minutes. In parentheses, t-statistics are reported.

(1)

		Spot		Implied index	
		5 mins.	10 mins.	5 mins.	10 mins.
futures return	average	0.0003 (16.02)	0.0000 (-1.31)	0.0000 (1.14)	0.0000 (1.47)
	std	0.0025	0.0027	0.0025	0.0025
innovation of futures return	average	0.0003 (12.88)	0.0000 (-1.26)	0.0000 (0.68)	0.0000 (1.05)
	std	0.0024	0.0025	0.0024	0.0025

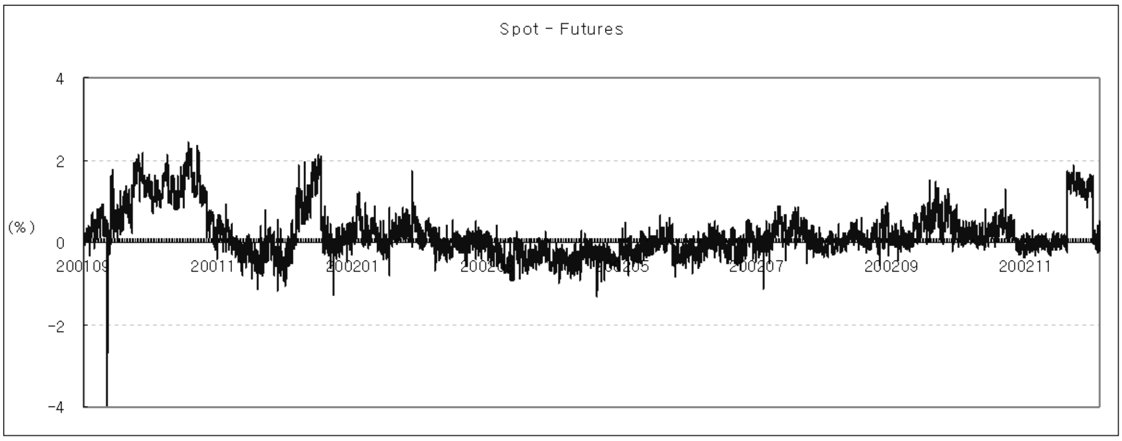
(2)

		Futures		Spot	
		5 mins.	10 mins.	5 mins.	10 mins.
implied forward return	average	0.0000 (0.78)	0.0000 (2.53)	0.0002 (14.05)	0.0000 (-0.54)
	std	0.0025	0.0025	0.0026	0.0026
innovation of implied forward return	average	0.0000 (0.54)	0.0000 (2.53)	0.0002 (12.26)	0.0000 (-0.06)
	std	0.0025	0.0025	0.0025	0.0025

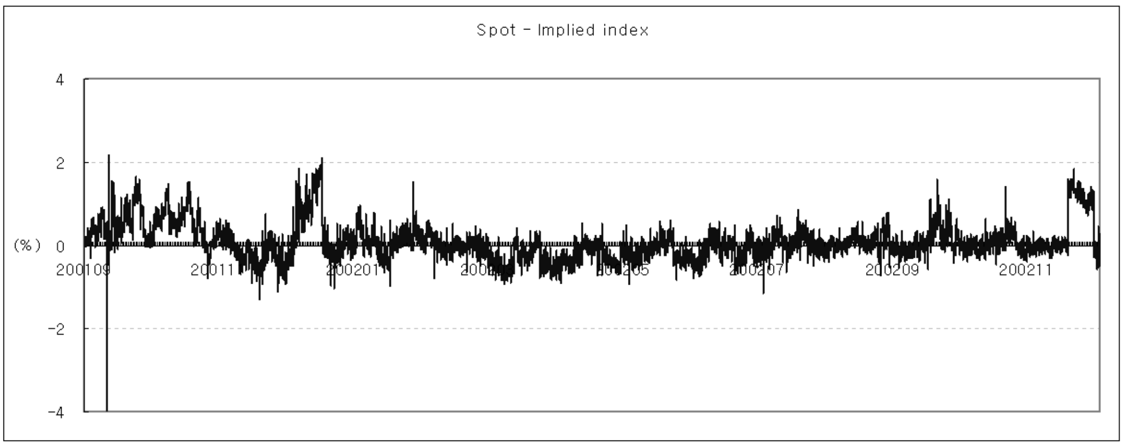
[Figure 1] Differences among Prices

The differences of prices among the KOSPI200 index, the KOSPI200 futures, and the KOSPI200 forwards implied by the put-call parity relation are shown for the sample period of September 2001 to December 2002. The differences are shown in percentages relative to spot prices in (a) and (b) and relative to futures prices in (c). In each picture, the horizontal axis shows the calendar time, and the vertical axis shows the percentage price difference.

(a) Spot price – Futures price



(b) Spot price – Implied Forward Price



(c) Futures Price – Implied Forward Price