Price Discovery Role in KOSPI 200 Options Market: Using the Stochastic Volatility Model

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Abstract

This paper empirically investigates the intraday relations between index returns and implied index returns estimated from options markets during the period of June 2003 to May 2004. We employ both Heston (1993) model and Black-Scholes model to calculate the implied forward prices from options data and present the comparison analysis of the results. We use the error correction model to estimate the contributions of stock and option markets to price discovery. In addition, we test if the lead-lag relation differs according to the types of news, good or bad, and discover that the results do not differ. Lastly, overall results reveal that the stock market leads both call and put options market. Also, it is interesting to note that more unidirectional lead trend from stock market to options market is witnessed in use of Heston (1993) model.

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I. Introduction

In a perfectly functioning capital market, there should be complete simultaneity among the markets. In other words, any new information disseminating into the markets should be reflected simultaneously. Thus, there should be no arbitrage opportunities allowed among the markets. However, factors such as lower transaction costs, higher liquidity and higher financial leverage may make one market more attractive than the others and thus lead one market to absorb new information faster. In addition, if one market is more information efficient, this market should lead the others and thus price discovery may be interpreted as an indication of the relative market efficiencies.

This market efficiency has grabbed researchers' interests and there have been various studies regarding the price discovery roles in the markets. Many of the papers document that when the relationship between the stock market and the futures market is examined, the futures market strongly leads the stock market. While the majority of the papers documents that the futures market leads the stock market, there are some conflicts in researches regarding the relation between the stock market and the options market. Stephan and Whaley (1990) use Black-Scholes model to calculate the implied forward prices from options data and conclude that the stock market leads the options market for active CBOE call options, both in terms of price changes and trading activity. On the other hand, numerous papers documenting that the derivative markets lead the underlying asset market are published. Bhattacharya (1987) uses transaction data to examine the intraday lead-lag relation and concludes that the options market leads the stock market in conveying new information arriving in the market. However, he documents that this information is insufficient to overcome the bid-ask spread and transaction costs. Finucane (1991) also documents that the options market leads the stock market by 15 minutes when put-call parity is used to compute the implied forward prices.

Manaster and Rendleman (1982) analyze the relations between the stock prices and the prices implied by options data and document that closing option prices contain some information which is not contained in closing stock prices. Several years later, Diltz and Kim (1996) improve the paper of Manaster and Rendleman and show consistent results that changes in option prices lead changes in stock prices. To purge the problem of non-synchroneity and bid-ask bias that Manaster and Rendleman (1982) had, Diltz and Kim (1996) use the bid-ask spread data of the call option prices and stock prices of CBOE and NYSE markets, respectively. Also, they use error correction model (ECM) after conducting a cointegration test. Diltz and Kim (1996) also document that there exists a bi-directional causality between the two markets.

These studies regarding lead-lag relations have been popular in Korea as well. For instance, SK Kim and Hong (2003) use Black-Scholes model to calculate the implied forward prices from the intraday options data and document that the stock market leads the options market. SH Kim and Hong (2003) also uses intraday data from year 1997 to 2001 and test the lead-lag relation between the price changes of the index option market and the stock market. Different from SK Kim and Hong (2003), they use put-call parity to avoid any model-specific error and use only at-the-money options data to calculate the implied forward prices. In addition, they perform co-integration test and use error correction model. Then, they conclude that the lead-lag relation is bidirectional. More recently, Kang, Lee, and Lee (2004) document that the KOSPI 200 futures and options markets lead the KOSPI 200 spot market, both in terms of returns and volatilities. In doing so, they use put-call parity condition to extract the implied forward prices from the options data. It seems that there is not enough support for any of the two arguments that either the stock market leads the options market or the options market leads the stock market. It can be thought that the investors use options for volatility trading rather than for directional trading. Thus, compared to the futures market, the options market is not fully utilized for assessing directions of price differences.

Our paper distinguishes from the others described above for several aspects. Most importantly, we employ Heston (1993) model to calculate implied forward prices from the options data. Several researchers have already tested the importance of stochastic volatility of the underlying asset in option valuation. For instance, Bakshi, Cao, and Chan (1997) empirically test the

S&P 500 market and report that it is significantly essential to consider stochastic volatility in option valuation. As well, Kim and Kim (2004a, b) document the importance of stochastic volatility in option valuation and empirically support the argument with Korean market data.

We include the data of all types of moneyness in the calculation acknowledging some negative impacts that in-the-money and out-of-the-money options are often overvalued and thus the errors in volatility estimation tend to be larger than those for the at-the-money options. With respect to this volatility overestimation issue, we admit that the methodology by using put-call parity, as in Kang, Lee, and Lee (2004), is effective for it offers a model-free approach. However, in this case, an option of a particular moneyness type is used and often an at-the-money or near-the-money option of largest trading volume is selected. Then, some of the information implied in options data of other types of moneyness may be overlooked. Ederington and Guan (1999) state that information implied in options prices with respect to moneyness differs and thus we assume that inclusion of all types of options with respect to moneyness in calculating implied forward prices may indeed be useful in obtaining all of the information in available options data. Among the several stochastic volatility options models, we select the model by Heston (1993) which assumes that volatility of an underlying asset is stochastic and carry out implied forward price calculation. Then, we compare the results with those of Black-Scholes model, the simple but delicate model. Additionally, we adopt recent studies which conduct cointegration test and use error correction model. Cointegration tests are carried out using Johansen's test and the method of error correction model (ECM) is employed when the lead-lag relation between the stock and the options market is investigated.

Throughout the paper, we show that the stock market returns lead the options market returns by 30 to 55 minutes. More specifically, in use of Heston model, stock returns lead call and put options returns by 50 minutes and 55 minutes, respectively. When Black-Scholes model is used for implied forward price calculation, the results show that the stock returns lead call and put options returns by 30 minutes and 30 minutes, respectively. Also, it is interesting to note that more unidirectional lead trend from stock market to options market is witnessed in use of Heston model.

Remainder of the paper is organized as the following. Next section explains the models such as Heston model and Error Correction model adopted in the paper in detail. Section III describes the data and empirical results. Finally, the last section concludes and summarizes the results.

II. Methodology

2.1. Heston Model

Heston (1993) has provided a closed-form solution for pricing a European style option when volatility follows a mean-reverting square-root process. Different from Eisenberg and Jarrow (1991) or Stein and Stein (1991) where they assume that volatility is uncorrelated with the spot asset and use Black-Scholes formula values, Heston adopts the stochastic volatility to capture the skewness effect arisen from the correlation between the underlying asset and volatility.

The actual diffusion processes for the underlying asset and its volatility are specified as the following:

$$\begin{aligned} dS &= \mu S dt + \sqrt{v_t} S dW_s \\ dv_t &= \kappa(\theta - v_t)dt + \sigma\sqrt{v_t} dW_v \end{aligned} \tag{1}$$

where dW_s and dW_v have an arbitrary correlation ρ, v_t is the instantaneous variance. κ is the speed of adjustment to the long-run mean θ, and σ is the variation coefficient of variance. From the equations above, Heston shows that risk neutral probabilities of a European call option with τ periods to maturity is given by

$$P_j = \frac{1}{2} + \frac{1}{\pi}\int_0^\infty \mathrm{Re}\left[\frac{e^{-i\phi \ln[K]} f_j(x, v_t, \tau; \phi)}{i\phi}\right] d\phi (j = 1,2) \tag{2}$$

where Re[.] denotes the real part of complex variables, i is the imaginary number $\sqrt{-1}$, $f_j(x, v_t, \tau; \phi) = \exp[C(\tau;\phi) + D(\tau;\phi)v_t + i\phi x]$ and $C(\tau;\phi)$ and $D(\tau;\phi)$ are functions of θ, κ,

ρ , σ and v_t .

Finally, Heston gives the solution of option value as the following:

$$C(S,v,t) = SP_1 - KP(t,T)P_2 \quad (3)$$

where the first term is the present value of the spot asset upon optimal exercise and the second term is the present value of the strike price.

To estimate the parameters of this model, we minimize the sum of squared percentage errors between the model and the market prices:

$$\min_{\phi_t} \sum_{i=0}^{N} \left[\frac{O_i^*(t,\tau;K) - O_i(t,\tau;K)}{O_i(t,\tau;K)} \right]^2 (t = 1,...,T) \quad (4)$$

Here, we estimate six parameters including the implied forward price and thus at least six data are needed for estimation for any particular time and strike price.

We follow similar process to calculate implied forward prices using Black-Scholes Model except that for BS model we estimate two parameters: implied forward price and volatility.

2.2. Cointegration and Error Correction Model

Individual economic series sometimes may be nonstationary but the linear combinations of the series are expected to have a relationship of equilibrium. For instance, the difference between the implied forward prices from options data and the stock prices may increase temporarily but in theory the difference should revert to long-run equilibrium. This long-run equilibrium is called a cointegration relationship in time series. A long-run relationship between the implied forward price and the stock price series are explained as the following equation:

$$P_{o,t} - \hat{\beta}_0 - \hat{\beta}_1 P_{s,t} = \hat{e}_{o,t} \quad (5)$$

where $P_{s,t}$ and $P_{o,t}$ are contemporaneous stock prices and implied forward prices from options data at time t, $\hat{\beta}_0$ and $\hat{\beta}_1$ are parameters, and $\hat{e}_{o,t}$ is the deviation from the parity. In the equation

(5), ordinary least squares (OLS) is not appropriate if $P_{s,t}$ and $P_{o,t}$ are nonstationary for standard errors are not consistent.

As explained by Engle and Granger (1987), if $P_{s,t}$ and $P_{o,t}$ are nonstationary but the deviations, e_t, are stationary, then the two series, $P_{s,t}$ and $P_{o,t}$, are said to be cointegrated and there exists an equilibrium relationship. In order for $P_{s,t}$ and $P_{o,t}$ to be cointegrated, they should be integrated of the same order and the order of integration may be determined by conducting unit root test. If each series is nonstationary but the first differences and the deviations are stationary, the prices are defined to be cointegrated of order (1, 1).

According to Granger and Newbold (1974), if the two series are covariance stationary without trends-in-mean and are cointegrated, then there exists an error correction representation for each series which is not subject to spurious regression problems.

In this paper, we follow the methodology by Wahab and Lashgari (1993) and Pizzi, Economopoulos and O'neill (1998) and use the returns of the series instead of the first order differences of the price series. There are four possible error correction model specifications as follows for the two series $P_{s,t}$ and $P_{o,t}$:

$$\begin{aligned}
r_{s,t} &= \alpha_1 + \alpha_s \hat{e}_{o,t-1} + \sum_{k=1}^{n} \alpha_{11}(k) r_{s,t-k} + \sum_{k=1}^{n'} \alpha_{12}(k) r_{o,t-k} + \varepsilon_{s,t} \\
r_{o,t} &= \alpha_2 + \alpha_o \hat{e}_{o,t-1} + \sum_{k=1}^{n} \alpha_{21}(k) r_{s,t-k} + \sum_{k=1}^{n'} \alpha_{22}(k) r_{o,t-k} + \varepsilon_{o,t} \\
P_{o,t} &- \hat{\beta}_0 - \hat{\beta}_1 P_{s,t} = \hat{e}_{o,t} \\
r_{s,t} &= \alpha_1' + \alpha_s' \hat{e}_{o,t-1} + \sum_{k=1}^{n} \alpha_{11}'(k) r_{s,t-k} + \sum_{k=1}^{n'} \alpha_{12}'(k) r_{o,t-k} + \varepsilon_{s,t}' \\
r_{o,t} &= \alpha_2' + \alpha_o' \hat{e}_{o,t-1} + \sum_{k=1}^{n} \alpha_{21}'(k) r_{s,t-k} + \sum_{k=1}^{n'} \alpha_{22}'(k) r_{o,t-k} + \varepsilon_{o,t}' \\
P_{s,t} &- \hat{\beta}_0 - \hat{\beta}_1 P_{o,t} = \hat{e}_{s,t}
\end{aligned} \tag{6}$$

where $r_{s,t}$ and $r_{o,t}$ are stock returns and implied forward returns of options at time t, respectively.

In order to factor out the effects of infrequent trading and bid-ask spread, both Wahab and Lashgari (1993), Pizzi, Economopoulos and O'neill (1998), Kang, Lee, and Lee (2004) use the standard errors after ARMA filtering. However, those studies do not take the fact that ARMA model itself is time-varying into consideration. Thus, we use the returns themselves in error correction model and focus more on the factual lead-lag relations of the returns of the stock and options data. According to Enders (1995), the results are equivalent whether the stock or futures data are used as dependent variables in obtaining the standard error terms. Finally, we apply the first three equations from the equations (6) in our analysis.

III. Empirical Tests

3.1. Data

KOSPI 200 options are based on the KOSPI 200 index, consisting 200 constituent blue-chip stocks by Korea Stock Exchange (KSE). Introduced in July 7th, 1997, KOSPI 200 options market started with an unprecedented enthusiasm. During the five-year duration from 1999 to 2003, in terms of trading volume, the KSE options market ranked as the most heavily traded options market in the world with its annual trading volume reaching almost 1,890 million contracts in year 2002. Obviously, the main explanation for such extraordinary growth of the KOSPI 200 options market would be the interest and enthusiasm of the investors in the market. In addition, the KSE's proactive responses to the changing environment of the world exchanges, including reforming of the regulations that made the system more user-friendly and solidifying the stability and reliability, have made significant contributions to the market growth.

The sample period includes data from June 2003 to May 2004. Minute-by-minute transaction prices for the KOSPI 200 options are obtained from Korea Stock Exchange (KSE). The 91-day certificate of deposit (CD) yields are used as risk-free interest rates and are obtained from Korea

Bond Pricing and Korea Rating Co. (KBP). In the following, a few criteria are explained to filter data used in the empirical tests.

1. To eliminate any liquidity-related biases, options with less than six days or more than sixty days to expirations are excluded.
2. Five-minute data are sorted out from minute-by-minute data of options prices.
3. The following condition of no arbitrage should be satisfied to be included in the test.

$$\begin{aligned} C_{t,\tau} &\geq S_t - KB_{t,\tau} \\ P_{t,\tau} &\geq KB_{t,\tau} - S_t \end{aligned} \tag{7}$$

4. where $B_{t,\tau}$ denotes a zero-coupon bond that pays 1 in τ periods from time t, and $r_{t,s}$ the risk-free interest rate with maturity s at time t.
5. Since there are simultaneous bids and offers starting from 2:50pm, transaction data only from 9:00am to 2:50pm are employed in the test.
6. Since we have to use actually traded option data only, we adopt those data only where actual transaction occurs and that option volume is not equal to the one five minutes ago.
7. To mitigate the impact of price discreteness in option valuation, prices lower than 0.2 are excluded in the sample.

3.2. Empirical Results

3.2.1. Statistics

In this section, we observe averages and standard deviations of the differences between the stock price and the implied forward price calculated using Heston and Black-Scholes models. We divide our sample period into 4 subperiods and report the results.

As shown in the table 1, the average differences between the real stock price and the implied forward price using Heston model is smaller than those using Black-Scholes model for both calls and puts. Also, the standard deviations of the differences using Heston model is smaller than those using Black-Scholes model. In other words, we observe that when Heston model is used to calculate the implied forward prices, more accurate forward prices are computed compared to Black-Scholes results.

In figure 1, we also present graphs of stock prices versus implied forward prices to see how much they are related to each other. For all 4 cases of calls and puts using Heston and Black-Scholes models, a similar pattern is realized between the stock price and the implied forward price series. As clearly shown in the figure 1, we know that the two price series are highly likely to be cointegrated and thus we conduct Johansen’s cointegration test in the following section.

3.2.2. Cointegration Test Results

We employ Johansen (1991, 1992)’s cointegration test in examining the relationship between the stock price and the implied forward price series. In doing so, we examine all four cases of computing implied forward prices using calls and puts with Heston and Black-Scholes models. We test if there is a long-run equilibrium relationship between the stock price and implied forward price series by conducting cointegration test. As in table 2, we notice the hypothesis that there is no cointegration between the two time series is strongly rejected with high LR statistics values. Thus, the price relationship between the stock and the options markets reverts to equilibrium level since these two series are closely related by the arbitrage opportunities. Therefore, we show that there exists cointegration relation ship and now are able to apply error correction model for the series.

3.2.3. Error Correction Model Results

We now examine the price discovery roles of the stock and the options market using error correction model derived from cointegration relationship. Table 3 and table 4 describe the results of lead-lag relations between the stock and the options markets when the implied forward prices are calculated using Heston model. When the implied forward returns are used as dependent variable, the return series, r_s', are significant at 1% level up to order 10, revealing that stock returns lead implied forward returns from call options by 50 minutes. Also, stock returns lead implied forward returns from put options by 55 minutes. On the other hand, options returns lead stock returns by 35 minutes and 10 minutes for calls and puts, respectively. Furthermore, in use of Heston model, the lead effect of options market on the stock market is stronger for the call options market compared to that for the put options market.

As seen in table 5 and table 6, we now use Black-Scholes model to calculate the implied forward prices from the options data. Then, we conduct the same methodology of error correcting regression and find the following results. In the use of Black-Scholes model, stock returns lead options returns by 30 minutes for both call and put options data. On the other hand, call and put options returns lead the stock returns by 20 minutes and 25 minutes, respectively. In addition, the lead relations are relatively bidirectional compared to those in the use of Heston model since the t-statistics values are of similar magnitude for rs's and rc's / rp's. This unidirectional lead relationship between the stock and the options markets in case of Heston model is compared to results in case of Black-Scholes model in the later section more thoroughly.

3.2.4. Comparison of the Heston and the Black-Scholes Results

We see from the t-statistics values for Heston and Black-Scholes results when Heston model is used to compute the implied forward returns, the stock returns tend to lead the options returns much stronger. In table 7, we show the F-statistics using Wald test.

In use of Heston model, the hypothesis that the stock returns do not lead implied forward returns are much strongly rejected with the F-statistic values of 124.95 and 75.57 for calls and puts, respectively. In comparison, hypotheses that one market leads the other are rejected with relatively similar magnitude of F-statistics values when Black-Scholes model is used.

This unidirectional relationship in the use of Heston model is more described with figure 2 and 3. Regardless of which model is used to compute the implied forward prices, we see that the stock returns tend to lead the options returns, with higher coefficients when the graph is drawn with dependent variable as implied forward returns. This case shows how much the stock market leads the options market and we observe this result by the significance of the lagged coefficients of the stock returns. As we see from the figures 2 and 3, the coefficients in use of Black-Scholes model are relatively similar in magnitude throughout the four cases. On the other hand, when the results are compared with the use of Heston model, we see that the stock market leads the options market more strongly. In other words, we observe unidirectional relation such that there is stronger lead effect of the stock returns on the options returns. This interesting result may be interpreted as the following. If Heston model which captures the stochastic volatility does explain the options market better as shown in Bakshi, Cao, and Chan (1997) and Kim and Kim (2004a,b), we may conclude that the stock returns do indeed lead the options returns and that these results are more precisely presented in the use of Heston model. In other words, Heston model is able to represent the true options market better.

3.2.5. Price Discovery under Good News and Bad News

Until now, we have shown that the stock market returns lead the options market returns and that Heston model does have a unidirectional lead effect of the stock returns on the options returns. However, if the stock market moves significantly up or down depending on the types of news, whether good or bad, then the role of the options market may change extensively by the speculative investors.

In this section, we test if the price discovery roles differ depending on the types of news, good or bad. Korean market is well known for retail investors' market that fair amount of trading volumes account for individual investors. Thus, a large number of transactions are executed based on speculation rather than hedge purpose. In this case, if the market is bullish, there will be more profits from call options and if the market is bearish, more profits from put options will be realized.

We now examine if the price discovery functions react differently under bullish and bearish markets compared to the whole market. Based on the assumptions below, we continue our empirical tests.

Hypothesis 1: In bullish markets by good news, there will be more price discoveries from the call options market to the stock market.

Hypothesis 2: In bearish markets by bad news, there will be more price discoveries from the put options market to the stock market.

We adopt the method by Chan (1992) and analyze if the results differ depending on the types of the news. We define the bullish and bearish markets as follows. The observations are sorted by the size of KOSPI 200 index returns in descending order. In doing so, the trading hours are partitioned into 1-hour intervals and the stock returns are calculated for each interval. The 1-hour intervals are stratified into five subsections and the top 20% and bottom 20% are called quintile 1 and quintile 5. Quintile 1 is the good news group which contains the highest returns and upward price movements, while quintile 5 is the bad news group which contains smallest returns and downward price movements. Now, we created two dummy variables for quintile 1 and 5 and include these dummy variables in the regressions. For instance, the first dummy variable is set to 1 if the data are in quintile 1 and 0 otherwise. This dummy variable is used for the error-corrected regression for testing the lead-lag relation between the stock returns and the implied forward returns obtained from the call options data. Likewise, another dummy variable is set to 1 if the data are in quintile 5 and 0 otherwise. This variable is included in the error-corrected regression for testing the lead-lag relation between the stock returns and the implied forward returns obtained from the put options data.

As shown in the table 8 through 11, all of the dummy slop coefficients which measure the differential impact on the lead-lag relationship under both good news and bad news turn out to be statistically insignificant. To summarize the results, the lead-lag relation between the stock and the options markets are not affected by the types of news whether it is good or bad.

IV. Conclusion

In this paper, we empirically test the intraday relations between the KOSPI 200 stock market and the options market during the sample period of June 2003 to May 2004. We use Heston model and Black-Scholes model to compute the implied forward prices from the options data and compare the results. In addition, we employ error correction model after conducting Johansen's cointegration test on the stock price and implied forward price series. We show that the stock market returns tend to have stronger lead impacts on the options market returns regardless of the model used to calculate the implied forward returns. However, in the use of Heston model, we recognize a more unidirectional lead relation of the stock returns for the options returns. If Heston model does indeed explain Korean financial markets better by capturing the stochastic volatility in option valuation, this result may be interpreted as such that the stock market does lead the options market strongly. On the other hand, in use of Black-Scholes model, we see more of a bidirectional lead-lag relation between the markets.

Different from the relation between the stock and the futures markets, we show that the stock market has more price discovery roles, revealing that the stock market is more information efficient. Due to lower transaction costs, higher financial leverages, and no restrictions on short-sellings, investors use the futures market for direction-based trading, hedge, or risk management purpose. However, the options market is more utilized for volatility-based trading rather than direction-based trading and thus no strong lead relation of the options market is recognized empirically. Rather, a stronger lead effect of the stock market is realized for the options market.

There are several drawbacks of this study. For such cases where the data is less than six for a particular time, we have to exclude those data from the sample since we need at least six data to estimate six parameters for Heston model. In other words, the sample data is not complete in the sense that some of the relatively important data may have been eliminated without proper justification. In addition, we have only tested recent one-year period in our paper. For further studies, more sample periods may be tested to see further trends and market maturation effect. Also, bid-ask spread effects and infrequent trading effects may be taken into account and comparisons may improve the paper.

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<Table 1> Differences in Stock Prices and Implied Forward Prices

This table reports the Differences in Stock Prices and Implied Forward Prices using Heston (1993) model and Black and Scholes (1983) model.

Panel A: Heston Model

Subperiods	Calls		Puts	
(Unit: %)	Average	St. Dev.	Average	St. Dev.
06/2003 - 08/2003	0.1341474	0.1252751	0.2281055	0.2116047
09/2003 - 11/2003	0.1773141	0.1746086	0.1977089	0.1798236
12/2003 - 02/2004	0.1724301	0.1557118	0.2687331	0.2523574
03/2004 - 05/2004	0.1984748	0.2022403	0.2213671	0.2086102

Panel B: BS Model

Subperiods	Calls		Puts	
(Unit: %)	Average	St. Dev.	Average	St. Dev.
06/2003 - 08/2003	0.3097682	0.1678396	0.6142167	0.3019218
09/2003 - 11/2003	0.1952655	0.2026947	0.6472090	0.2504913
12/2003 - 02/2004	0.4476831	0.2661648	0.5155326	0.2166747
03/2004 - 05/2004	0.4295568	0.2510050	0.4525409	0.2483516

* Differences = (Implied Forward Price / Stock Price – 1) * 100

<Table 2> Johansen's Cointegration Test Results

This table reports the Johansen's cointegration test results between index price and implied forward price estimated from option prices. Implied forward prices are calculated from call options data using Heston (1993) and Black-Sholes model. Panel A describes the Johansen's cointegration test results between real index price and implied forward price estimated from calls using the Heston (1993)'s model. Panel B describes the Johansen's cointegration test results between real index price and implied forward price estimated from puts using the Heston (1993)'s model. Panel C describes the Johansen's cointegration test results between real index price and implied forward price estimated from calls using the Black and Scholes (1973) model. Panel D describes the Johansen's cointegration test results between real index price and implied forward price estimated from puts using the Black and Scholes (1973) model. H0 is the hypothesis that there are no cointegration vectors between the series

Panel A: Calls from Heston Model

Period: June 2003 - May 2004				
	Eigenvalue	Likelihood Ratio	5 % Critical Value	1% Critical Value
H0	0.3427	6290.1770	12.53	16.31
Unnormalized Cointegrating Coefficients				
P_s	P_c			
0.0085	-0.0094			
0.0055	-0.0047			
Normalized Cointegratin Coefficients				
P_s	P_c			
1.0000	-1.0002	Log likelihood	8999.6050	
	0.0000			

Panel B: Puts from Heston Model

Period: June 2003 - May 2004				
	Eigenvalue	Likelihood Ratio	5 % Critical Value	1% Critical Value
H0	0.9935	73097.2560	12.53	16.31
Unnormalized Cointegrating Coefficients				
P_s	P_p			
-0.0022	0.0022			
0.0002	-0.0001			
Normalized Cointegratin Coefficients				
P_s	P_p			
1.0000	-0.9990	Log likelihood	1578.2369	
	0.0000			

Panel C: Calls from Black and Scholes Model

Period: June 2003 - May 2004				
	Eigenvalue	Likelihood Ratio	5 % Critical Value	1% Critical Value
H0	0.9974	68080.7109	12.53	16.31
Unnormalized Cointegrating Coefficients				
P_s	P_c			
-0.0014	0.0014			
-0.0003	0.0004			
Normalized Cointegratin Coefficients				
P_s	P_p			
1.0000	-0.9976	Log likelihood	209.1173	
	0.0000			

Panel D: Puts from Black and Scholes Model

Period: June 2003 - May 2004				
	Eigenvalue	Likelihood Ratio	5 % Critical Value	1% Critical Value
H0	0.1933	1783.6848	12.53	16.31
Unnormalized Cointegrating Coefficients				
P_s	P_p			
-0.0215	0.0215			
0.0112	-0.0111			
Normalized Cointegratin Coefficients				
P_s	P_p			
1.0000	-0.9974	Log likelihood	5231.1068	
	0.0000			

<Table 3> Error Correction Model Results for Call Options in Use of Heston Model

This table reports the error correction model results between real index price and implied forward price from call options using the Heston (1993) model. The error correction model is as below.

$$r_{s,t} = \alpha_1 + \alpha_c \hat{e}_{c,t-1} + \sum_{k=1}^{n} \alpha_{11}(k) r_{s,t-k} + \sum_{k=1}^{n'} \alpha_{12}(k) r_{c,t-k} + \varepsilon_{s,t}$$

$$r_{c,t} = \alpha_2 + \alpha_c \hat{e}_{c,t-1} + \sum_{k=1}^{n} \alpha_{21}(k) r_{s,t-k} + \sum_{k=1}^{n'} \alpha_{22}(k) r_{c,t-k} + \varepsilon_{c,t}$$

$$P_{c,t} - \hat{\beta}_0 - \hat{\beta}_1 P_{s,t} = \hat{e}_{c,t}$$

r_s and r_c are log returns of stock price and implied forward price, respectively.
**, *: statistically significant at 1% and 5% levels

	r_s	t-stat	r_c	t-stat
c	0.0000	0.9564	0.0000	1.3028
$\hat{e}_c$ (-1)	0.0000	0.1448	0.0007**	6.8534
r_c (-1)	0.0638**	4.9729	-0.6603	-43.4418
r_c (-2)	0.0762**	5.1866	-0.5304	-30.4592
r_c (-3)	0.0758**	4.7942	-0.4290	-22.9065
r_c (-4)	0.0685**	4.1683	-0.3573	-18.3630
r_c (-5)	0.0610**	3.6546	-0.3009	-15.2097
r_c (-6)	0.0573**	3.4292	-0.2371	-11.9843
r_c (-7)	0.0445**	2.7024	-0.1894	-9.7110
r_c (-8)	0.0399*	2.5055	-0.1448	-7.6709
r_c (-9)	0.0356*	2.3623	-0.0914	-5.1205
r_c (-10)	0.0154	1.1208	-0.0719	-4.4250
r_c (-11)	0.0267	2.3131	-0.0285	-2.0895
r_c (-12)	0.0087	1.2044	-0.0094	-1.0994
r_s (-1)	-0.0901	-6.2329	0.6440**	37.6070
r_s (-2)	-0.0899	-5.5561	0.5419**	28.2860
r_s (-3)	-0.0917	-5.3090	0.4441**	21.7082
r_s (-4)	-0.0763	-4.2574	0.3694**	17.3934
r_s (-5)	-0.0747	-4.0930	0.3016**	13.9606
r_s (-6)	-0.0505	-2.7631	0.2604**	12.0210
r_s (-7)	-0.0475	-2.6218	0.2107**	9.8250
r_s (-8)	-0.0362	-2.0479	0.1589**	7.5955
r_s (-9)	-0.0378	-2.2433	0.1033**	5.1716
r_s (-10)	-0.0254	-1.6194	0.0814**	4.3812
r_s (-11)	-0.0200	-1.4398	0.0338*	2.0506
r_s (-12)	-0.0060	-0.5449	0.0224	1.7229

<Table 4> Error Correction Model Results for Put Options in Use of Heston Model

This table reports the error correction model results between real index price and implied forward price from put options using the Heston (1993) model. The error correction model is as below.

$$r_{s,t} = \alpha_1 + \alpha_p \hat{e}_{p,t-1} + \sum_{k=1}^{n} \alpha_{11}(k) r_{s,t-k} + \sum_{k=1}^{n'} \alpha_{12}(k) r_{p,t-k} + \varepsilon_{s,t}$$

$$r_{p,t} = \alpha_2 + \alpha_p \hat{e}_{p,t-1} + \sum_{k=1}^{n} \alpha_{21}(k) r_{s,t-k} + \sum_{k=1}^{n'} \alpha_{22}(k) r_{p,t-k} + \varepsilon_{p,t}$$

$$P_{p,t} - \hat{\beta}_0 - \hat{\beta}_1 P_{s,t} = \hat{e}_{p,t}$$

r_s and r_p are log returns of stock price and implied forward price, respectively.

**, *: statistically significant at 1% and 5% levels

	r_s	t-stat	r_c	t-stat
c	0.0000	0.7165	0.0000	-1.0941
$\hat{e}_p$ (-1)	0.0000	0.0684	0.0012**	8.7232
r_p (-1)	0.0453**	3.7395	-0.6275	-36.4182
r_p (-2)	0.0582**	4.3564	-0.5041	-26.5277
r_p (-3)	0.0333*	2.3604	-0.4456	-22.2473
r_p (-4)	0.0389*	2.6804	-0.3723	-18.0623
r_p (-5)	0.0047	0.3227	-0.3336	-16.0274
r_p (-6)	0.0069	0.4743	-0.2821	-13.6465
r_p (-7)	-0.0012	-0.0840	-0.2482	-12.2480
r_p (-8)	-0.0078	-0.5703	-0.1853	-9.5305
r_p (-9)	-0.0037	-0.2921	-0.1410	-7.8186
r_p (-10)	0.0013	0.1166	-0.0901	-5.6301
r_p (-11)	0.0032	0.3638	-0.0578	-4.5912
r_p (-12)	0.0008	0.6507	-0.0012	-0.6716
r_s (-1)	-0.0745	-4.9465	0.6127**	28.6218
r_s (-2)	-0.0663	-4.1109	0.4952**	21.5922
r_s (-3)	-0.0480	-2.8673	0.4399**	18.4880
r_s (-4)	-0.0437	-2.5505	0.3865**	15.8700
r_s (-5)	-0.0256	-1.4784	0.3410**	13.8592
r_s (-6)	-0.0101	-0.5836	0.2996**	12.2193
r_s (-7)	0.0051	0.2971	0.2586**	10.6714
r_s (-8)	0.0063	0.3811	0.2030**	8.6335
r_s (-9)	0.0074	0.4730	0.1479**	6.6262
r_s (-10)	-0.0067	-0.4630	0.0896**	4.3562
r_s (-11)	0.0032	0.2506	0.0853**	4.7230
r_s (-12)	0.0097	1.0148	0.0170	1.2472

<Table 5> Error Correction Model Results for Call Options in Use of Black-Scholes Model

This table reports the error correction model results between real index price and implied forward price from call options using the Black and Scholes (1973) model. The error correction model is as below.

$$r_{s,t} = \alpha_1 + \alpha_c \hat{e}_{c,t-1} + \sum_{k=1}^{n} \alpha_{11}(k) r_{s,t-k} + \sum_{k=1}^{n'} \alpha_{12}(k) r_{c,t-k} + \varepsilon_{s,t}$$

$$r_{c,t} = \alpha_2 + \alpha_c \hat{e}_{c,t-1} + \sum_{k=1}^{n} \alpha_{21}(k) r_{s,t-k} + \sum_{k=1}^{n'} \alpha_{22}(k) r_{c,t-k} + \varepsilon_{c,t}$$

$$P_{c,t} - \hat{\beta}_0 - \hat{\beta}_1 P_{s,t} = \hat{e}_{c,t}$$

r_s and r_c are log returns of stock price and implied forward price, respectively.
**, *: statistically significant at 1% and 5% levels

	r_s	t-stat	r_c	t-stat
c	0.0000	2.5290	0.0000	1.7311
$\hat{e}_c$ (-1)	-0.0001*	-2.0489	0.0000	0.1574
r_c (-1)	0.2505**	12.1750	-0.3304	-16.1115
r_c (-2)	0.1340**	5.7601	-0.2440	-10.5196
r_c (-3)	0.1141**	4.6896	-0.1309	-5.3997
r_c (-4)	0.0872**	3.5277	-0.1125	-4.5672
r_c (-5)	0.0313	1.2561	-0.1019	-4.0978
r_c (-6)	0.0568	2.2876	-0.0761	-3.0779
r_c (-7)	0.0507	2.0532	-0.0173	-0.7029
r_c (-8)	0.0590	2.4141	-0.0292	-1.1970
r_c (-9)	0.0406	1.6883	-0.0195	-0.8125
r_c (-10)	0.0217	0.9461	-0.0439	-1.9232
r_c (-11)	-0.0173	-0.8664	-0.0666	-3.3401
r_c (-12)	0.0017	0.9985	0.0002	0.1173
r_s (-1)	-0.2463	-12.0196	0.3005**	14.7156
r_s (-2)	-0.1368	-5.9704	0.2318**	10.1471
r_s (-3)	-0.1304	-5.4497	0.1299**	5.4471
r_s (-4)	-0.0991	-4.0655	0.1096**	4.5122
r_s (-5)	-0.0621	-2.5247	0.0853**	3.4817
r_s (-6)	-0.0474	-1.9325	0.0846**	3.4616
r_s (-7)	-0.0441	-1.8065	0.0500*	2.0514
r_s (-8)	-0.0627	-2.5874	0.0205	0.8479
r_s (-9)	-0.0398	-1.6698	0.0233	0.9835
r_s (-10)	-0.0275	-1.2101	0.0362	1.5964
r_s (-11)	0.0220	1.1036	0.0710	3.5784
r_s (-12)	0.0037	0.3614	0.0099	0.9622

<Table 6> Error Correction Model Results for Put Options in Use of Black-Scholes Model

This table reports the error correction model results between real index price and implied forward price from put options using the Black and Scholes (1973) model. The error correction model is as below.

$$r_{s,t} = \alpha_1 + \alpha_p \hat{e}_{p,t-1} + \sum_{k=1}^{n} \alpha_{11}(k) r_{s,t-k} + \sum_{k=1}^{n'} \alpha_{12}(k) r_{p,t-k} + \varepsilon_{s,t}$$

$$r_{p,t} = \alpha_2 + \alpha_p \hat{e}_{p,t-1} + \sum_{k=1}^{n} \alpha_{21}(k) r_{s,t-k} + \sum_{k=1}^{n'} \alpha_{22}(k) r_{p,t-k} + \varepsilon_{p,t}$$

$$P_{p,t} - \hat{\beta}_0 - \hat{\beta}_1 P_{s,t} = \hat{e}_{p,t}$$

r_s and r_p are log returns of stock price and implied forward price, respectively.

**, *: statistically significant at 1% and 5% levels

	r_s	t-stat	r_c	t-stat
c	0.0000	0.4831	0.0000	-0.0424
$\hat{e}_p$ (-1)	0.0000	0.3048	0.0002**	2.5813
r_p (-1)	0.1602**	9.1960	-0.4006	-17.6090
r_p (-2)	0.1188**	5.9997	-0.2836	-10.9703
r_p (-3)	0.0980**	4.6806	-0.1434	-5.2451
r_p (-4)	0.0732**	3.4194	-0.1334	-4.7748
r_p (-5)	0.0566**	2.6364	-0.1151	-4.1037
r_p (-6)	0.0275	1.2822	-0.0774	-2.7605
r_p (-7)	0.0469	2.1972	-0.0487	-1.7464
r_p (-8)	0.0596	2.8386	-0.0344	-1.2547
r_p (-9)	0.0299	1.4499	-0.0182	-0.6758
r_p (-10)	0.0148	0.7473	-0.0327	-1.2624
r_p (-11)	-0.0047	-0.2537	-0.0506	-2.1040
r_p (-12)	-0.0385	-2.4990	-0.0619	-3.0748
r_s (-1)	-0.2007	-9.0078	0.4151**	14.2661
r_s (-2)	-0.1471	-5.9709	0.2974**	9.2437
r_s (-3)	-0.1239	-4.8067	0.1799**	5.3465
r_s (-4)	-0.0756	-2.8799	0.1754**	5.1145
r_s (-5)	-0.0664	-2.5218	0.1041**	3.0247
r_s (-6)	-0.0286	-1.0898	0.1068**	3.1196
r_s (-7)	-0.0572	-2.1928	0.0517	1.5177
r_s (-8)	-0.0579	-2.2537	0.0425	1.2661
r_s (-9)	-0.0168	-0.6652	0.0564	1.7080
r_s (-10)	-0.0412	-1.7004	-0.0058	-0.1838
r_s (-11)	0.0062	0.2698	0.0593	1.9823
r_s (-12)	0.0449	2.2953	0.0909	3.5561

<Table 7> F-statistics Results for Heston and Black-Scholes Models

This table reports the Wald test results for the error correction model between real index price and implied forward price from option prices using Heston (1993) and Black and Scholes Models. The error correction model is as below.

$$r_{s,t} = \alpha_1 + \alpha_s \hat{e}_{o,t-1} + \sum_{k=1}^{n} \alpha_{11}(k) r_{s,t-k} + \sum_{k=1}^{n'} \alpha_{12}(k) r_{o,t-k} + \varepsilon_{s,t}$$

$$r_{o,t} = \alpha_2 + \alpha_o \hat{e}_{o,t-1} + \sum_{k=1}^{n} \alpha_{21}(k) r_{s,t-k} + \sum_{k=1}^{n'} \alpha_{22}(k) r_{o,t-k} + \varepsilon_{o,t}$$

$$P_{o,t} - \hat{\beta}_0 - \hat{\beta}_1 P_{s,t} = \hat{e}_{o,t}$$

r_s and r_f are log returns of stock price and implied forward price, respectively.

(i) Dependent Variable: r_s

F-statistic value for $H_o : \forall a_{12}(-k) = 0$ (Implied forward returns do not lead stock returns.)

(ii) Dependent Variable: r_o

F-statistic value for $H_s : \forall a_{21}(-k) = 0$ (Stock returns do not lead implied forward returns.)

	Heston		Black-Scholes	
	Calls	Puts	Calls	Puts
H_o	3.3762	3.0435	13.5280	27.9059
H_s	124.9474	75.5664	20.2864	8.5072

<Table 8> Error Correction Model Results for Call Options in Use of Heston Model with Dummy Variables

This table reports the error correction model results between real index price and implied forward price from call options using the Heston (1993)'s model with dummy variables which is determined according to the type of news. The error correction model with dummy variables is as below.

$$r_{s,t} = \alpha_1 + \alpha_c \hat{e}_{c,t-1} + \alpha_d D_c + \sum_{k=1}^{n} \alpha_{11}(k) r_{s,t-k} + \sum_{k=1}^{n'} \alpha_{12}(k) r_{c,t-k} + \sum_{k=1}^{n} \alpha_{13}(k) r_{s,t-k} \cdot D_c + \sum_{k=1}^{n'} \alpha_{14}(k) r_{c,t-k} \cdot D_c + \varepsilon_{s,t}$$

$$r_{c,t} = \alpha_2 + \alpha_c \hat{e}_{c,t-1} + \alpha_d D_c + \sum_{k=1}^{n} \alpha_{21}(k) r_{s,t-k} + \sum_{k=1}^{n'} \alpha_{22}(k) r_{c,t-k} + \sum_{k=1}^{n} \alpha_{23}(k) r_{s,t-k} \cdot D_c + \sum_{k=1}^{n'} \alpha_{24}(k) r_{c,t-k} \cdot D_c + \varepsilon_{c,t}$$

$$P_{c,t} - \hat{\beta}_0 - \hat{\beta}_1 P_{s,t} = \hat{e}_{c,t}$$

r_s and r_c are log returns of stock price and implied forward price, respectively.

D_c is set to 1 for Quintile 1, consisting of the top 20% returns.

	r_s	t-stat	r_c	t-stat
c	-0.0001**	-8.4860	-0.0001**	-6.0855
$\hat{e}_c$ (-1)	0.0000	-0.5351	0.0006**	6.3765
D_c	0.0009**	22.6899	0.0008**	16.6159
r_c (-1)	0.0652**	4.8054	-0.6646	-40.9697
r_c (-2)	0.0750**	4.8081	-0.5371	-28.7988
r_c (-3)	0.0770**	4.5970	-0.4297	-21.4638
r_c (-4)	0.0694**	3.9912	-0.3532	-16.9997
r_c (-5)	0.0566**	3.2069	-0.2976	-14.1056
r_c (-6)	0.0601**	3.4076	-0.2343	-11.1151
r_c (-7)	0.0422*	2.4211	-0.1955	-9.3884
r_c (-8)	0.0373*	2.2004	-0.1542	-7.6049
r_c (-9)	0.0303	1.8748	-0.0936	-4.8422
r_c (-10)	0.0091	0.6139	-0.0720	-4.0525
r_c (-11)	0.0233	1.8387	-0.0293	-1.9289
r_c (-12)	0.0075	0.9208	-0.0096	-0.9833
r_s (-1)	-0.1097	-6.8914	0.6126**	32.2091
r_s (-2)	-0.1217	-6.8974	0.5224**	24.7794
r_s (-3)	-0.1045	-5.5657	0.4329**	19.2855
r_s (-4)	-0.0870	-4.4771	0.3544**	15.2565
r_s (-5)	-0.0864	-4.3750	0.2835**	12.0142
r_s (-6)	-0.0803	-4.0662	0.2374**	10.0543
r_s (-7)	-0.0503	-2.5700	0.2103**	8.9849
r_s (-8)	-0.0537	-2.7942	0.1481**	6.4506
r_s (-9)	-0.0374	-2.0227	0.0974**	4.4008
r_s (-10)	-0.0357	-2.0458	0.0768**	3.6809
r_s (-11)	-0.0169	-1.0685	0.0315	1.6709
r_s (-12)	-0.0058	-0.4421	0.0140	0.9028

	r_s	t-stat	r_c	t-stat
$D_c r_c$ (-1)	-0.0459*	-2.0340	-0.0176	-0.6504
$D_c r_c$ (-2)	-0.0367	-1.4034	-0.0026	-0.0839
$D_c r_c$ (-3)	-0.0401	-1.4580	-0.0225	-0.6843
$D_c r_c$ (-4)	-0.0382	-1.3662	-0.0450	-1.3470
$D_c r_c$ (-5)	-0.0109	-0.3903	-0.0383	-1.1448
$D_c r_c$ (-6)	-0.0386	-1.3805	-0.0317	-0.9477
$D_c r_c$ (-7)	-0.0125	-0.4502	0.0114	0.3439
$D_c r_c$ (-8)	-0.0119	-0.4304	0.0217	0.6574
$D_c r_c$ (-9)	0.0069	0.2550	-0.0030	-0.0913
$D_c r_c$ (-10)	0.0178	0.6872	-0.0007	-0.0241
$D_c r_c$ (-11)	0.0085	0.3613	0.0034	0.1199
$D_c r_c$ (-12)	0.0065	0.4199	0.0036	0.1965
$D_c r_s$ (-1)	-0.0027	-0.1011	0.0335	1.0709
$D_c r_s$ (-2)	0.0380	1.2783	-0.0050	-0.1396
$D_c r_s$ (-3)	-0.0107	-0.3460	-0.0209	-0.5643
$D_c r_s$ (-4)	-0.0157	-0.4988	0.0047	0.1244
$D_c r_s$ (-5)	-0.0091	-0.2869	0.0223	0.5892
$D_c r_s$ (-6)	0.0546	1.7286	0.0343	0.9073
$D_c r_s$ (-7)	-0.0225	-0.7142	-0.0389	-1.0320
$D_c r_s$ (-8)	0.0225	0.7188	-0.0041	-0.1101
$D_c r_s$ (-9)	-0.0196	-0.6363	-0.0005	-0.0124
$D_c r_s$ (-10)	0.0133	0.4413	-0.0009	-0.0259
$D_c r_s$ (-11)	-0.0104	-0.3692	0.0024	0.0718
$D_c r_s$ (-12)	-0.0065	-0.2820	0.0190	0.6939

<Table 9> Error Correction Model Results for Put Options in Use of Heston Model with Dummy Variables

This table reports the error correction model results between real index price and implied forward price from put options using the Heston (1993)'s model with dummy variables which is determined according to the type of news. The error correction model with dummy variables is as below.

$$r_{s,t} = \alpha_1 + \alpha_p \hat{e}_{p,t-1} + \alpha_d D_p + \sum_{k=1}^{n} \alpha_{11}(k) r_{s,t-k} + \sum_{k=1}^{n'} \alpha_{12}(k) r_{p,t-k} + \sum_{k=1}^{n} \alpha_{13}(k) r_{s,t-k} \cdot D_p + \sum_{k=1}^{n'} \alpha_{14}(k) r_{p,t-k} \cdot D_p + \varepsilon_{s,t}$$

$$r_{p,t} = \alpha_2 + \alpha_p \hat{e}_{p,t-1} + \alpha_d D_p + \sum_{k=1}^{n} \alpha_{21}(k) r_{s,t-k} + \sum_{k=1}^{n'} \alpha_{22}(k) r_{p,t-k} + \sum_{k=1}^{n} \alpha_{23}(k) r_{s,t-k} \cdot D_c + \sum_{k=1}^{n'} \alpha_{24}(k) r_{p,t-k} \cdot D_p + \varepsilon_{p,t}$$

$$P_{p,t} - \hat{\beta}_0 - \hat{\beta}_1 P_{s,t} = \hat{e}_{c,t}$$

r_s and r_p are log returns of stock price and implied forward price, respectively.

D_p is set to 1 for Quintile 5, consisting of the bottom 20% returns.

	r_s	t-stat	r_p	t-stat
c	0.0002**	9.2708	0.0002**	5.6986
$\hat{e}_c$ (-1)	0.0001	0.6287	0.0012**	9.2502
D_p	-0.0010**	-21.8760	-0.0010**	-15.1241
r_p (-1)	0.0406**	3.2208	-0.6275	-34.6487
r_p (-2)	0.0415**	2.9749	-0.5094	-25.3942
r_p (-3)	0.0203	1.3848	-0.4550	-21.5559
r_p (-4)	0.0275*	1.8218	-0.3848	-17.6961
r_p (-5)	0.0030	0.1976	-0.3418	-15.5282
r_p (-6)	-0.0002	-0.0110	-0.3015	-13.7583
r_p (-7)	-0.0054	-0.3570	-0.2630	-12.1974
r_p (-8)	-0.0089	-0.6114	-0.1926	-9.2475
r_p (-9)	-0.0008	-0.0627	-0.1482	-7.6134
r_p (-10)	0.0019	0.1530	-0.1026	-5.8347
r_p (-11)	-0.0020	-0.2014	-0.0649	-4.5082
r_p (-12)	0.0046	1.0971	-0.0157	-2.6049
r_s (-1)	-0.1072	-6.2723	0.5640**	22.9513
r_s (-2)	-0.0561	-3.0915	0.4779**	18.3152
r_s (-3)	-0.0735	-3.9447	0.3979**	14.8410
r_s (-4)	-0.0603	-3.1643	0.3712**	13.5361
r_s (-5)	-0.0200	-1.0378	0.3371**	12.1794
r_s (-6)	-0.0129	-0.6739	0.3177**	11.5183
r_s (-7)	-0.0157	-0.8257	0.2467**	9.0151
r_s (-8)	0.0069	0.3738	0.2031**	7.6187
r_s (-9)	0.0033	0.1864	0.1456**	5.6999
r_s (-10)	-0.0201	-1.2063	0.0734**	3.0700
r_s (-11)	0.0175	1.1669	0.1032**	4.7700
r_s (-12)	0.0077	0.6260	0.0357*	2.0243

	r_s	t-stat	r_p	t-stat
D_pr_p (-1)	0.0268	1.4152	0.0078	0.2850
D_pr_p (-2)	0.0712**	3.1639	0.0188	0.5811
D_pr_p (-3)	0.0574*	2.3791	0.0394	1.1339
D_pr_p (-4)	0.0505*	2.0235	0.0501	1.3953
D_pr_p (-5)	0.0084	0.3287	0.0278	0.7622
D_pr_p (-6)	0.0317	1.2379	0.0670	1.8200
D_pr_p (-7)	0.0160	0.6227	0.0425	1.1535
D_pr_p (-8)	0.0032	0.1256	0.0034	0.0921
D_pr_p (-9)	-0.0132	-0.5350	0.0005	0.0154
D_pr_p (-10)	-0.0040	-0.1715	0.0153	0.4600
D_pr_p (-11)	0.0320	1.6095	-0.0151	-0.5285
D_pr_p (-12)	-0.0043	-0.9781	0.0158	2.5173
D_pr_s (-1)	-0.0303	-1.1695	0.0132	0.3541
D_pr_s (-2)	-0.1496	-5.2266	-0.0603	-1.4657
D_pr_s (-3)	-0.0481	-1.6095	0.0062	0.1446
D_pr_s (-4)	-0.0587	-1.9157	-0.0629	-1.4275
D_pr_s (-5)	-0.0870	-2.8048	-0.0609	-1.3656
D_pr_s (-6)	-0.0619	-1.9893	-0.1260	-2.8136
D_pr_s (-7)	-0.0011	-0.0367	-0.0238	-0.5317
D_pr_s (-8)	-0.0426	-1.3622	-0.0257	-0.5702
D_pr_s (-9)	-0.0096	-0.3119	-0.0053	-0.1205
D_pr_s (-10)	0.0249	0.8472	0.0485	1.1476
D_pr_s (-11)	-0.0652	-2.4049	-0.0303	-0.7782
D_pr_s (-12)	0.0021	0.1037	-0.0262	-0.8984

<Table 10> Error Correction Model Results for Call Options in Use of Black-Scholes Model with Dummy Variables

This table reports the error correction model results between real index price and implied forward price from call options using the Black and Scholes model with dummy variables which is determined according to the type of news. The error correction model with dummy variables is as below.

$$r_{s,t} = \alpha_1 + \alpha_c \hat{e}_{c,t-1} + \alpha_d D_c + \sum_{k=1}^{n} \alpha_{11}(k) r_{s,t-k} + \sum_{k=1}^{n'} \alpha_{12}(k) r_{c,t-k} + \sum_{k=1}^{n} \alpha_{13}(k) r_{s,t-k} \cdot D_c + \sum_{k=1}^{n'} \alpha_{14}(k) r_{c,t-k} \cdot D_c + \varepsilon_{s,t}$$

$$r_{c,t} = \alpha_2 + \alpha_c \hat{e}_{c,t-1} + \alpha_d D_c + \sum_{k=1}^{n} \alpha_{21}(k) r_{s,t-k} + \sum_{k=1}^{n'} \alpha_{22}(k) r_{c,t-k} + \sum_{k=1}^{n} \alpha_{23}(k) r_{s,t-k} \cdot D_c + \sum_{k=1}^{n'} \alpha_{24}(k) r_{c,t-k} \cdot D_c + \varepsilon_{c,t}$$

$$P_{c,t} - \hat{\beta}_0 - \hat{\beta}_1 P_{s,t} = \hat{e}_{c,t}$$

r_s and r_c are log returns of stock price and implied forward price, respectively.

D_c is set to 1 for Quintile 1, consisting of the top 20% returns.

	r_s	t-stat	r_c	t-stat
c	-0.0001**	-4.9696	-0.0001**	-6.1517
$\hat{e}_c$ (-1)	-0.0001**	-1.0838	0.0001	1.1923
D_c	0.0009**	19.2459	0.0008**	18.5770
r_c (-1)	0.2679**	11.4326	-0.3359	-14.3702
r_c (-2)	0.1602**	6.0364	-0.2435	-9.1971
r_c (-3)	0.1136**	4.0922	-0.1511	-5.4568
r_c (-4)	0.0868**	3.0825	-0.1310	-4.6611
r_c (-5)	0.0312	1.1000	-0.1132	-3.9977
r_c (-6)	0.0440	1.5524	-0.1007	-3.5606
r_c (-7)	0.0383	1.3543	-0.0256	-0.9078
r_c (-8)	0.0421	1.5015	-0.0442	-1.5804
r_c (-9)	0.0225	0.8148	-0.0370	-1.3446
r_c (-10)	0.0152	0.5791	-0.0464	-1.7690
r_c (-11)	-0.0261	-1.1391	-0.0787	-3.4398
r_c (-12)	0.0020	1.1586	0.0005	0.2979
r_s (-1)	-0.2703	-11.4353	0.2832**	12.0128
r_s (-2)	-0.1847	-7.0274	0.1900**	7.2487
r_s (-3)	-0.1329	-4.8672	0.1330**	4.8835
r_s (-4)	-0.0989	-3.5678	0.1200**	4.3408
r_s (-5)	-0.0663	-2.3701	0.0882**	3.1630
r_s (-6)	-0.0519	-1.8561	0.0863**	3.0935
r_s (-7)	-0.0348	-1.2479	0.0547*	1.9670
r_s (-8)	-0.0471	-1.7011	0.0321	1.1646
r_s (-9)	-0.0305	-1.1212	0.0369	1.3592
r_s (-10)	-0.0258	-0.9903	0.0411	1.5834
r_s (-11)	0.0401	1.7582	0.0845	3.7184
r_s (-12)	0.0113	0.8688	0.0185	1.4305

	r_s	t-stat	r_c	t-stat
$D_c r_c$ (-1)	-0.0895*	-2.1074	-0.0229	-0.5406
$D_c r_c$ (-2)	-0.1268**	-2.7146	-0.0531	-1.1408
$D_c r_c$ (-3)	-0.0050	-0.1049	0.0487	1.0232
$D_c r_c$ (-4)	0.0002	0.0037	0.0534	1.1102
$D_c r_c$ (-5)	-0.0210	-0.4325	0.0085	0.1755
$D_c r_c$ (-6)	0.0196	0.4059	0.0539	1.1216
$D_c r_c$ (-7)	0.0279	0.5777	0.0043	0.0887
$D_c r_c$ (-8)	0.0594	1.2315	0.0439	0.9125
$D_c r_c$ (-9)	0.0944	1.9648	0.0884	1.8445
$D_c r_c$ (-10)	0.0551	1.1610	0.0325	0.6879
$D_c r_c$ (-11)	0.0785	1.7294	0.0727	1.6054
$D_c r_c$ (-12)	0.0565	1.5630	0.0243	0.6728
$D_c r_s$ (-1)	0.0076	0.1820	-0.0159	-0.3805
$D_c r_s$ (-2)	0.0899	1.9576	0.0665	1.4530
$D_c r_s$ (-3)	-0.0613	-1.3043	-0.0802	-1.7110
$D_c r_s$ (-4)	-0.0603	-1.2682	-0.0933	-1.9663
$D_c r_s$ (-5)	-0.0237	-0.4936	-0.0435	-0.9098
$D_c r_s$ (-6)	-0.0246	-0.5183	-0.0456	-0.9606
$D_c r_s$ (-7)	-0.0524	-1.1028	-0.0303	-0.6393
$D_c r_s$ (-8)	-0.0848	-1.7828	-0.0655	-1.3798
$D_c r_s$ (-9)	-0.0851	-1.8006	-0.0918	-1.9476
$D_c r_s$ (-10)	-0.0487	-1.0435	-0.0457	-0.9809
$D_c r_s$ (-11)	-0.0964	-2.1500	-0.0720	-1.6115
$D_c r_s$ (-12)	-0.0639	-1.6898	-0.0385	-1.0209

<Table 11> Error Correction Model Results for Put Options in Use of Black-Scholes Model with Dummy Variables

This table reports the error correction model results between real index price and implied forward price from put options using the Black and Scholes model with dummy variables which is determined according to the type of news. The error correction model with dummy variables is as below.

$$r_{s,t} = \alpha_1 + \alpha_p \hat{e}_{p,t-1} + \alpha_d D_p + \sum_{k=1}^{n} \alpha_{11}(k) r_{s,t-k} + \sum_{k=1}^{n'} \alpha_{12}(k) r_{p,t-k} + \sum_{k=1}^{n} \alpha_{13}(k) r_{s,t-k} \cdot D_p + \sum_{k=1}^{n'} \alpha_{14}(k) r_{p,t-k} \cdot D_p + \varepsilon_{s,t}$$

$$r_{p,t} = \alpha_2 + \alpha_p \hat{e}_{p,t-1} + \alpha_d D_p + \sum_{k=1}^{n} \alpha_{21}(k) r_{s,t-k} + \sum_{k=1}^{n'} \alpha_{22}(k) r_{p,t-k} + \sum_{k=1}^{n} \alpha_{23}(k) r_{s,t-k} \cdot D_c + \sum_{k=1}^{n'} \alpha_{24}(k) r_{p,t-k} \cdot D_p + \varepsilon_{p,t}$$

$$P_{p,t} - \hat{\beta}_0 - \hat{\beta}_1 P_{s,t} = \hat{e}_{c,t}$$

r_s and r_p are log returns of stock price and implied forward price, respectively.

D_p is set to 1 for Quintile 5, consisting of the bottom 20% returns.

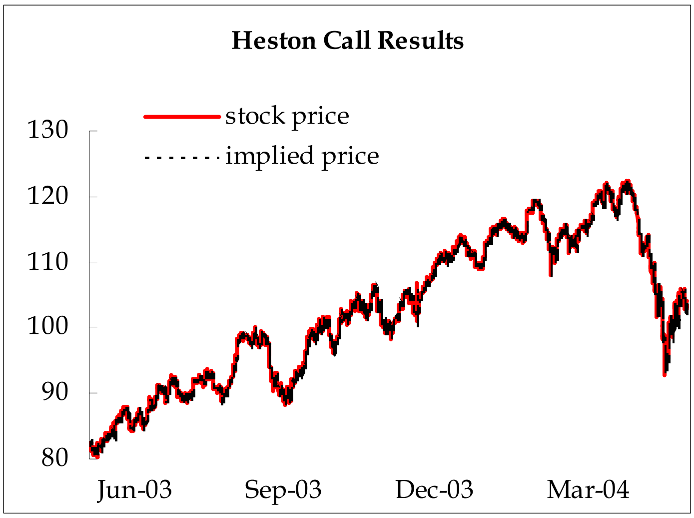
	r_s	t-stat	r_p	t-stat
c	0.0002**	5.5320	0.0002**	4.9347
$\hat{e}_c$ (-1)	0.0001	0.7187	0.0003**	3.0735
D_p	-0.0009**	-14.2193	-0.0011**	-13.0156
r_p (-1)	0.1407**	7.2605	-0.4456	-17.6133
r_p (-2)	0.1047**	4.7338	-0.3390	-11.7379
r_p (-3)	0.1029**	4.3602	-0.1548	-5.0261
r_p (-4)	0.0714*	2.9562	-0.1453	-4.6104
r_p (-5)	0.0600	2.4738	-0.0931	-2.9408
r_p (-6)	0.0305	1.2590	-0.0836	-2.6445
r_p (-7)	0.0472	1.9589	-0.0554	-1.7596
r_p (-8)	0.0475	1.9997	-0.0560	-1.8040
r_p (-9)	0.0228	0.9757	-0.0498	-1.6324
r_p (-10)	-0.0003	-0.0122	-0.0830	-2.7982
r_p (-11)	-0.0137	-0.6435	-0.0791	-2.8476
r_p (-12)	-0.0390	-2.1664	-0.0577	-2.4541
r_s (-1)	-0.2167	-8.5518	0.3922**	11.8529
r_s (-2)	-0.1287	-4.6369	0.3057**	8.4365
r_s (-3)	-0.1669	-5.7809	0.1528**	4.0534
r_s (-4)	-0.0970	-3.2881	0.1668**	4.3317
r_s (-5)	-0.0724	-2.4403	0.0779*	2.0134
r_s (-6)	-0.0357	-1.2086	0.1221**	3.1691
r_s (-7)	-0.0694	-2.3570	0.0520	1.3517
r_s (-8)	-0.0372	-1.2801	0.0826	2.1767
r_s (-9)	0.0047	0.1631	0.1042	2.7863
r_s (-10)	-0.0441	-1.6004	0.0292	0.8106
r_s (-11)	0.0325	1.2338	0.1154	3.3583
r_s (-12)	0.0501	2.2043	0.0966	3.2567

	r_s	t-stat	r_p	t-stat
$D_p r_p$ (-1)	0.0512	1.4499	0.1225	2.6577
$D_p r_p$ (-2)	0.0363	0.9316	0.1639	3.2238
$D_p r_p$ (-3)	-0.0413	-1.0383	-0.0007	-0.0139
$D_p r_p$ (-4)	0.0071	0.1780	0.0372	0.7099
$D_p r_p$ (-5)	-0.0083	-0.2070	-0.0746	-1.4262
$D_p r_p$ (-6)	0.0001	0.0013	0.0468	0.8910
$D_p r_p$ (-7)	0.0127	0.3161	0.0527	1.0078
$D_p r_p$ (-8)	0.0470	1.1877	0.0806	1.5580
$D_p r_p$ (-9)	0.0600	1.5047	0.1452	2.7899
$D_p r_p$ (-10)	0.0768	1.9743	0.2060	4.0555
$D_p r_p$ (-11)	0.0590	1.5792	0.1247	2.5555
$D_p r_p$ (-12)	0.0213	0.6516	-0.0007	-0.0167
$D_p r_p$ (-1)	-0.0469	-1.0128	-0.0629	-1.0398
$D_p r_p$ (-2)	-0.1330	-2.6610	-0.1616	-2.4763
$D_p r_p$ (-3)	0.0599	1.1724	-0.0084	-0.1259
$D_p r_p$ (-4)	-0.0199	-0.3861	-0.0730	-1.0860
$D_p r_p$ (-5)	-0.0376	-0.7318	0.0230	0.3438
$D_p r_p$ (-6)	-0.0395	-0.7706	-0.1342	-2.0073
$D_p r_p$ (-7)	-0.0194	-0.3811	-0.0676	-1.0149
$D_p r_p$ (-8)	-0.1013	-2.0170	-0.1615	-2.4644
$D_p r_p$ (-9)	-0.1224	-2.4275	-0.2270	-3.4490
$D_p r_p$ (-10)	-0.0441	-0.8974	-0.1927	-3.0059
$D_p r_p$ (-11)	-0.1219	-2.5611	-0.2178	-3.5052
$D_p r_p$ (-12)	-0.0357	-0.8427	-0.0223	-0.4025

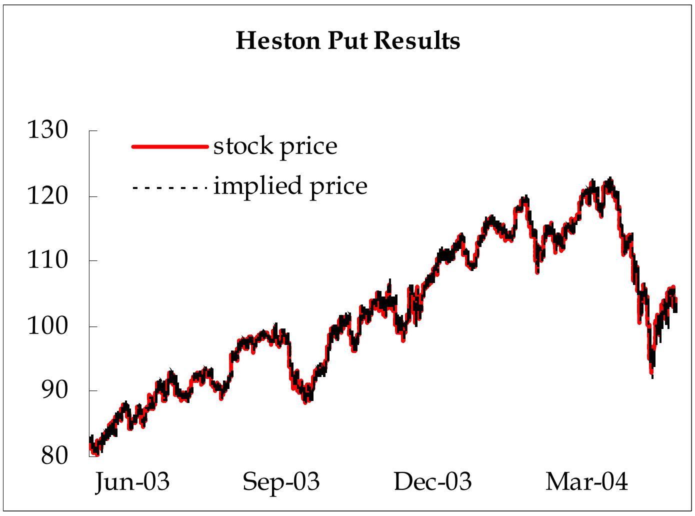
< Figure 1> Real Prices & Implied Prices

These figures represent the relationship between real index prices and implied price from options. Panel A describes the relationship between real index prices and implied prices from call options using Heston (1993)'s model. Panel B describes the relationship between real index prices and implied prices from put options using Heston (1993)'s model. Panel C describes the relationship between real index prices and implied prices from call options using Black and Scholes' model. Panel D describes the relationship between real index prices and implied prices from put options using Black and Scholes' model.

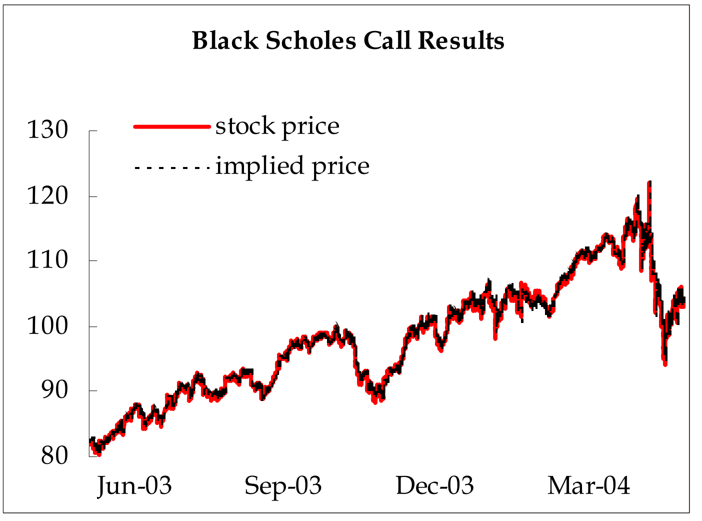
Panel A: Heston Call



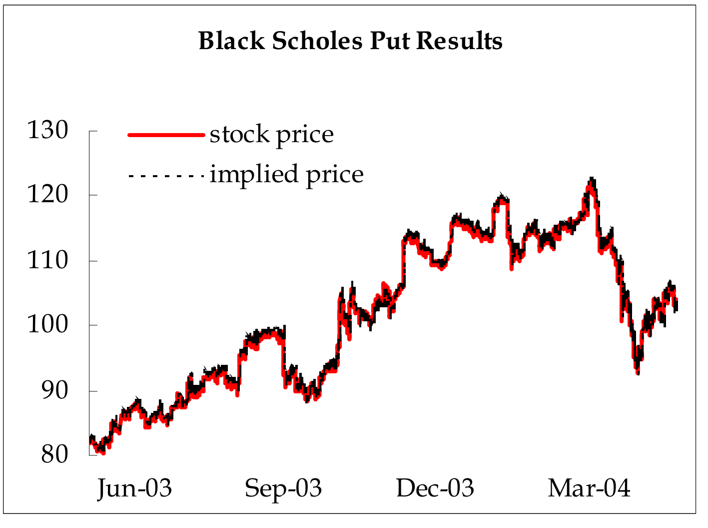
Panel B: Heston Puts



Panel C: Black and Scholes Calls



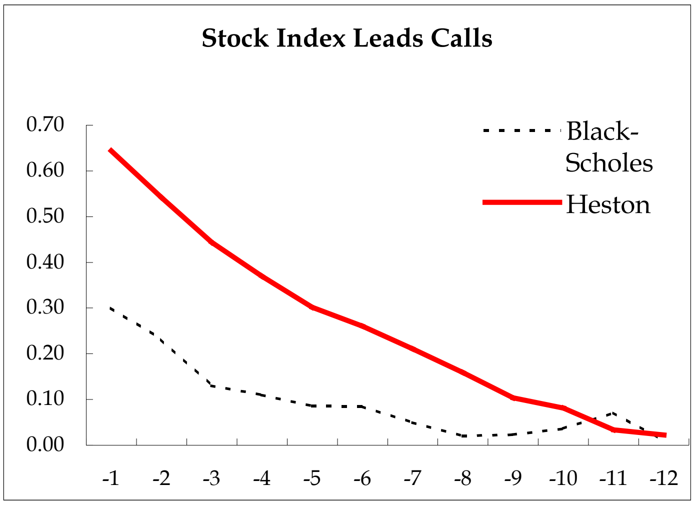
Panel D: Black and Scholes Puts



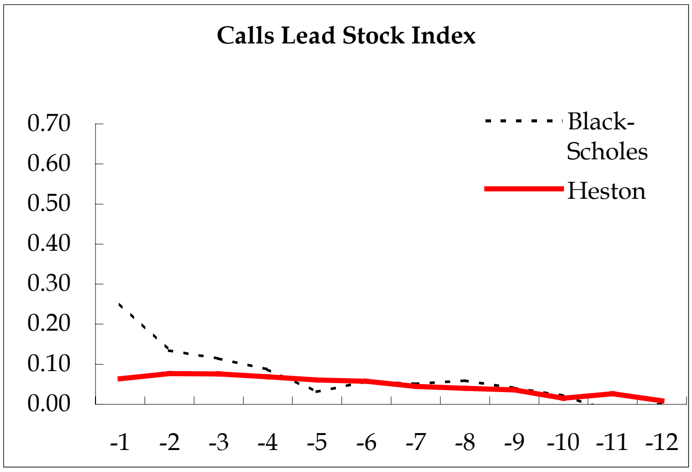
< Figure 2> Lead-lag Coefficients of Stock Returns and Call Options Returns

Panel A and B represent the coefficients realized for the lagged series when the implied forward returns and the stock returns, respectively, are used as dependent variables.

Panel A: Stock Index Leads Calls



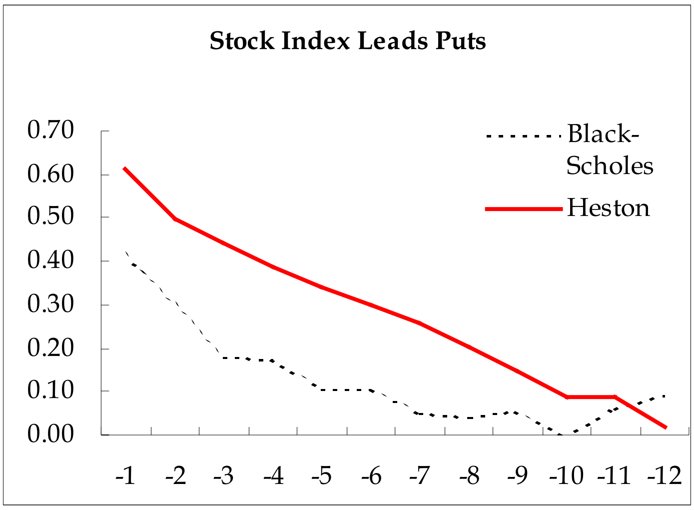
Panel B: Calls Lead Stock Index



< Figure 3> Lead-lag Coefficients of Stock Returns and Put Options Returns

Panel A and B represent the coefficients realized for the lagged series when the implied forward returns and the stock returns, respectively, are used as dependent variables.

Panel A: Stock Index Leads Puts



Panel B: Puts Lead Stock Index