The Impact of Net Buying Pressure on Implied Volatility: The Learning Hypothesis versus the Limits of Arbitrage Hypothesis

Jangkoo Kang* and Hyoung-Jin Park**

Graduate School of Management

Korea Advanced Institute of Science and Technology

Seoul, 130-012, Korea

*Tel.: +82-2-958-3521; email: jkkang@kgsm.kaist.ac.kr;

**Tel.: +82-2-958-3693; email: narita@kgsm.kaist.ac.kr

Abstract

This study examines the impacts of net buying pressure on implied volatility, and documents the fact that Bollen and Whaley (2004)'s net buying pressure hypothesis does not hold in the daily data of the KOSPI200 options market. In addition, using intraday data, we show that the net buying pressure of put options lowers implied volatilities and net selling pressure of put options raises implied volatilities, while the net buying pressure of call options raises implied volatilities and the net selling pressure of call options lowers implied volatilities. Moreover, we document the fact that the net buying pressure in the options market leads the stock market return. These facts suggest that option traders in the KOSPI200 options market are directional traders rather than volatility traders, and these facts support the learning hypothesis rather than the limits of arbitrage hypothesis.

1. Introduction

Implied volatility is the volatility parameter of the Black-Scholes model fitting the observed price of an option with the model price of the corresponding option. In the Black-Scholes model, options with the same underlying asset and with the same expiration date should have the same implied volatility that can be regarded as the standard deviation of the underlying asset. However, in reality, implied volatilities across moneyness frequently show a volatility smile or a smirk (Bates, 1996).

Much research has been devoted to the examination on what causes the anomaly of volatility smiles, but this research has yet to come up with the satisfactory explanation. First, many studies relax the log-normal assumption of Black and Scholes, and then examine whether stochastic volatility or jumps of the underlying asset price or volatility can explain the volatility smile phenomenon. Heston (1993), Hull and White (1994), Duan (1995), Naik and Lee (1995), Bakshi, Cao and Chen (1997), Bates (1998), Pan (2002), and Eraker (2004) are just a few of the examples of this approach. The alternative models suggested in this literature perform better than the Black-Scholes model in pricing and hedging options, but the models don’t seem to explain fully both the underlying market and the option market, as is shown in Ait-Sahalia, Wang and Yared (2001) or Chernov and Ghysels (2000).

Another approach that may explain the volatility smile phenomenon is the study of market imperfections such as discrete trades, nonsynchronous trading problems, transaction costs, and temporary trading imbalances in the market. Kim, Kim and Ziskind (1994) and Hentschel (2003) show that noises in option and underlying asset prices can cause the volatility smile phenomenon. Bollen and Whaley (2004) point out the incompleteness of markets and suggest that the volatility smile may be the result of trading imbalances. Bollen and Whaley present empirical evidence that, on a daily basis, the trading imbalance of the S&P 500 option market drives the option prices higher or lower and thus results in bending the implied volatility curve across the moneyness.

This paper is an extension of Bollen and Whaley's approach. Our paper extends their study in three ways. First, we analyze the net buying pressure hypothesis by Bollen and Whaley using intraday data as well as daily data. Since Bollen and Whaley use only daily data, their analysis is somewhat limited. For example, they guess that the net buying pressure of put options affects call prices as well as put prices because call option prices are connected with put option prices through arbitrage relations. This price transmission process can be clarified when intraday data are used. Second, we analyze not only the net buying pressure of all the investors on various options, but also the net buying pressure of each investor group on various options. Third, we examine the KOSPI200 options, and so provide an opportunity to see whether Bollen and Whaley's analysis can be applied to a different market in general.

This paper analyzes the KOSPI200 option market and tests whether the net buying pressure hypothesis holds in the market. There are some advantages in analyzing the KOSPI 200 option market rather than the S&P 500 option market Bollen and Whaley examined. First, the KOSPI200 option market data provided by the Korea Securities Exchange (KSE) contains information regarding investor types (domestic individuals, domestic institutions or foreigners), all quoted and transaction prices, the best bid and ask prices, and trading volume. This rich information enables us to investigate the net buying pressure hypothesis more deeply. Second, the KOSPI200 options are the most actively traded index options in the world. Even though Bollen and Whaley documents the fact that the net buying pressure hypothesis holds quite well in the S&P 500 option market, this hypothesis may not hold in other markets. Since the

KOSPI200 option market is one of the most liquid option markets, it will be interesting to examine whether the net buying pressure hypothesis holds in markets other than the S&P 500 option market.

This paper shows that Bollen and Whaley's net buying pressure hypothesis does not hold in the daily data of the KOSPI200 option market. The net buying pressure in the KOSPI200 option market doesn't seem to have any statistically significant or consistent effect on the changes of implied volatilities, while the net buying pressure on ATM put options affects the implied volatilities of all options regardless of their moneyness in Bollen and Whaley's sample. Since there is a possibility that the net buying pressure does not show up in the daily data, though it exists, we re-examined the hypothesis using intraday data. We performed an event study to see whether the net buying pressure greater than the two standard deviations of the average net buying pressure of our whole sample affects the implied volatilities of options in the way that Bollen and Whaley document in their sample. In this event study, we find that the net buying pressure affects the implied volatilities significantly, but in a different way than Bollen and Whaley assume: The net buying pressure of put options lowers implied volatilities and the net selling pressure of put options raises implied volatilities, while the net buying pressure of call options raises implied volatilities and the net selling pressure of call options lowers implied volatilities. Additionally, we document that informed investors in the KOSPI200 option market trade earlier than in the KOSPI200 stock market. Those facts imply that investors may be directional traders rather than volatility traders. Investors seem to buy call options if the underlying asset price is expected to rise, and they buy put options if the underlying asset price is expected to fall.

The remainder of this article is organized as follows. Section 2 introduces the net buying pressure hypothesis by Bollen and Whaley. Section 3 presents the data used in the paper.

Section 4 explains the empirical methodology and provides empirical results. Section 5 contains concluding remarks.

2. Net buying pressure hypotheses

In academic literature, there have been many attempts to explain the volatility smile observed in the market. Some studies relax the log-normality assumption of Black and Scholes, and extend the Black-Scholes model to more general option pricing models. Heston (1993), Naik and Lee (1995), Bates (1996), and Duffie, Pan and Singleton (2000) are just a few of the examples of this approach. Others turn their attention to market imperfections such as tick size, trading costs, nonsyncronous and discrete trading, and trading imbalances to account for the volatility smile phenomenon. Kim, Kim and Ziskind (1994), and Hentschel (2003) show that market imperfections can generate volatility smile curves, even though the underlying asset price follows the log-normal process Black and Scholes assume.

Recently, Bollen and Whaley (2004) attribute the volatility smile phenomenon to net buying pressure, which is a measure of trading imbalance. They point out that net buying pressure has a positive relationship with implied volatility and suggest that net buying pressure may result in the volatility smile phenomenon. They suggest two alternative hypotheses that might account for the positive relationship between net buying pressure and implied volatility. One is that the supply curve of an option has a positive slope. If each option contract has an upward sloping supply curve, each implied volatility at time t is determined depending on the demand for each option contract, and so the implied volatility function across moneyness at time t is determined accordingly. Bollen and Whaley suggest that this upward sloping supply curve is possible because of limits of arbitrage. Market makers will not stand ready to sell an unlimited number of contracts in an option series, even though there are profitable arbitrage opportunities in the market, since market makers are risk-averse and there is a possibility that mark-to-market losses may force liquidation of their positions before convergence (Shleifer and Vishny, 1997; Liu and Longstaff, 2000). Therefore, the more imbalanced their positions are, the higher price they will charge. Since institutional demand for options tend to be focused on out-of-money put options, the implied volatility curve tends to be downward sloping, which results in the volatility smile phenomenon observed in the market. Bollen and Whaley call this hypothesis the "limits to arbitrage hypothesis."

The other alternative hypothesis is the "learning hypothesis." In this hypothesis, the slope of the supply curve of each option is flat. Thus, option prices change only when new information about the underlying asset price or its volatility hits the market and so the supply curve shifts.

Bollen and Whaley implicitly assume that option traders are volatility traders, and focus only on volatility shocks. In this case, under the learning hypothesis, the level of the implied volatility is fixed, regardless of the demand for each option contract. However, if a volatility shock occurs and an order imbalance functions as a signal of the shock to investors, then the order imbalance will change the expectations of investors about future volatility and so the implied volatility will change accordingly. Thus, we may observe the positive relationship between net buying pressure and implied volatility. We will call Bollen and Whaley's learning hypothesis the volatility-learning hypothesis.

However, there is a possibility that option traders are directional traders. Since buying a call (put) option can be regarded as taking a leveraged long (short) position in its underlying asset, traders with information about the future underlying asset price movements can enjoy higher returns by taking a position in options than by taking a position in the underlying asset. Thus, option trading is good for directional traders as well as volatility traders. In the directional trader case, the learning hypothesis, under which the slope of the supply curve of each option is flat, means that the order imbalance will change the expectations of investors about the future price movements of the underlying asset and so option prices will change accordingly. We will call this version of the learning hypothesis the direction-learning hypothesis.

The limits of arbitrage and the learning hypotheses have been an issue in the stock market literature as well. For example, Scholes (1972) and Mikkelson and Partch (1985) investigate these two hypotheses in secondary distributions, and provide evidence in favor of the learning hypothesis. However, Bollen and Whaley seem to be the first to examine these hypotheses in option markets and relate these hypotheses to the volatility smile anomaly.

To differentiate the limits of arbitrage hypothesis from the volatility learning hypothesis, Bollen and Whaley suggest two empirical tests. First, they include the lagged changes in implied volatility in a regression that examines the relationship between changes in implied volatility and option demand. Under the limits of arbitrage hypothesis, changes in implied volatility would reverse since investors taking the risk by supplying liquidity want to rebalance their portfolio. On the other hand, the volatility learning hypothesis predicts no serial correlation because information is already reflected in price and implied volatility by investors' trading activities. Second, they examine the impact of the net buying pressures of ATM options on changes in implied volatilities of other option series. Under the limits of arbitrage hypothesis, the option series' own demand will affect its implied volatility and so implied volatilities of different option series do not have to move together. Thus, the net buying pressure of ATM options may not affect the implied volatilities of OTM or ITM options. However, under the volatility learning hypothesis, the net buying pressure of ATM options will drive the changes in implied volatilities of all options in the same direction, since ATM options have the highest vega and so are most informative about future volatility.

Bollen and Whaley's empirical tests also differentiate the direction learning hypothesis from the other hypotheses. First, the direction learning hypothesis may imply a negative coefficient on the lagged change in implied volatility. If new information on the future underlying asset price movements arrives in the option market before it arrives in the underlying asset market, the implied volatility calculated with the underlying asset price will move. For example, if investors, at time t, get the information that the future underlying asset price will go up, and if the investors take positions in calls and puts before taking positions in stocks, then the implied volatility from call options calculated with the stock price, which is yet to reflect the new information, will increase and the implied volatility from put options with the stock price will go down. After the stock price correctly reflects the new information at time t+1, the change in implied volatility will be reversed. Thus, the direction learning hypothesis also implies the negative serial correlation of changes in implied volatility. Thus, the prediction of the direction learning hypothesis on the coefficient of the lagged implied volatility in Bollen and Whaley's regression is the same as the one under the limits of arbitrage hypothesis. Second, the direction learning hypothesis predicts the signs of the coefficients on the net buying pressure of calls and puts differently from the other two alternative hypotheses. Under the direction learning hypothesis, the implied volatility of a call (put) option will be a positive (negative) function of the net buying pressure of call options, and a negative (positive) function of the net buying pressure of put options if the net buying pressure of options has some information content regarding the future price movements of the underlying asset. Later, we will examine the direction learning hypothesis in more detail.

3. Data

3.1 Data Specification

In this paper, we use the KOSPI200 index options to test the net buying pressure hypothesis. The KOSPI200 index consists of 200 blue-chip stocks representing the Korean stock market and industry groups. The base date of KOSPI 200 is January 3, 1990, with a base index 100. KOSPI 200 has been calculated since June 15, 1994. The KOSPI200 index options are European options and cash settled. Their contract months are the three consecutive following months plus one nearest the quarterly cycle just like the S&P 500 index options. The last trading day of the KOSPI200 index option is the second Thursday of the contract month. The trading hours of the KOSPI200 index options are from 9:00 to 15:05. In this paper, we use the data only from 9:30 AM to 15:00 PM, a period for which all the trades are done with competitive bidding.

Our data set from Korea Stock Exchange (KSE)[1] consists of all the trades, quotes, information about trader types and volume records with a time stamp recorded to the nearest second in the KOSPI200 index options market from June 1,1998 to February 28, 2002. In addition, the dataset provides information on the best bid and ask quotes. The KOSPI200 option markets are electronic call markets and pure order-driven markets that have neither dealers nor specialists. As all orders are fed into the Automated Trading System that is a matching scheme satisfying supply and demand, the data is clean relative to the S&P 500 index options. Since quote and trade information is recorded in a correct sequence, we can easily find the closest bid/ask prices prior to a transaction. When the system receives an order, it also records which type of investor made the order; individual, categorized institutional, or foreign investor. Thus,

[1] Since January 2, 2004, the KOSPI200 index futures and options have been traded in the Korea Futures Exchange (KOFEX). Until 2003, these products were traded in KSE. The KOSPI200 index has been estimated and reported by KSE.

we can clearly identify whether a particular option trading is buy-driven or sell-driven and also we can identify which type of investor made the order. This unique feature enables us to investigate the net buying pressure hypothesis more deeply.

In order to estimate the implied volatilities of options using the Black-Scholes model, we use linearly interpolated interest rates using one-month, two-month, three-month, six-month, and one-year Korean Government bond yields. This data is obtained from the Korea Securities Dealers Association. In addition, we get dividend yields of the KOSPI200 Index from the website of KSE[2].

3.2 Classification of options

We classify options into five different moneyness categories following Bollen and Whaley. Bollen and Whaley measure moneyness of an option using the option's delta, which can be interpreted as the likelihood of being in the money at expiration.

The Black-Scholes formulas for a call and a put option are

$$\begin{aligned} c &= Se^{-d\tau}N(d_1) - Xe^{-r\tau}N(d_2) \\ p &= Xe^{-r\tau}N(-d_2) - Se^{-d\tau}N(-d_1) \end{aligned} \tag{1}$$

where $d_1 = (\ln(S/X) + (r - d + 0.5\sigma^2)\tau)/\sigma\sqrt{\tau}$ and $d_2 = d_1 - \sigma\sqrt{\tau}$

In equation (1), S is the spot index level and X is the option's exercise price. r and d are the risk free interest rate and continuously compounded dividend yield of the spot index, respectively. σ is the annualized standard deviation of the continuously compounded index

[2] www.kse.or.kr The dividend yields of the KOSPI200 index are calculated as the total dividend from the KOSPI 200 index constituents over the total market value of the KOSPI 200 index constituents. KSE has updated this dividend yield monthly.

return, and $N(.)$ is the cumulative standard normal distribution function. τ is the option's time to expiration. The delta of an option is calculated as follows:

The delta of a call option: $\Delta_C = e^{-d\tau} N(d_1)$ and

The delta of a put option: $\Delta_P = e^{-d\tau} (N(d_1) - 1)$ (2)

Deltas of all options in our data set are computed by using (1) and (2). The proxy for the standard deviation σ in (1) is estimated as the historical volatility of the return of the KOSPI200 index over the most recent sixty trading days. Depending on the value of delta, each option is placed into one of the five moneyness categories. Table 1-A illustrates how each of five moneyness categories is defined. This categorization is exactly the same as in Bollen and Whaley.

Table 1-B shows the summary statistics of the implied volatilities of each moneyness category in our sample period. Both implied volatility functions estimated from call options and from put options monotonically decrease up to the 4^{th} category, and they then increase a little bit in the 5^{th} category. In addition, we can observe that the historical volatilities of the KOSPI200 index are lower than the implied volatilities of the KOSPI200 options, regardless of moneyness.

In Figure 1, the level of KOSPI200 index and the implied volatilities of KOSPI200 options are plotted during our sample period. These time-series are computed on daily basis. During 1998, which is the period right after the Asian financial crisis, the index level was around 40 and was lower than its base value of 100. Since 1999, the level of the KOSPI200 index has grown in general, as the Korean economy has recovered. We can also recognize that the implied volatilities of ATM call and put options move a lot around the realized volatility of the index. The level of the KOSPI 200 index volatility is higher than that of the S&P 500 index volatility.

3.3 Net buying pressure and investor types

Our study examines the relation between trading imbalance and implied volatility. Since trading imbalance means the difference between the number of buy orders and the number of sell orders, we need to identify whether a particular trade is buyer-initiated or seller-initiated. There are many studies on how to identify it. For example, Easley, O'Hara, and Srinivas (1998), Chordia, Roll and Subrahmanyam (2002) regard a trade as a buy volume if the transaction price is closer to the prevailing ask quote than the prevailing bid quote, and as a sell volume if the transaction price is closer to the prevailing bid quote than the prevailing ask quote. Applying this definition to options contracts, Bollen and Whaley proxy trading imbalance by the net buying pressure, which is defined as the difference between the number of contracts traded at prices higher than the prevailing bid/ask quote midpoint and the number of contracts traded at prices below the prevailing bid/ask quote midpoint times the absolute value of the option's delta.

In our paper, we define the net buying pressure differently from Bollen and Whaley. Since all orders in KSE are fed into the automated trading system in KSE, which matches buy orders with sell orders continuously, all the trades take place either at the ask or the bid price. Thus, we identify a trade as a purchase if the transaction price is the ask price, and as a sale if the transaction price is the bid price. The net buying pressure is computed as the difference between the number of purchase contracts and the number of sale contracts times the absolute value of the option's delta. This definition of the net buying pressure, thanks to the characteristics of the KSE trading system and our data, provides a more accurate and cleaner measure of trade imbalance than the one used in Bollen and Whaley for the U.S. option market.

Table 2 shows the trading volume of the KOSPI200 options contracts and their ownership across investor types in our sample. Panel A of the table shows that individual investors are the most active trading group of all. Around 70% of the trades in the KOSPI200 option market during our sample period is done by individual investors. This trading volume of individual investors is surprisingly high, relative to their average ownership of the underlying stocks in KOSPI200 stock index. As we can see in panel B of the table, individual investors own only 24% of the underlying stocks. These facts show that individual investors trade much more actively in the option market than the other investor groups do. Since individual investors are expected to be speculators rather than hedgers, we can guess that the KOSPI 200 option market may be closer to a speculative market than the S&P 500 index option market is. The second finding of the table is that individual investors and foreigners are on average buyers of calls and puts, while institutional investors are on average sellers of calls and put. Since selling calls or puts is riskier than buying calls and puts in the sense that investors selling calls or puts are taking the risk of losing money greater than their total investments, individual investors who have limited resources may avoid it.

Table 3 summarizes the trading activities in the KOSPI200 option market across moneyness over the sample period. Panel A of the table shows the number of contracts traded over the sample period across moneyness groups. The first thing to note is that the trading volume of calls is greater than that of puts. Looking at panel A, 55.7% of all the contracts traded in the KOSPI200 option market is call options, while only 44.3% is put options. This is different from the S&P500 index option market that has more trades of puts than of calls. Noting that Bollen and Whaley attribute the dominant role of the net buying pressures of puts in the S&P500 index option market to the prevalence of puts in the market, we expect that the net buying pressures of call options are more important in the KOSPI200 option market if Bollen and Whaley's hypothesis is true. While OTM options have the heaviest trading volume, followed by DOTM options, and then ATM options in the case of call options, ATM options have the heaviest trading volumes for put options.

Panel B of Table 3 illustrates the total net buying pressure over the sample period across moneyness categories. We can see in this panel that the trades in call options are in general initiated by sellers and trades in put options are in general initiated by buyers.

Trading volume and net buying for each investor group are reported in Table 4. Individual investors initiated 66.8% of total option trades, while institutional investors and foreigners initiated 25.7% and 7.5% of total option trades, respectively. Thus, individual investors are dominant trade-initiators in the KOSPI200 option market. Panel B of the table illustrates the net buying pressure in call and put options across investor groups. As in table 3, we can see in this table that investors have net selling positions in call options and net buying positions in put options in general, regardless of the investor type. One notable exception is that individual and institutional investors are net sellers (buyers) of DOTM calls (puts), while foreign investors are net buyers (sellers) of DOTM calls (puts). This general tendency of the negative net buying positions in call options and the positive net buying position in put options is consistent with the net buying pressure hypothesis in the sense that the average implied volatility of put options is in general higher than that of call options in panel B of Table 1.

Table 5 shows the correlation matrix of three investor groups' net buying pressure among moneyness classes of call options and put options. As we can see in this table, the net buying pressure of a call (put) option in a particular moneyness category is positively correlated with the net buying pressure of a call (put) option in another moneyness category, regardless of the investor group. For example, the correlation coefficients among the total net buying pressure variables range from 0.165 to 0.389, which shows that investors tend to place buy orders in the same direction. These positive correlations are consistent with the learning hypotheses, since there will be net buying pressure on all options if there is a shock or new information regarding the price or the volatility of the underlying asset returns. On the other hand, these positive correlations cannot be accounted for by the limits of arbitrage hypothesis. The limits of arbitrage hypothesis predicts weak correlations among net buying pressure of option series, since there is no reason for investors to trade all the option series in the same direction.

Another notable thing in this table is that the total net buying pressure on call options (put options) in a particular moneyness category is strongly correlated with the net buying pressure of individual investors or institutional investors on call options (put options) in the same moneyness category. Also, note that the net buying pressure of foreign investors is weakly or even negatively correlated with that of the other investor groups.

Table 6 reports the correlation matrix between the net buying pressure of call options and the net buying pressure of put options. If we look at the correlation matrix, almost all the coefficients are negative. That is, the net buying pressure of a call option is negatively correlated with the net buying pressure of a put option, regardless of the moneyness category and regardless of the investor group. These negative correlations are consistent with the direction learning hypothesis. If new information implying that the future underlying asset price will go up (down), investors will take long positions in calls and short positions in puts, which will generate a negative correlation between the net buying pressure of calls and the net buying pressure of puts. On the other hand, the volatility learning hypothesis cannot account for the negative correlations in Table 6. Under the volatility learning hypothesis, we expect that the net buying pressure of calls is positively correlated with the net buying pressure of puts. The limits of arbitrage hypothesis also cannot account for the negative correlations, since there is no reason for investors to trade all the call options in one direction, and simultaneously trade all the put options in the opposite direction. Thus, Table 6 provides some evidence supporting the direction learning hypothesis.

Figure 2 illustrates the time series behavior of the net buying pressure on the KOSPI200 index options across various investor types. In this figure, the whole sample period is partitioned into two sub periods, from June 2, 1998 to Dec 31, 2000 and from Jan 2, 2001 to Feb 28, 2002. The KOSPI200 option market experienced a big increase in trading volume and has more volatile and bigger net buying pressure in the second subperiod.

Figure 2 shows two notable things. First, the net buying pressure on call options is bigger and more volatile than that on put options, irrespective of moneyness or which subperiod we are looking at. This is probably because call options are more actively traded in the KOSPI200 option market than put options. Second, institutional investors put net selling pressure on OTM call options, while they put net buying pressure on OTM put options. The other investor groups don’t show any particular tendency to initiate selling or buying a particular option. This shows that one investor group may behave differently and so may affect the implied volatility function differently than the other investor groups.

4. Empirical Analysis

We will provide empirical results of the paper in this section. This section investigates Bollen and Whaley’s net buying pressure hypothesis using not only Bollen and Whaley’s interday regressions but also intraday regressions.

Bollen and Whaley provide three reasons that their study may have advantages over earlier studies: usage of trading volume data on a series-by series basis, examination of the net buying pressure for each option series, and analysis of implied volatilities across five delta-value-based categories. Our study follows Bollen and Whaley's approach and so shares those advantages with Bollen and Whaley's study. In addition, our study extends their approach as follows: First, we investigate five-minute intraday option data as well as interday option data. Since net buying pressure changes continuously even during a day, looking at interday net buying pressure may distort empirical results. For example, even if net buying pressure for a day is zero, the day may experience huge positive net buying pressure for some time, and then huge negative net buying pressure at another time. Thus, we can examine empirical results more clearly and exactly by using intraday option data. Second, our study investigates how different the impact of the net buying pressure of an investor group on implied volatilities might be. For example, institutional investors' demand for put options to hedge their portfolios, which is emphasized in Bollen and Whaley, may affect implied volatilities differently. In addition, we can examine whether the impacts of the net buying pressure of informed investors (for example, institutional investors) on implied volatilities are different from those of the other investors.

In this section, we first provide empirical methodology, and interday and intraday regressions used in the paper. We show and analyze empirical results after discussing each regression method, respectively.

4.1 Daily Regressions

4.1.1 Empirical methodology for daily regressions

In order to assess the impact of net buying pressure on implied volatilities on a daily basis, we regress the daily change in the average implied volatility of options in a particular moneyness category on contemporaneous measures of index return, index trading volume, net buying pressure, and a lagged change in the average implied volatility. This regression specification is the one used in Bollen and Whaley (2004). The sample period is from June 1, 1998 to Feburary 28, 2002.

The contemporaneous return of the index and its trading volume are included in the regression as control variables for leverage and information flow effects. Index returns are expected to be negatively correlated with changes in implied volatility due to the leverage effect (Black, 1976) or the positive feedback effect (French, Schwert, and Stambaugh, 1987; Campbell and Hentschel, 1992). Trading volume is expected to be correlated with volatility, since both variables represent information flow in the market.

The lagged change in average implied volatility is included to differentiate alternative hypotheses discussed in section 2. Under the limits of arbitrage hypothesis, the temporary nature of the impact of the net buying pressure implies a negative coefficient on the lagged change in implied volatility. The direction learning hypothesis may also imply a negative coefficient on the lagged change in implied volatility, because option prices lead their underlying asset price under the direction learning hypothesis. In contrast, under the volatility learning hypothesis, the coefficient on the lagged change in implied volatility will be insignificant. Under the volatility learning hypothesis, the lagged change in implied volatility should be uncorrelated with the current change in implied volatility, since new information regarding the market volatility drives changes in implied volatility, and shocks regarding market volatility are unpredictable or serially uncorrelated.

In summary, our regression is specified as follows:

$$\Delta\sigma_t = \alpha_0 + \alpha_1 RS_t + \alpha_2 VS_t + \alpha_3 D_{1,t} + \alpha_4 D_{2,t} + \alpha_5 \Delta\sigma_{t-1} + \varepsilon_t \quad (3)$$

where $\Delta\sigma_t$ is the change in the average implied volatility in a moneyness category from the close on day t-1 to the close on day t, RS_t is the index return from the close on day t-1 to the close on day t, VS_t is the daily trading volume of the KOSPI200 index on day t expressed in billions in Korean won. $D_{1,t}$ and $D_{2,t}$ are the net buying pressure variables whose definitions will be determined in the regression tests that follow.

As in Bollen and Whaley, three sets of regression tests are performed. Unlike Bollen and Whaley, however, we run four regressions in each set to see the effect of the net buying pressure of different investor types on changes in implied volatility.

The first set of tests examines the extent to which the net buying pressure of ATM calls and puts impacts the changes in implied volatilities of ATM options. The regression is estimated for calls and puts, respectively, and their specifications are:

$$\Delta\sigma_t = \alpha_0 + \alpha_1 RS_t + \alpha_2 VS_t + \alpha_3 TNBP\_ATMC_t + \alpha_4 TNBP\_ATMP_t + \alpha_5 \Delta\sigma_{t-1} + \varepsilon_t \quad (4)$$

$$\Delta\sigma_t = \alpha_0 + \alpha_1 RS_t + \alpha_2 VS_t + \alpha_3 INBP\_ATMC_t + \alpha_4 INBP\_ATMP_t + \alpha_5 \Delta\sigma_{t-1} + \varepsilon_t \quad (5)$$

$$\Delta\sigma_t = \alpha_0 + \alpha_1 RS_t + \alpha_2 VS_t + \alpha_3 SNBP\_ATMC_t + \alpha_4 SNBP\_ATMP_t + \alpha_5 \Delta\sigma_{t-1} + \varepsilon_t \quad (6)$$

$$\Delta\sigma_t = \alpha_0 + \alpha_1 RS_t + \alpha_2 VS_t + \alpha_3 FNBP\_ATMC_t + \alpha_4 FNBP\_ATMP_t + \alpha_5 \Delta\sigma_{t-1} + \varepsilon_t \quad (7)$$

where $TNBP\_ATMC_t$ ($TNBP\_ATMP_t$) denotes the net buying pressure of total investors for ATM calls (puts), $INBP\_ATMC_t$ ($INBP\_ATMP_t$) denotes the net buying pressure of individual investors for ATM calls (puts), $SNBP\_ATMC_t$ ($SNBP\_ATMP_t$) denotes the net buying pressure of institutional investors for ATM calls (puts), and $FNBP\_ATMC_t$ ($FNBP\_ATMP_t$) denotes the net buying pressure of foreign investors for ATM calls (puts).

We can differentiate the three alternative hypotheses by comparing the size of the coefficients on the net buying pressure of calls and puts in these regression equations. Under the volatility learning hypothesis, the impacts of net buying pressure of ATM calls and puts on the change in ATM option volatility are expected to be positive and indistinguishable from each other, because both ATM calls and puts have the same vega and so they are equally sensitive to changes in expectations of future volatility. If the limits of arbitrage hypothesis is correct, these two coefficients will be positive, but need not be equal, since ATM calls and puts are traded with no relation to the expectations of changes in volatility. Under the direction learning hypothesis, in the regressions of the changes in ATM call (put) volatility, the coefficient of the net buying pressure of ATM calls will be positive (negative), and the coefficient of the net buying pressure of ATM puts will be negative (positive).

The second and the third sets of tests investigate changes in implied volatility of OTM calls and puts, respectively. In each set, we have four cases: investors on the whole, individual investors, institutional investors and foreign investors. In the case of the whole investor group, the following regression model specifications are used:

$$\Delta\sigma_t = \alpha_0 + \alpha_1 RS_t + \alpha_2 VS_t + \alpha_3 TNBP\_OTMC_t + \alpha_4 TNBP\_ATMC_t + \alpha_5 \Delta\sigma_{t-1} + \varepsilon_t \quad (8)$$

$$\Delta\sigma_t = \alpha_0 + \alpha_1 RS_t + \alpha_2 VS_t + \alpha_3 TNBP\_OTMC_t + \alpha_4 TNBP\_ATMP_t + \alpha_5 \Delta\sigma_{t-1} + \varepsilon_t \quad (9)$$

where $TNBP\_OTMC_t$ is the net buying pressure of total investors for OTM calls, $TNBP\_OTMP_t$ is the net buying pressure of total investors for OTM puts. In the cases of the other three investor groups, the net buying pressures of the whole investor group on ATM calls and puts are replaced by the net buying pressures of each investor group on ATM calls and puts. Since the change in implied volatility estimated from OTM calls as well as the one from OTM puts are used as dependent variables in (8) and (9), sixteen regressions are run in total.

These regressions in (8) and (9), in addition to the regressions in (4) through (7), can also be tested to distinguish the three alternative hypotheses. Under the volatility learning hypothesis, ATM options' net buying pressure should have a bigger impact on the changes in implied volatility of OTM options than does OTM options' own net buying pressure because ATM options have higher vegas than OTM options and so investors more speedily in the ATM option market than in the other option markets. Also, the volatility learning hypothesis predicts that the coefficient on the net buying pressure of every option should be positive. The limits of arbitrage hypothesis predicts that the coefficients of the net buying pressure of OTM call (put) options will be positive and bigger in the regressions of the changes in implied volatility of OTM call (put) options than those of the net buying pressure of ATM options. The direction learning hypothesis predicts that the coefficients of the net buying pressure of call (put) options will be positive and the coefficients of the net buying pressure of put (call) options will be negative, regardless of moneyness, in the regressions of the changes in implied volatility of OTM call (put) options.

4.1.2 Daily regression results

Table 7 reports daily regression results of equations (4) to (7). The results for changes in the implied volatility of ATM calls are reported in panel A, and the results for changes in the implied volatility of ATM puts are reported in panel B. If we look at the coefficients of index return, α_1's, they are in general negative, a result that is consistent with the leverage or positive feedback hypothesis, but not statistically significant except for the case of ATM put options in the institutional investor or foreign investor group. All the coefficients of the trading volume, α_2's, are not statistically significant.

The most striking feature in Table 7 is the sign and the magnitude of the coefficients of the net buying pressure, α_3's and α_4's. Except for one case, all the other coefficients are not statistically significant. The only statistically significant coefficient is negative, which is inconsistent with the limits of arbitrage or the volatility learning hypothesis examined in Bollen and Whaley. Both hypotheses call for the positive coefficients of the net buying pressure. Bollen and Whaley document the fact that the coefficient of the net buying pressure of put options, which are traded more actively than call options, is statistically significant and positive in the S&P 500 index option market. To be consistent with Bollen and Whaley's results and interpretation, the coefficient of the net buying pressure of call options should be significantly positive in the KOSPI200 option market. However, in our results, none of α_3's is statistically significant and five out of eight α_3's are negative. These results are not consistent with the direction learning hypothesis, either. The direction learning hypothesis predicts that α_3's are positive and α_4's are negative in the regressions of the changes in ATM call volatility or ATM put options. However, if we focus only on the regressions of the changes in ATM call volatility, which are estimated in the more active call market, the estimated α_3's and α_4's have the signs expected from the direction learning hypothesis, except for the case of foreign investors.

The coefficient of the lagged change in implied volatility is negative and statistically significant at the 5% significance level in every regression reported in Table 7, which is consistent with Bollen and Whaley. The magnitude of the coefficient is around -0.3, which is smaller than the value reported in Bollen and Whaley, -0.1727. Bollen and Whaley suggest that this negative value of the coefficient results from market makers (investors in our case) rebalancing their portfolios rather than from measurement errors, and argue that these negative coefficients are consistent with the limits of arbitrage hypothesis. However, this negative value of α_5 in every regression is also consistent with the direction learning hypothesis.

Table 8 reports the daily regression results of equations (8) and (9). The results for changes in the implied volatility of OTM call options are reported in panel A, and the results for changes in the implied volatility of OTM puts are in panel B. If we look at the coefficients of the index return, α_1's, all of them are negative, and generally statistically significant. This again confirms the leverage or positive feedback hypothesis. None of the coefficients of trading volume, α_2's, is statistically significant at the 5% significance level, as shown in Table 7. All of the coefficients of the lagged change in implied volatility, α_5's, are negative and statistically significant at the 5% significance level, as shown in Table 7.

If we look at α_3's in panel A of Table 8, seven out of eight coefficients are positive, and six of them are statistically significant at the 5% significance level. The only negative α_3, which is for the case of foreign investors, is not statistically significant at the 5% significance level. If we look at α_4s in panel A, they are positive if D_2 represents the net buying pressure of ATM calls, and negative if D_2 represents the net buying pressure of ATM puts, except for the case of foreign investors. Two of the negative α_4's are statistically significant at the 5% significance level. These results reported in panel A are consistent with the direction learning hypothesis.

None of the coefficients, α_3' and α_4's is statistically significant at the 5% significance level in panel B of Table 8. In addition, the signs of those coefficients are not consistent with any of the hypotheses suggested in this paper; only three of eight α_3's are positive, and the signs of α_4's in panel B are positive for the net buying pressure of calls and negative for the net buying pressure of puts. Following Bollen and Whaley, these weak results reported in panel B relative to the results reported in panel A can be attributed to the dominance of call options in the KOSPI200 index market.

In sum, daily regression results are consistent with the direction learning hypothesis if we look at the changes in implied volatility calculated from calls. The net buying pressure of ATM puts lowers the implied volatility calculated from ATM calls and OTM calls, while the net buying pressure of OTM calls increases the implied volatility calculated from OTM calls. In addition, we find that the changes in implied volatility are negatively serially correlated after controlling the net buying pressure, the trading volume and the leverage effect. The negative serial correlation is consistent with the direct learning hypothesis, though it is also consistent with the limits of arbitrage hypothesis. However, we cannot find any statistically significant evidence that the implied volatilities calculated from puts are affected by the net buying pressure of calls or puts.

4.2 Intraday Regressions

In the previous section, we show that the daily regression results in our sample are weakly consistent with the direction learning hypothesis. In this section, we examine the three alternative hypotheses suggested in the paper using the intraday data. If the net buying pressure at some time is canceled out by the net selling pressure at another time over a day, then the daily regressions examined in the previous section cannot appropriately show the relation between the net buying pressure and implied volatility.

4.2.1 Empirical methodology for intraday regressions

When we use intraday data and calculate the net buying pressure defined in the previous section, most of the net buying pressure is negligible and so it is more likely that the negligible net buying pressure doesn't have any effect on implied volatilities of options. Thus, if we use all of the intraday data and run the regressions as in the previous section, the regression results may not be informative. Thus, we perform empirical analyses using the cases that have net buying pressure of significant size.

The detailed data selection procedure is as follows. First, we calculate the net buying pressure for all five minute intervals over the sample period from June 1, 1998 to February 28, 2002. Next, we choose the five-minute-intervals having net buying pressure which lies outside two standard deviations around the average net buying pressure over the sample period. When we find the five-minute interval satisfying the above condition, we define the interval as an event interval, and define other intervals relative to this event interval. That is, if the event interval is time t, then the interval five minutes before the event interval is defined as time t-1 interval. Finally, for those selected intervals, we gather the data regarding option prices, implied volatilities, the KOSPI200 index level, and its trading volume.

Using the data selected from the above procedure, we run the same regressions as in the daily regression analyses of the previous section.

4.2.2 Intraday regression results

Table 9 reports intraday regression results of equations (4) to (7). This table is equivalent to Table 7 except that Table 9 uses intraday data, while Table 7 uses daily data. The results for changes in the implied volatility of ATM calls are reported in panel A, and the results for changes in the implied volatility of ATM puts are reported in panel B.

All of the coefficients of index return, α_1's in the regressions of changes in implied volatility of ATM call options in panel A are negative and statistically significant at the 5% significance level. This is consistent with the leverage or positive feedback hypothesis. However, those coefficients for the regressions of ATM put options are all positive and statistically significant, which contradicts the leverage or positive feedback hypothesis. This might be due to the fact that investor behavior is conditional on the stock market movement, which will be discussed later.

The coefficients of the trading volume, α_2's are negative and statistically significant at the 5% significance level in the regressions of changes in implied volatility of ATM call options in panel A. On the other hand, α_2's are positive but statistically insignificant at the 5% significance level in the regressions of changes in implied volatility of ATM put options in panel B. These coefficients show that the price of an ATM call tends to decrease if stocks are more actively traded, while the price of an ATM put tends to increase if stocks are less actively traded.

The coefficients of the lagged change in implied volatility, α_5's are all negative, but statistically significant at the 5% significance level only in the regressions of changes in implied volatility of ATM call options in panel A. The negative values of α_5's in panel A are consistent with the limits of arbitrage hypothesis and the direction learning hypothesis, while the insignificant values of α_5's in panel B are consistent with the volatility learning hypothesis. However, if we re-examine the limits of arbitrage or the direction learning hypothesis, the prediction on the serial correlation of changes in implied volatility is not about the relation between $\Delta\sigma_t$ and $\Delta\sigma_{t-1}$, but about between $\Delta\sigma_t$ and $\Delta\sigma_{t+1}$. Both the limits of arbitrage hypothesis and the direction learning hypothesis predict the reversal of implied volatilities at time t+1 after the net buying pressure at time t increases or decreases the implied volatilities at time t. In the daily regression analysis, the relationship between $\Delta\sigma_t$ and $\Delta\sigma_{t-1}$ is not much different from the one between $\Delta\sigma_t$ and $\Delta\sigma_{t+1}$ because we are looking at the daily stream of time-series of implied volatilities without interruption. On the other hand, in the intraday regressions, we are looking only at the extreme events, and so those two relationships can be substantially different from each other.

Panels C and D examine the following equations instead of equations (4) and (5) in panels A and B:

$$\Delta\sigma_t = \alpha_0 + \alpha_1 RS_t + \alpha_2 VS_t + \alpha_3 TNBP\_ATMC_t + \alpha_4 TNBP\_ATMP_t + \alpha_5 \Delta\sigma_{t+1} + \varepsilon_t \quad (10)$$

$$\Delta\sigma_t = \alpha_0 + \alpha_1 RS_t + \alpha_2 VS_t + \alpha_3 INBP\_ATMC_t + \alpha_4 INBP\_ATMP_t + \alpha_5 \Delta\sigma_{t+1} + \varepsilon_t . \quad (11)$$

As we can see in these panels, all the coefficients of $\Delta\sigma_{t+1}$, α_5's are negative and statistically significant, which is consistent with the limits of arbitrage or the direction learning hypothesis. All the other coefficients of panel C and D are essentially the same as those of panel A and B, respectively.

The main test of the learning hypotheses versus the limits of arbitrage hypothesis in Table 9 is revealed in the coefficients of the net buying pressure, α_3's and α_4's. The coefficients of the ATM option series' own net buying pressure, α_3's are always positive and are statistically significant at the 5% significance level except for the foreign investor group. On the other hand, the coefficients of the net buying pressure of the other ATM option series (that is, ATM puts for ATM calls, and ATM calls for ATM puts), α_4's are in general negative and are often statistically significant at the 5% significance level. The limits of arbitrage hypothesis or the volatility learning hypothesis cannot account for these results, but the direction learning hypothesis is consistent with these results. If investors get new information that stock prices will go up (down), then they will place buy orders in call (put) options and place sell orders in put (call) options, which results in net buying pressure on call (put) options and net selling pressure on put (call) options. The information on the news is spread out through the net buying pressure of call (put) options or the net selling pressure of put (call) options, and so the price or the implied volatility of the call (put) options increases. Combined with the evidence documented by Kang, Lee, and Lee (2004) that the KOSPI200 options market leads the KOSPI200 stock market by up to 10 minutes, the direction learning hypothesis can account for the positive α_3's and the negative α_4's.

This direction learning hypothesis can also account for the signs of α_1's and α_2's. If the market sometimes overreacts to information as documented in Stein (1989) or Poteshman (2001), investors will regard an increase (decrease) in stock prices or stock trading volume as a signal showing that stock prices will go down (up), which results in the negative signs of α_1's and α_2's in panel A and C of Table 9, and the positive signs of α_1's and α_2's in panel B and D of Table 9.

To examine the direction learning hypothesis further, we run the following regression:

$$EXTREME\_NBP_t = \alpha_0 + \sum_{i=-2}^{2} \alpha_{i+3} r_{t+i} + \alpha_6 EXTREME\_NBP_{t-1} + \varepsilon_t \qquad (12)$$

where $EXTREME\_NBP_t$ is the net buying pressure at a five minute interval t whose magnitude lies outside two standard deviations from the mean of the whole set of 5-minute net buying pressure, and r_t is the return of the KOSPI200 index over the five minute interval t. If the limits of arbitrage hypothesis holds, α_4 and α_5 should be close to zero since the net buying pressure of an option series has no information content. On the other hand, if the learning hypothesis under the assumptions that option traders are directional traders and that investors trade in the option market before in the stock market holds, α_4 or α_5 should be different from 0, and their signs will be determined by the characteristics of the option series.

Table 10 shows the estimation results of equation (12). As we can see in this table, the net buying pressure of call options and put options leads the KOSPI200 stock return. All the coefficients of r_{t+1} are statistically significant at the 5% significance level in the regressions reported in Table 9 except for the case of ITM put options in the foreign investor group, regardless of which option series is examined. Moreover, all the coefficients of r_{t+1} in the regressions of the net buying pressure of call options are positive, while all the coefficients of r_{t+1} in the regressions of the net buying pressure of put options are negative. These signs of the coefficients are consistent with the direction learning hypothesis. When the net buying pressure of call options is observed, the stock return goes up over the next five minute interval. On the other hand, when the net buying pressure of put options is observed, the stock return goes down over the next five minute interval. In addition, we can see that every investor group can be regarded as a directional option trader. We may guess before the analysis in Table 9 that institutional or foreign investors are more likely to be volatility traders, and that individual investors are more likely to be directional traders. However, that's not the case. All the coefficients are of the same sign, and the absolute values of the coefficients have the expected order, considering the trade size of each group.

The signs of the coefficients of r_t are also consistent with the direct learning hypothesis. The net buying pressure of calls increases when the positive information on the stock price is observed in the stock market, and the net buying pressure of puts increases when the negative information on the stock price is observed in the stock market.

Other interesting points in Table 10 are the coefficients of r_{t-1} (α_2) and the coefficients of r_{t+2} (α_5). The signs for these coefficients are opposite the signs of the coefficients of r_t and r_{t+1} in general, even though most of them are not statistically significant at the 5% significance level. The signs of the coefficients of r_{t-1} might indicate that option investors place buy orders after observing some overreaction to news in the stock market. These buy orders in the options market signal to the stock market the information option investors have over time intervals t and t+1, and correct the stock market. However, the correction process overshoots, and another overreaction in the stock market occurs over those intervals, and it is corrected at time interval t+2. This process is worth further investigation, but we will leave it for future research.

Figure 3 and Figure 4 illustrate the impact of the net buying pressure, EXTREME_NBP on ATM options and OTM options, respectively. In these figures, time 0 on the horizontal axis indicates the five-minute interval at which the net buying pressure lying outside two standard deviations of the sample mean of net buying pressure occurs, and each value i on the horizontal axis means the i-th five minute interval away from time 0 interval. These figures show the following: First, the positive (negative) net buying pressure of an option series at time t generates an increase (decrease) in the price of the option series at time t and t+1, regardless of ATM, OTM, call, or put options. Thus, the effect of net buying pressure on option prices lasts for 10 minutes. Second, positive (negative) net buying pressure on call options occurs at the same time as positive (negative) net buying pressure of futures contracts, while positive (negative) net buying pressure on put options occurs at the same time as negative (positive) net buying pressure of futures contracts. Third, net buying pressure on options (and futures) leads the stock index and futures returns by 5 to 10 minutes. When we observe positive (negative) net buying pressure on call options, we can predict that stock returns will increase (decrease) for the next 5 minute interval as well as for the current 5 minute interval. On the other hand, when we observe positive (negative) net buying pressure on put options, we can predict that stock returns will decrease (increase) for the next 5 minute interval as well as for the current 5 minute interval. These figures are consistent with Table 10 and the direction learning hypothesis.

This direction learning hypothesis is again confirmed in Table 11. Table 11 reports intraday regression results of equations (8) and (9). This table is equivalent to Table 8 except that Table 11 uses intraday data, while Table 8 uses daily data. The results for changes in the implied volatility of OTM call options are reported in panel A, and the results for changes in the implied volatility of OTM puts are reported in panel B.

As in Table 9, all of the coefficients of the index return, α_1's in the regressions of changes in implied volatility of OTM call options in panel A are negative and statistically significant at the 5% significance level, while those coefficients for the regressions of OTM put options are all positive and statistically significant. These show that call option prices move in the opposite direction of stock prices and put option prices move in the same direction of stock prices, after controlling the net buying pressure of options. These troublesome results might be due to overreaction in the stock market. However, it is also likely to be due to measurement errors in the stock price index such as the infrequent trading effect.

The coefficients of the OTM option series' own net buying pressure, α_3's are always positive and are statistically significant at the 5% significance level except for the foreign investor group. In addition, the coefficients of the net buying pressure of the ATM option series, α_4's shows a general pattern consistent with the direction learning. In the regressions of changes in the implied volatility of OTM call options, α_4's are positive when the explanatory variable is the net buying pressure of ATM call options, while they are negative when the explanatory variable is the net buying pressure of ATM put options. In the regressions of changes in the implied volatility of OTM put options, α_4's are positive when the explanatory variable is the net buying pressure of ATM put options, while they are negative when the explanatory variable is the net buying pressure of ATM call options.

It is also interesting that α_5's, the coefficients of the lagged change in implied volatility, are not statistically significant at the 5% significance level in Table 11. However, if we substitute $\Delta\sigma_{t+1}$ in place of $\Delta\sigma_{t-1}$ as one of the independent variables in the regressions, all the coefficients of $\Delta\sigma_{t+1}$, α_5's are negative and statistically significant at the 5% significance level, which is consistent with the direction learning hypothesis.

To sum up, our empirical evidence shows that an option series' own net buying pressure affects the implied volatility of the option significantly and positively. This evidence seems to be consistent with Bollen and Whaley's limits of arbitrage hypothesis, but we offer a different story based on the learning hypothesis under the assumption that option traders are directional traders. This direction learning hypothesis is more in line with our empirical results than the limits of arbitrage hypothesis.

5. Conclusion

In the Black and Scholes economy, implied volatilities should be constant over time and across moneyness. However, in reality, implied volatilities are time-varying and different across moneyness. There are many ways to explain this implied volatility function. For example, we can generate time-varying implied volatilities and a volatility smile or smirk by relaxing the lognormal assumption of the Black and Scholes model.

Bollen and Whaley provide another hypothesis that can explain the observed implied volatility function: the net buying pressure hypothesis. That is, under this hypothesis, the implied volatility of a particular option series is determined by the demand and the supply of the option series. This hypothesis can be backed by the limits of arbitrage argument by Shleifer and Vishny. An alternative hypothesis is the learning hypothesis. According to this hypothesis, the supply curve of an option series is flat, and so only the supply shock or new information on future volatility of the option series will change the implied volatility of the option series. Bollen and Whaley implicitly assume that option traders are volatility traders, and test these hypotheses in their study by looking at the relations between the net buying pressure of options and implied volatility using daily data.

We show in this paper that option traders are directional traders rather than volatility traders.

They buy call options when stock prices are expected to rise, and they buy put options when stock prices are expected to decline. Thus, positive net buying pressure on call options increases call prices and decreases put prices, while positive net buying pressure on put options increases put prices and decreases call prices. In addition, we document the fact that we can predict that stock returns will increase (decrease) for the next 5 minute interval as well as for the current 5 minute interval when we observe positive (negative) net buying pressure on call options. On the other hand, when we observe positive (negative) net buying pressure on put options, we can predict that stock returns will decrease (increase) for the next 5 minute interval as well as for the current 5 minute interval.

In conclusion, we support the learning hypothesis, and document the fact that option traders in the KOSPI200 options market are directional traders rather than volatility traders.

References

Ait-Sahalia, Y., Wang, Y. and Yared, F. (2001). "Do Option Markets correctly Price the Probabilities of Movement of the Underlying Asset? ", *Journal of Econometrics* 102: 67-110.

Bakshi, Cao and Chen, (1997) "Empirical Performance of Alternative Option Pricing Models", *Journal of Finance* 52, No. 5, 2003-2049.

Bates, D. (1996) "Jumps and Stochastic Volatility: Exchange Rate Processes Implicit in Deutsche Mark Options," *Review of Financial Studies* 9:1, 69-107.

Black, Fisher, (1976) "Studies of stock price volatility changes", *Proceedings of the 1976 Meetings of the Business and Economics Section, American Statistical Association*, 177-181

Black, F., and M. Scholes., (1973) "The Pricing of Options and Corporate liabilities", *Journal of Political Economy* 81, 637-659.

Bollen, N.P.B and R. Whaley, (2004) "Does Net Buying Pressure Affect the Shape of Implied Volatility Functions? ",*Journal of Finance*, 59,711-753.

Campbell, J. and L. Hentschel, (1992), "No news is good news: An asymmetric model of changing volatility in stock returns", *Journal of Financial Economics* 31, 281-318.

Choe, H., Kho, B.C., and Stulz, R.M., (1999) "Do foreign investors destabilize stock markets? The Korean experience in 1997" *, Journal of Financial Economics*, 54, 227-264.

Chordia, T., Roll, R., and Subrahmanyam, A., (2002) "Order imbalance, liquidity and market returns" *, Journal of Financial Economics*, 65, 111-130.

Cherbov, M., and Ghysels, E.,(2000) "A study towards a unified approach to the joint estimation of objective and risk neutral measures for the purpose of options valuation," *Journal of Financial Economics*, 56, 407-458.

Derman, E., & Kani, I. (1994) "Riding the Smile", *Risk*, 7, 32-39.

Duffie, Pan and Singleton (2000) "Transform Analysis and Asset Pricing for Affine Jump Diffusions", *Econometrica,* 68, 1343-1376.

Duprire, B., (1994) "Pricing with a Smile", *Risk*, 7, 18-20.

Duan, J.C., (1995) "The GARCH Option Pricing Model", *Mathematical Finance* 5, 13-32.

Easley, D., O'Hara, M., Srinivas, P., (1998) " Option Volume and Stock Prices: evidence on where informed trader trade", *Journal of Finance* 53, 431-465.

Eraker., (2004) " Do Stock Prices and Volatility Jump? Reconciling Evidence from Spot and Option Prices ", *Journal of Finance* 59, 1367-1403

French, K., G.. W. Schwert, and R. Stambaugh, (1987), "Expected stock returns and volatility", *Journal of Financial Economics* 19, 3-30.

Heston, Steven L, (1993) "A Closed-Form Solution for Options with Stochastic Volatility with Applications to Bond and Currency Options," *Review of Financial Studies*, 6, 327-43.

Hentschel, L (2003), "Errors in implied volatility estimation", *Journal of Financial and Quantitative Analysis* 38,779-810.

Hull and White, (1987) "The pricing of options on assets with stochastic volatilities", *Journal of finance* 42, Issue 2.

Kang, J., S. Lee, and C. Lee, (2004), "The lead-lag relations of returns and volatilities among spot, futures, and options markets: A case of the KOSPI200 index markets", presented at the first Conference of the Asia-Pacific Association of Derivatives.

Kim, I. J., K. C. Kim and R. Ziskind, (1994) "On the Apparent Systematic Bias of Implied Volatility in the Black and Scholes Model," *Advances in Investment Analysis and Portfolio Management*, Vol. 2, 133-158.

Lee, Charles M.C. and Ready, M.J., (1991) "Inferring Trade Direction from Intraday Data", *Journal of finance*, 46, 733-746.

Liu, J. and F.A. Longstaff (2000), "Losing money on arbitrage: Optimal dynamic portfolio choice in markets with arbitrage opportunities", working paper, UCLA.

Lakonishok, J., Shleifer, A., and Vishny, R.W., (1992) "The impact of intuitional trading on stock prices", *Journal of Financial Economics*, 32, 23-43.

Mikkelson, W. H., and M. Partch (1985), "Stock price effects and costs of secondary distributions", *Journal of Financial Economics* 14, 165-194.

Naik, V and M. Lee (1990) "General Equilibrium Pricing of Options On the Market Portfolio with Discontinuous Returns", *Review of Financial Studies* 3, 493-521.

Pan, Jun. (2002), "The jump-risk premia implicit in option prices: Evidence from an integrated time-series study", *Journal of Financial Economics*, 63, 3-50

Poteshman, M., (2001), "Underreaction, overreaction, and increasing misreaction to information in the options market", *Journal of Finance* 56, 851-876.

Rubinstein, M. (1994) "Implied Binomial Trees", *Journal of Finance*, 49, 771-818.

Scholes, M., (1972) "The market for securities: Substitution versus price pressure and the effects of information on share price", *Journal of Business* 45, 179-211.

Shleifer, A. and R. Vishny, (1997) "The limit of arbitrage", *Journal of Finance*, 52, 35-55.

Stein, J., (1989) "Overreactions in the Options Market", *Journal of Finance,* 44, 1011-1023.

Table 1

Summary statistics of implied and realized volatilities of KOSPI200 index options

This table shows the definition of each moneyness category used by Bollen and Whaley(2004) and reports the descriptive statistics for implied volatility across the five moneyness. In calculating implied volatilities and deltas, the closing prices of KOSPI200 index are used. The sample period is from June 1,1998 to Feb 28, 2002. During the sample period, the realized volatility was 48.58%.

A) Terminology of Bollen and Whaley

Call Category		Delta range	Put Category		Delta range
1	DITM	$0.875 < \Delta_C \leq 0.98$	1	DOTM	$-0.125 < \Delta_P \leq -0.02$
2	ITM	$0.625 < \Delta_C \leq 0.875$	2	OTM	$-0.375 < \Delta_P \leq -0.125$
3	ATM	$0.375 < \Delta_C \leq 0.625$	3	ATM	$-0.625 < \Delta_P \leq -0.375$
4	OTM	$0.125 < \Delta_C \leq 0.375$	4	ITM	$-0.875 < \Delta_P \leq -0.625$
5	DOTM	$0.02 < \Delta_C \leq 0.125$	5	DITM	$-0.98 < \Delta_P \leq -0.875$

* DITM stands for Deep in-the-money, ITM is In-the-money, ATM is At-the-money, OTM is Out-of -the-money, and DOTM is Deep out-of-the-money.

B) Summary Statistics of Implied Volatilities

	Average Implied Volatility					Average difference between implied and realized volatility				
Category	1	2	3	4	5	1	2	3	4	5
Call	0.693	0.450	0.446	0.459	0.486	0.158	0.025	0.020	0.032	0.044
Put	0.533	0.472	0.466	0.482	0.681	0.095	0.046	0.040	0.053	0.148

Table 2
Summary statistics of KOSPI200 index options traded

These tables show the number of contracts traded, the trading volume of the KOSPI200 index options, and ownership information of each investor group. The sample period is from June 1,1998 to Feb 28, 2002. These statistics are from trading statistic reports of Korea Stock Exchange.

Panel A. Trading Volume of KOSPI200 options by Investor group.

	Classification	Individual	Institution	Foreigner	The rest	Totals
Call	Contracts for selling	1097461991 (0.66)	436544069 (0.26)	109786627 (0.07)	20601671 (0.01)	1664394358
	Contracts for buying	1125724355 (0.68)	407141531 (0.24)	111079257 (0.07)	20449215 (0.01)	1664394358
	Net Trade	28262364	-29402538	1292630	-152456	
Put	Contracts for selling	912972119 (0.69)	300917142 (0.23)	91375892 (0.07)	17219611 (0.01)	1322484764
	Contracts for buying	929281793 (0.70)	281431709 (0.21)	94941368 (0.07)	16829894 (0.01)	1322484764
	Net Trade	16309674	-19485433	3565476	-389717	

Panel B. Shareholdings by Investor group (unit: number of shares)

Investor Type	Individual	Institution	Foreigner
Number of Shares	286175254	569839667	346974896
Percentage	(0.24)	(0.47)	(0.29)

Table 3
The number of KOSPI200 index options traded

This table shows the number of contracts traded in the KOSPI200 options market and the net buying across the moneyness groups. The delta values are calculated by using the closing prices of KOSPI200 index, the yield to maturity of the Korea Treasury bond matching the option's time to maturity, and the historical volatility over the most recent sixty trading days. The sample period is from June 1,1998 to Feb 28, 2002. In Panel B, the net buying of contracts are defined as the number of contracts traded above the prevailing bid/ask midpoint less the number of contracts traded below the prevailing midpoint times the absolute value of the option's delta.

Delta Value	Call		Put	
Categorization	No. of Contract	Prop. of Total	No. of Contract	Prop. of Total
Panel A: Number of Contracts Traded				
1	2889680	0.002	205512000	0.162
2	20071600	0.016	293116000	0.231
3	99520200	0.078	52733100	0.041
4	394278000	0.310	10178700	0.008
5	190643000	0.150	1795180	0.001
Totals	707402480	0.557	563334980	0.443
Panel B: Net Buying of Contracts				
1	-9829		608676	
2	444775		2922536	
3	-592986		818967	
4	-2192300		333372	
5	-419975		137779	
Totals	-2770315		4821330	

Table 4

The number of KOSPI200 index options traded across investor types

This table shows the number of contracts traded in the KOSPI200 options market and the net buying across investor types. The delta values are calculated by using the closing prices of KOSPI200 index, the yield to maturity of the Korea Treasury bond matching the option's time to maturity, and the historical volatility over the most recent sixty trading days. The sample period is from June 1, 1998 to Feb 28, 2002. All trades are allocated into three investor groups using a trader indicator. The trade indicator allocates each trade to one of investor types, institutional, individual or foreign investors, by which group the trader who enters into or quotes the trade than the counterparty faster belongs to. In Panel B, the net buying of contracts across investor types are defined as the number of contracts traded above the prevailing bid/ask midpoint less the number of contracts traded below the prevailing midpoint times the absolute value of the option's delta.

Delta Value Categorization	Individual Investors				Institutional Investors				Foreign Investors			
	Call		Put		Call		Put		Call		Put	
	No. of Contract	Prop. of Total	No. of Contract	Prop. of Total	No. of Contract	Prop. of Total	No. of Contract	Prop. of Total	No. of Contract	Prop. of Total	No. of Contract	Prop. of Total
Panel A: Number of Contracts Traded												
1	1113600	0.001	147720000	0.116	1198200	0.001	41545000	0.033	577880	0.000	16247000	0.013
2	10683000	0.008	202630000	0.159	7017700	0.006	69868000	0.055	2370900	0.002	20618000	0.016
3	58344000	0.046	31238000	0.025	31909000	0.025	15821000	0.012	9267200	0.007	5674100	0.004
4	260890000	0.205	5345000	0.004	108280000	0.085	3557400	0.003	25108000	0.020	1276300	0.001
5	130560000	0.103	772190	0.001	47159000	0.037	656080	0.001	12924000	0.010	366910	0.000
Totals		0.363		0.305		0.154		0.103		0.040		0.035
Panel B: Net Buying of Contracts												
1	50297		217330		-18073		394370		-42053		-3024	
2	-45515		1166600		273970		1719400		216320		36536	
3	-69946		734820		-347460		104390		-175580		-20243	
4	-153330		218270		-1713900		28476		-325070		86626	
5	-54114		-78297		-428200		135850		62339		80226	
Totals	-272608		2258723		-2233663		2382486		-264044		180121	

Table 5

The Correlations of Net Buying Pressure in the KOSPI200 Index Calls and Puts

For call options, Delta value 2 is ITM, Delta value 3 is ATM, and Delta value 4 is OTM option. For Put options, Delta value 2 is OTM, Delta value 3 is ATM, Delta value 4 is ITM option. The sample period is from June 1,1998 to Feb 28, 2002. The upper triangular part of the table shows the correlations among the net buying pressure of put options, while the lower triangular part of the table shows the correlations among the net buying pressure of call options.

		Put Option's Net Buying Pressure											
		Total			Individual			Institution			Foreigner		
Call Option's Net Buying Pressure	Delta Categorization	2	3	4	2	3	4	2	3	4	2	3	4
Total	2		0.358	0.247	0.918	0.329	0.260	0.757	0.249	0.154	0.275	0.043	0.045
	3	0.207		0.165	0.344	0.826	0.127	0.259	0.753	0.119	0.063	0.243	0.072
	4	0.282	0.389		0.245	0.185	0.682	0.180	0.118	0.774	0.013	-0.063	0.477
Individual	2	0.807	0.202	0.251		0.319	0.252	0.492	0.234	0.153	0.048	0.043	0.051
	3	0.226	0.867	0.329	0.202		0.124	0.233	0.367	0.098	0.055	-0.130	0.163
	4	0.291	0.374	0.917	0.252	0.315		0.198	0.088	0.230	0.015	-0.004	0.019
Institution	2	0.796	0.144	0.234	0.399	0.162	0.241		0.173	0.101	0.148	0.052	0.037
	3	0.136	0.787	0.328	0.139	0.472	0.310	0.094		0.117	0.079	0.078	0.004
	4	0.157	0.276	0.720	0.148	0.219	0.432	0.125	0.235		0.027	-0.014	0.163
Foreigner	2	0.454	0.061	0.065	0.078	0.093	0.081	0.233	0.027	0.028		-0.044	-0.029
	3	-0.018	0.261	0.084	0.017	-0.053	0.093	-0.026	0.090	0.094	-0.053		-0.144
	4	0.022	0.026	0.237	0.033	0.059	0.006	0.029	0.037	0.153	-0.040	-0.117	

Table 6

The Correlations of Net Buying Pressure between Calls and Puts

For call options, Delta value 2 is ITM, Delta value 3 is ATM, and Delta value 4 is OTM option. For Put options, Delta value 2 is OTM, Delta value 3 is ATM, Delta value 4 is ITM option. The sample period is from June 1, 1998 to Feb 28, 2002.

			Put Option's Net Buying Pressure											
			Total			Individual			Institution			Foreigner		
		Delta Categorization	2	3	4	2	3	4	2	3	4	2	3	4
Call Option's Net Buying Pressure	Total	2	-0.387	-0.133	-0.240	-0.045	-0.024	-0.019	-0.031	-0.026	-0.011	-0.003	-0.019	-0.037
		3	-0.476	-0.460	-0.096	-0.107	-0.062	-0.021	-0.071	-0.049	-0.023	-0.031	-0.007	-0.019
		4	-0.677	-0.376	-0.236	-0.190	-0.126	-0.025	-0.127	-0.103	-0.034	-0.037	-0.043	-0.035
	Individual	2	-0.322	-0.114	-0.229	-0.041	-0.027	-0.017	-0.037	-0.026	-0.010	-0.005	-0.015	-0.004
		3	-0.426	-0.395	-0.083	-0.100	-0.057	-0.022	-0.065	-0.032	-0.018	-0.018	-0.013	-0.011
		4	-0.643	-0.355	-0.244	-0.175	-0.126	-0.026	-0.118	-0.094	-0.027	-0.009	-0.037	-0.030
	Institution	2	-0.321	-0.101	-0.162	-0.022	-0.020	-0.017	-0.022	-0.030	-0.012	-0.009	-0.020	0.007
		3	-0.360	-0.418	-0.072	-0.089	-0.045	-0.012	-0.064	-0.044	-0.022	-0.026	-0.005	-0.010
		4	-0.514	-0.273	-0.159	-0.165	-0.081	-0.018	-0.095	-0.077	-0.034	-0.063	-0.030	-0.032
	Foreigner	2	-0.110	-0.045	-0.076	-0.032	0.004	-0.002	0.007	0.014	0.005	0.013	-0.002	-0.120
		3	-0.160	-0.080	-0.042	-0.010	-0.021	-0.006	-0.002	-0.035	-0.006	-0.029	0.015	-0.026
		4	-0.162	-0.127	-0.018	-0.029	-0.034	-0.001	-0.046	-0.045	-0.013	-0.049	-0.035	-0.009

Table 7

Daily regression results for the impact of the net buying pressure on changes in the implied volatility of ATM options

The regression models are specified as follows: $\Delta\sigma_t = \alpha_0 + \alpha_1 RS_t + \alpha_2 VS_t + \alpha_3 D_{1,t} + \alpha_4 D_{2,t} + \alpha_5 \Delta\sigma_{t-1} + \varepsilon_t$ where $\Delta\sigma_t$ is the daily change of the option's implied volatility at time t and RS_t is the daily return of KOSPI200 Index. The returns of the index are estimated by the closing prices of index. VS_t is the trading volume of the index at time t, and $D_{1,t}$ and $D_{2,t}$ are the daily net buying pressures at time t. Panel A contains the results for the change in the implied volatility of ATM call options, and panel B contains the results for the change in the implied volatility of ATM put options. An asterisk * is attached when the coefficient is significant at the 5% significance level. The sample period is from June 1, 1998 to Feb 28, 2002

Panel A: Changes in ATM Call Volatility as a Function of D_1 and D_2								
			Parameter Estimates					
D_1	D_2	Adj. R^2	α_0	α_1	α_2	α_3	α_4	α_5
TNBP_ATMC[+]	TNBP_ATMP	0.142	0.004	-0.132	-0.001	0.016	-0.041*	-0.334*
INBP_ATMC	INBP_ATMP	0.123	0.002	-0.133	-0.001	0.026	-0.032	-0.329*
SNBP_ATMC	SNBP_ATMP	0.133	0.002	-0.122	-0.001	0.019	-0.051	-0.333*
FNBP_ATMC	FNBP_ATMP	0.094	0.001	0.040	-0.001	-0.007	-0.037	-0.302*
Panel B: Changes in ATM Put Volatility as a Function of D_1 and D_2								
TNBP_ATMP	TNBP_ATMC	0.124	0.000	-0.440	0.002	-0.037	-0.001	-0.308*
INBP_ATMP	INBP_ATMC	0.117	-0.001	-0.454	0.002	-0.042	0.002	-0.305*
SNBP_ATMP	SNBP_ATMC	0.115	-0.002	-0.478*	0.001	-0.032	0.005	-0.305*
FNBP_ATMP	FNBP_ATMC	0.128	-0.001	-0.452*	0.000	-0.011	-0.006	-0.316*

[+]Note: TNBP_ATMC stands for total investor's net buying pressure on at-the-money call options, INBP_ATMC for individual investor's net buying pressure on at-the-money call options, SNBP_ATMC for institutional investor's net buying pressure on at-the-money call options, and FNBP_ATMC for foreign investor's net buying pressure on at-the-money call options. In the same way, TNBP_ATMP stands for total investor's net buying pressure on at-the-money put options.

Table 8

Daily regression results for the impact of the net buying pressure on changes in the implied volatility of OTM options

The regression models are specified as follows: $\Delta\sigma_t = \alpha_0 + \alpha_1 RS_t + \alpha_2 VS_t + \alpha_3 D_{1,t} + \alpha_4 D_{2,t} + \alpha_5 \Delta\sigma_{t-1} + \varepsilon_t$ where $\Delta\sigma_t$ is the daily change of the option's implied volatility at time t and RS_t is the daily return of KOSPI200 Index. The returns of the index are estimated by the closing prices of index. VS_t is the trading volume of the index at time t, and $D_{1,t}$ and $D_{2,t}$ are the daily net buying pressures at time t. Panel A contains the results for the change in the implied volatility of OTM call options, and panel B contains the results for the change in the implied volatility of OTM put options. An asterisk * is attached when the coefficient is significant at the 5% significance level. The sample period is from June 1, 1998 to Feb 28, 2002

D_1	D_2	Adj. R^2	Parameter Estimates α_0	α_1	α_2	α_3	α_4	α_5
Panel A: Changes in OTM Call Volatility as a Function of D_1 and D_2								
TNBP_OTMC[+]	TNBP_ATMC	0.095	0.001	-0.405*	0.001	0.010	0.004	-0.251*
TNBP_OTMC	TNBP_ATMP	0.112	0.003	-0.365*	0.001	0.011*	-0.031*	-0.263*
INBP_OTMC	INBP_ATMC	0.094	-0.001	-0.405*	0.000	0.014*	0.005	-0.244*
INBP_OTMC	INBP_ATMP	0.100	0.000	-0.369*	0.001	0.016*	-0.025	-0.257*
SNBP_OTMC	SNBP_ATMC	0.093	0.003	-0.399*	0.001	0.018*	0.010	-0.244*
SNBP_OTMC	SNBP_ATMP	0.107	0.003	-0.342*	0.001	0.020*	-0.044*	-0.261*
FNBP_OTMC	FNBP_ATMC	0.078	-0.002	-0.164	0.000	0.027*	-0.010	-0.255*
FNBP_OTMC	FNBP_ATMP	0.041	-0.002	-0.003	0.000	-0.023	-0.018	-0.178*
Panel B: Changes in OTM Put Volatility as a Function of D_1 and D_2								
TNBP_OTMP	TNBP_ATMC	0.110	-0.001	-0.384*	0.002	-0.005	0.008	-0.283*
TNBP_OTMP	TNBP_ATMP	0.110	-0.002	-0.358*	0.002	0.000	-0.020	-0.285*
INBP_OTMP	INBP_ATMC	0.106	-0.002	-0.366*	0.002	-0.007	0.005	-0.283*
INBP_OTMP	INBP_ATMP	0.106	-0.002	-0.365*	0.002	-0.005	-0.003	-0.283*
SNBP_OTMP	SNBP_ATMC	0.112	-0.001	-0.400*	0.002	-0.007	0.016	-0.282*
SNBP_OTMP	SNBP_ATMP	0.108	-0.002	-0.364*	0.002	-0.005	-0.017	-0.283*
FNBP_OTMP	FNBP_ATMC	0.093	-0.003	-0.201	0.001	0.003	0.001	-0.294*
FNBP_OTMP	FNBP_ATMP	0.113	-0.002	-0.348*	0.001	0.001	-0.022	-0.279*

[+]Note: TNBP_OTMC stands for total investor's net buying pressure on out-of-the-money call options; INBP_OTMC for individual investor's net buying pressure on out-of-the-money call options, SNBP_OTMC for institutional investor's net buying pressure on out-of-the-money call options, and FNBP_OTMC for foreign investor's net buying pressure on out-of-the-money call options. TNBP_OTMP, TNBP_OTMP, TNBP_OTMP and TNBP_OTMP are defined similarly.

Table 9

Intraday regression results for the impact of the net buying pressure on the changes of implied volatility in ATM options

The regression models are specified as below:

$$\Delta\sigma_t = \alpha_0 + \alpha_1 RS_t + \alpha_2 VS_t + \alpha_3 D_{1,t} + \alpha_4 D_{2,t} + \alpha_5 \Delta\sigma_{t-1} + \varepsilon_t$$ in Panel A and B,

$$\Delta\sigma_t = \alpha_0 + \alpha_1 RS_t + \alpha_2 VS_t + \alpha_3 D_{1,t} + \alpha_4 D_{2,t} + \alpha_5 \Delta\sigma_{t+1} + \varepsilon_t$$ in Panel C and D,

where $\Delta\sigma_t$ is the change in the implied volatility of an option over 5-minute interval t, and RS_t is the return of KOSPI200 Index over 5-minute interval t. The returns of the index and futures are estimated by the mean values in 5- minute intervals. VS_t is the summed trading volumes of the index at 5-minute interval t and $D_{1,t}$ and $D_{2,t}$ are summed net buying pressures at 5-minute interval t. Panel A and C contain the results for the change in the implied volatility of ATM call options, and panel B and D contain the results for the change in the implied volatility of ATM put options. An asterisk * is attached when the coefficient is significant at the 5% significance level. The sample period is from June 1,1998 to Feb 28, 2002

Panel A: Changes in ATM Call Volatility as a Function of D_1 and D_2: $\Delta\sigma_t = \alpha_0 + \alpha_1 RS_t + \alpha_2 VS_t + \alpha_3 D_{1,t} + \alpha_4 D_{2,t} + \alpha_5 \Delta\sigma_{t-1} + \varepsilon_t$									
		Parameter Estimates							
D_1	D_2	No. of Obs.	Adj. R^2	α_0	α_1	α_2	α_3	α_4	α_5
EXTREME_TNBP_ATMC$^+$	EXTREME_TNBP_ATMP	3686	0.102	0.000	-2.172*	-0.038*	0.006*	-0.011	-0.116*
EXTREME_INBP_ATMC	EXTREME_INBP_ATMP		0.102	0.000	-2.159*	-0.038*	0.015*	0.001	-0.117*
EXTREME_SNBP_ATMC	EXTREME_SNBP_ATMP		0.103	0.000	-2.181*	-0.039*	0.015*	-0.031*	-0.115*
EXTREME_FNBP_ATMC	EXTREME_FNBP_ATMP		0.100	0.000	-2.086*	-0.039*	0.024*	-0.014	-0.118*
Panel B: Changes in ATM Put Volatility as a Function of D_1 and D_2: $\Delta\sigma_t = \alpha_0 + \alpha_1 RS_t + \alpha_2 VS_t + \alpha_3 D_{1,t} + \alpha_4 D_{2,t} + \alpha_5 \Delta\sigma_{t-1} + \varepsilon_t$									
EXTREME_TNBP_ATMP	EXTREME_TNBP_ATMC	3518	0.072	-0.001*	1.713*	0.023	0.018*	-0.019*	-0.020
EXTREME_INBP_ATMP	EXTREME_INBP_ATMC		0.069	-0.001*	1.673*	0.022	0.026*	-0.025*	-0.020
EXTREME_SNBP_ATMP	EXTREME_SNBP_ATMC		0.070	-0.001*	1.684*	0.024	0.035*	-0.042*	-0.020
EXTREME_FNBP_ATMP	EXTREME_FNBP_ATMC		0.056	-0.001*	1.572*	0.022	0.017	-0.013	-0.019

- continued

Panel C: Changes in ATM Call Volatility as a Function of D_1 and D_2: $\Delta\sigma_t = \alpha_0 + \alpha_1 RS_t + \alpha_2 VS_t + \alpha_3 D_{1,t} + \alpha_4 D_{2,t} + \alpha_5 \Delta\sigma_{t+1} + \varepsilon_t$									
		Parameter Estimates							
D_1	D_2	No. of Obs.	Adj. R^2	α_0	α_1	α_2	α_3	α_4	α_5
EXTREME_TNBP_ATMC+	EXTREME_TNBP_ATMP	3686	0.109	0.000	-2.251*	-0.027	0.005	-0.009	-0.136*
EXTREME_INBP_ATMC	EXTREME_INBP_ATMP		0.109	0.000	-2.242*	-0.027	0.012*	0.002	-0.136*
EXTREME_SNBP_ATMC	EXTREME_SNBP_ATMP		0.110	0.000	-2.264*	-0.028	0.011*	-0.030*	-0.136*
EXTREME_FNBP_ATMC	EXTREME_FNBP_ATMP		0.108	0.000	-2.183*	-0.028	0.022*	-0.002	-0.140*
Panel D: Changes in ATM Put Volatility as a Function of D_1 and D_2: $\Delta\sigma_t = \alpha_0 + \alpha_1 RS_t + \alpha_2 VS_t + \alpha_3 D_{1,t} + \alpha_4 D_{2,t} + \alpha_5 \Delta\sigma_{t+1} + \varepsilon_t$									
EXTREME_TNBP_ATMP	EXTREME_TNBP_ATMC	3518	0.084	-0.001*	1.786*	0.020	0.015*	-0.019*	-0.111*
EXTREME_INBP_ATMP	EXTREME_INBP_ATMC		0.080	-0.001*	1.748*	0.019	0.021*	-0.024*	-0.111*
EXTREME_SNBP_ATMP	EXTREME_SNBP_ATMC		0.082	-0.001*	1.766*	0.022	0.032*	-0.040*	-0.115*
EXTREME_FNBP_ATMP	EXTREME_FNBP_ATMC		0.070	-0.001*	1.667*	0.019	0.017	-0.014	-0.122*

+Note: EXTREME_TNBP_ATMC stands for significantly large total investor's net buying pressure on at-the-money call options. Specifically, EXTREME_TNBP_ATMC is the net buying pressure which is outside the two standard deviation from the average of the whole sample of 5-minute net buying pressures.; EXTREME_INBP_ATMC is significantly large individual's net buying pressure on at-the-money options, EXTREME_SNBP_ATMC is significantly large institutional investor's net buying pressure on at-the-money call options, and EXTREME_FNBP_ATMC is significantly large foreign investor's net buying pressure on at-the-money call options. EXTREME_TNBP_ATMP, EXTREME_INBP_ATMP, EXTREME_SNBP_ATMP, and EXTREME_FNBP_ATMP are defined similarly.

Table 10

Relation between net buying pressure and the KOSPI200 index returns

The estimation of the relation between net buying pressure on options and returns of KOSPI200 index is based on a regression of the following form:

$$EXTREME\_NBP_t = \alpha_0 + \sum_{i=-2}^{2} \alpha_{i+3} r_{t+i} + \alpha_6 EXTREME\_NBP_{t-1} + \varepsilon_t$$

where *EXTREME_NBP*$_t$ is the net buying pressure over the five minute interval t which is outside two standard deviation from the average of the whole sample of 5-minute net buying pressures, r_t is the return of the KOSPI200 index over the five minute interval t. An asterisk * is attached when the coefficient is significant at the 5% significance level.

Category	Investor type	α_0	α_1	α_2	α_3	α_4	α_5	α_6
Panel A. Relations between Call option's net buying pressure and returns of the KOSPI200 index								
		Parameter Estimates						
ITM	Total	0.01	-0.62	-1.98	1.68	9.77*	-2.59	-0.04
	Individual	0.00	-0.94	-1.36	1.44	4.89*	-1.32	-0.01
	Institutional	0.00	0.68	-0.56	0.69	3.72*	-0.59	-0.02
	Foreigner	0.00*	-0.35	-0.04	-0.63	1.36*	-0.78*	0.38*
ATM	Total	0.00	-0.10	-0.52	2.69	10.29*	-2.14	0.11
	Individual	0.00	-0.55	-0.56	1.02	5.98*	-0.96	0.16
	Institutional	0.00	0.26	0.38	1.10	3.93*	-0.77	0.08
	Foreigner	0.00	0.14	-0.41	0.45	0.42*	-0.44*	0.46*
OTM	Total	0.00	-0.28	-0.70	4.69	13.61*	-3.14	-0.03
	Individual	0.00	-0.57	-0.96	3.11	9.04*	-1.91	-0.04
	Institutional	0.00*	0.02	0.16	0.81	4.28*	-1.26	0.05
	Foreigner	0.00	0.22	-0.15	0.67*	0.34*	-0.04	0.33*
Panel B. Relations between Put option's net buying pressure and returns of the KOSPI200 index								
ITM	Total	-0.01	1.70	1.78	-1.59	-5.99*	2.30	0.21*
	Individual	0.00	0.34	1.13	-1.42*	-2.49*	1.22*	-0.18*
	Institutional	0.00	0.67	0.29	-0.22	-2.73*	0.61	0.62*
	Foreigner	0.00*	0.46*	0.38*	-0.23	-0.21	0.32	0.76*
ATM	Total	0.00	0.05	0.28	-1.43	-7.32*	1.18	0.00
	Individual	0.00	0.63	0.30	-0.29	-4.52*	0.82	0.12*
	Institutional	0.00	-0.36	0.07	-0.45	-2.57*	0.29	0.23*
	Foreigner	0.00	-0.11	-0.01	-0.13	-0.41*	0.17	0.17*
OTM	Total	-0.01	0.36	0.30	-3.27	-10.25*	2.22	-0.02
	Individual	0.00	0.65	0.55	-1.96	-6.92*	1.35	-0.02
	Institutional	0.00	-0.10	-0.05	-0.64	-2.92*	0.65	0.07
	Foreigner	0.00	-0.11	-0.07	-0.50*	-0.46*	0.26*	0.27*

Table 11

Intraday regression results for the impact of the net buying pressure on in the implied volatility of OTM options

The regression models are specified as below: $\Delta\sigma_t = \alpha_0 + \alpha_1 RS_t + \alpha_2 VS_t + \alpha_3 D_{1,t} + \alpha_4 D_{2,t} + \alpha_5 \Delta\sigma_{t-1} + \varepsilon_t$ where $\Delta\sigma_t$ is the change in the implied volatility of an option over 5-minute interval t, and RS_t is the return of KOSPI200 Index over 5-minute interval t. The returns of the index are estimated by the mean values in 5-minute intervals. VS_t is the summed trading volume of the index at 5-minute interval t, and $D_{1,t}$ and $D_{2,t}$ are summed net buying pressures at 5-minute interval t. Panel A contains the results for the change in the implied volatility of OTM call options, and panel B contains the results for the change in the implied volatility of OTM put options. An asterisk * is attached when the coefficient is significant at the 5% significance level. The sample period is from June 1,1998 to Feb 28, 2002.

D_1	D_2	No. of Obs.	Adj. R^2	Parameter Estimates α_0	α_1	α_2	α_3	α_4	α_5
Panel A: Changes in OTM Call Volatility as a Function of D_1 and D_2									
EXTREME_TNBP_OTMC+	EXTREME_TNBP_ATMC	5857	0.105	0.000*	-1.318*	-0.015*	0.008*	0.002	0.015
EXTREME_TNBP_OTMC	EXTREME_TNBP_ATMP		0.106	-0.001*	-1.321*	-0.015*	0.008*	-0.011*	0.015
EXTREME_INBP_OTMC	EXTREME_INBP_ATMC		0.104	-0.001*	-1.300*	-0.015*	0.009*	0.007*	0.015
EXTREME_INBP_OTMC	EXTREME_INBP_ATMP		0.104	-0.001*	-1.299*	-0.015*	0.009*	-0.015*	0.015
EXTREME_SNBP_OTMC	EXTREME_SNBP_ATMC		0.104	0.000*	-1.297*	-0.016*	0.022*	0.007*	0.016
EXTREME_SNBP_OTMC	EXTREME_SNBP_ATMP		0.105	0.000*	-1.303*	-0.015*	0.022*	-0.022*	0.016
EXTREME_FNBP_OTMC	EXTREME_FNBP_ATMC		0.094	-0.001*	-1.217*	-0.015*	-0.005	-0.001	0.017
EXTREME_FNBP_OTMC	EXTREME_FNBP_ATMP		0.094	-0.001*	-1.218*	-0.015*	-0.005	-0.018*	0.017
Panel B: Changes in OTM Put Volatility as a Function of D_1 and D_2									
EXTREME_TNBP_OTMP	EXTREME_TNBP_ATMC	5888	0.075	-0.001*	1.096*	-0.018*	0.013*	-0.003*	0.001
EXTREME_TNBP_OTMP	EXTREME_TNBP_ATMP		0.076	-0.001*	1.097*	-0.018*	0.012*	0.011*	0.002
EXTREME_INBP_OTMP	EXTREME_INBP_ATMC		0.074	-0.001*	1.076*	-0.017*	0.017*	-0.003	0.000
EXTREME_INBP_OTMP	EXTREME_INBP_ATMP		0.074	-0.001*	1.074*	-0.017*	0.017*	0.009*	0.000
EXTREME_SNBP_OTMP	EXTREME_SNBP_ATMC		0.073	-0.001*	1.071*	-0.018*	0.032*	-0.015*	0.002
EXTREME_SNBP_OTMP	EXTREME_SNBP_ATMP		0.073	0.000*	1.073*	-0.020*	0.033*	0.028*	0.003
EXTREME_FNBP_OTMP	EXTREME_FNBP_ATMC		0.060	-0.001*	0.980*	-0.017*	-0.007	-0.009*	0.001
EXTREME_FNBP_OTMP	EXTREME_FNBP_ATMP		0.060	-0.001*	0.979*	-0.017*	-0.005	0.016*	0.001

+Note: EXTREME_TNBP_ATMC stands for significantly large total investor's net buying pressure on at-the-money call options. Specifically, EXTREME_TNBP_ATMC is the net buying pressure which is outside the two standard deviations from the average of the whole sample of 5-minute net buying pressures. The other variables are defined similarly.

Figure 1
KOSPI200 index level and its options' implied volatilities

The daily closing price of KOSPI index is used as the value of the index. The sample period is from June 1,1998 to Feb 28, 2002.

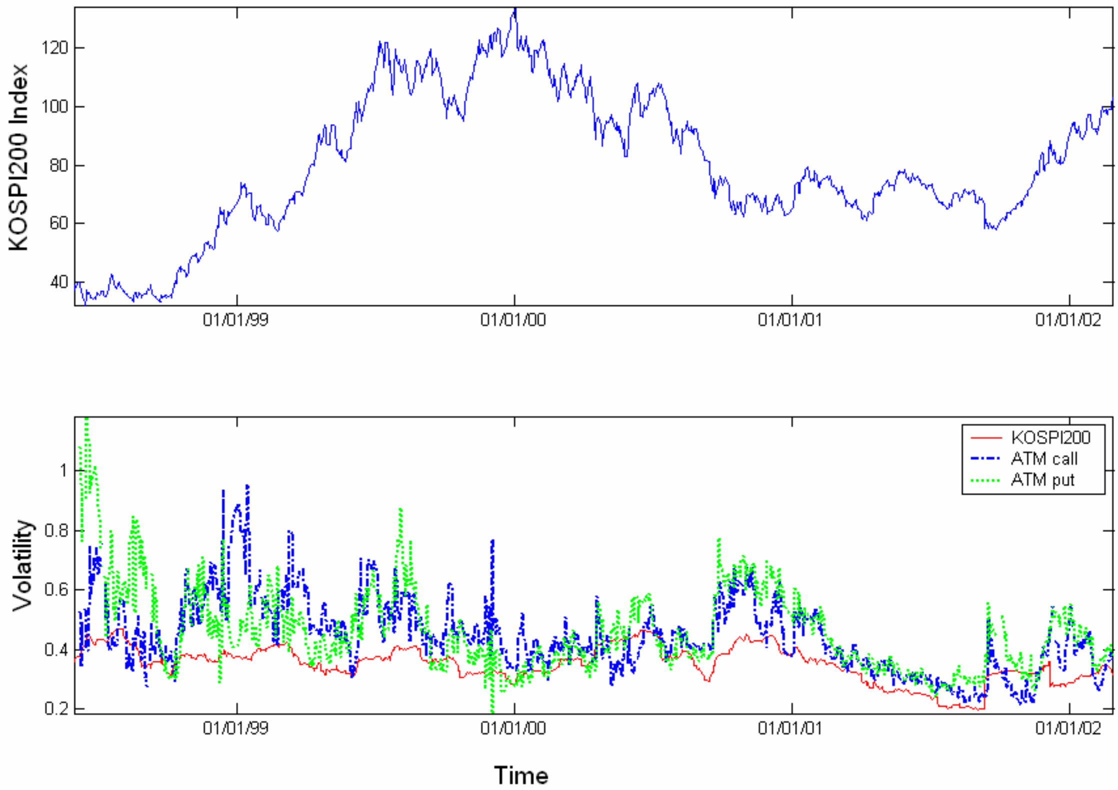
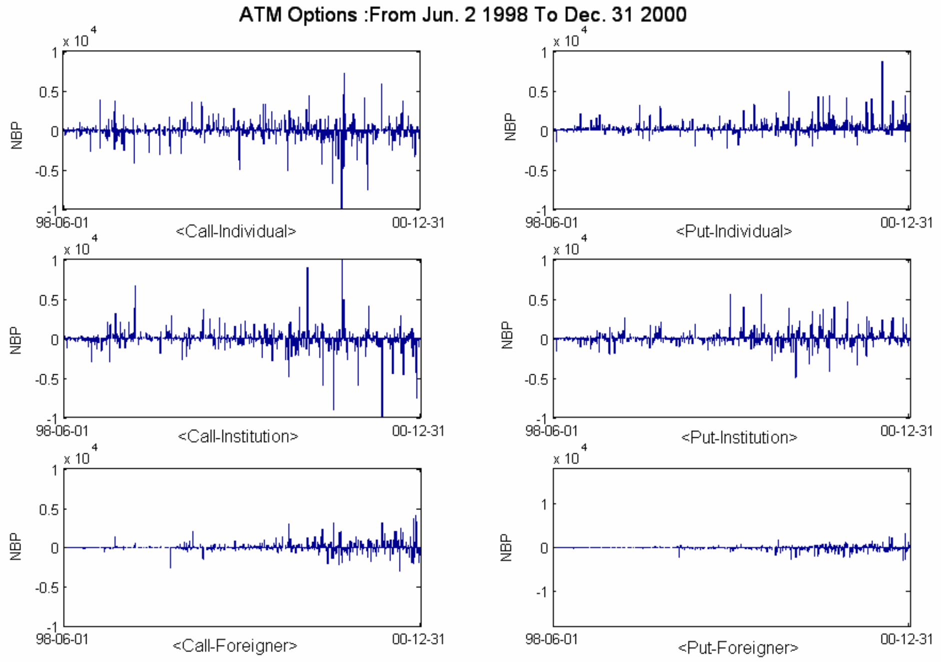
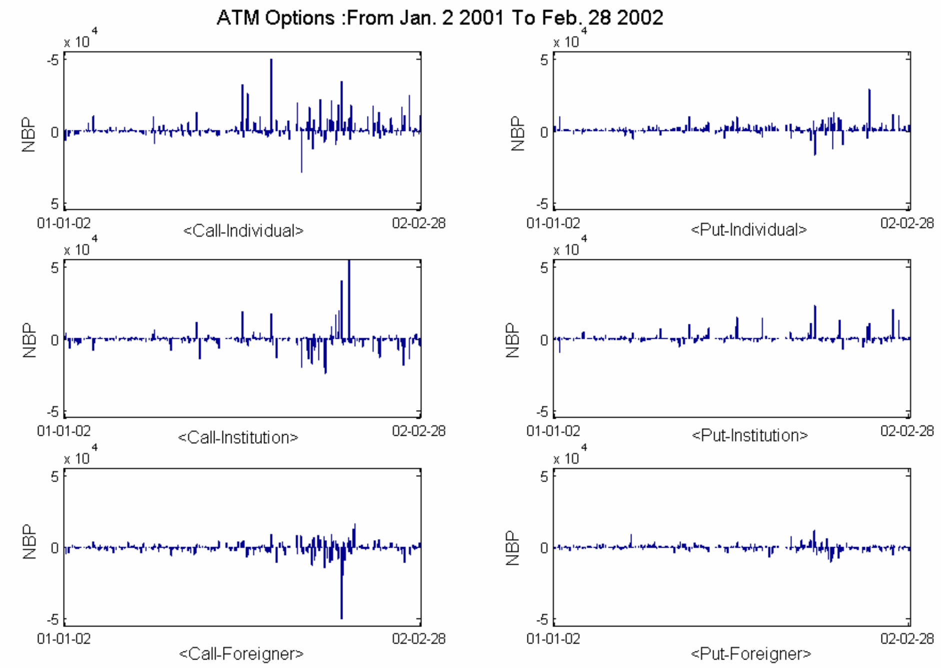


Figure 2
Time-series of net buying pressure across investor types

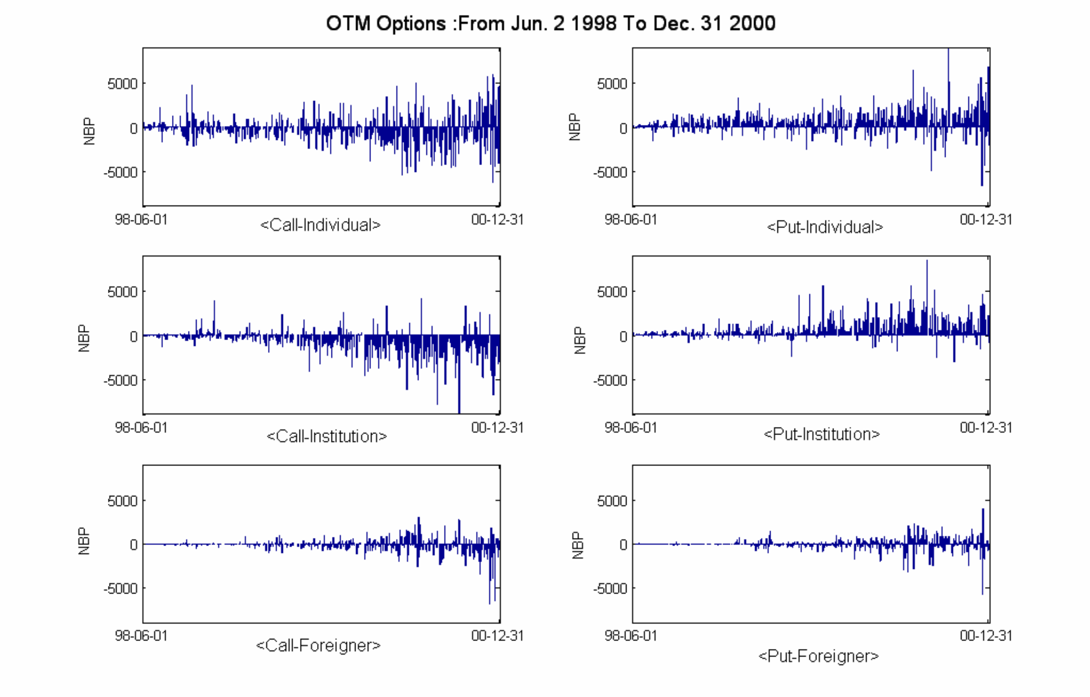
Figures below show net buying pressure on KOSPI200 index options across investor types; individual investors, institutional investors, and foreign investors. The sample period is divided into two sub periods; one is from June 2, 1998 to Dec 31, 2000 and the other is from Jan 2, 2001 to Feb 28, 2002. Panel A shows the time series of net buying pressure on ATM options and panel B shows the time series of net buying pressures on OTM options.

Panel A. Time series of net buying pressure on ATM options across investor groups





Panel B. Time series of net buying pressure on OTM options across investor groups



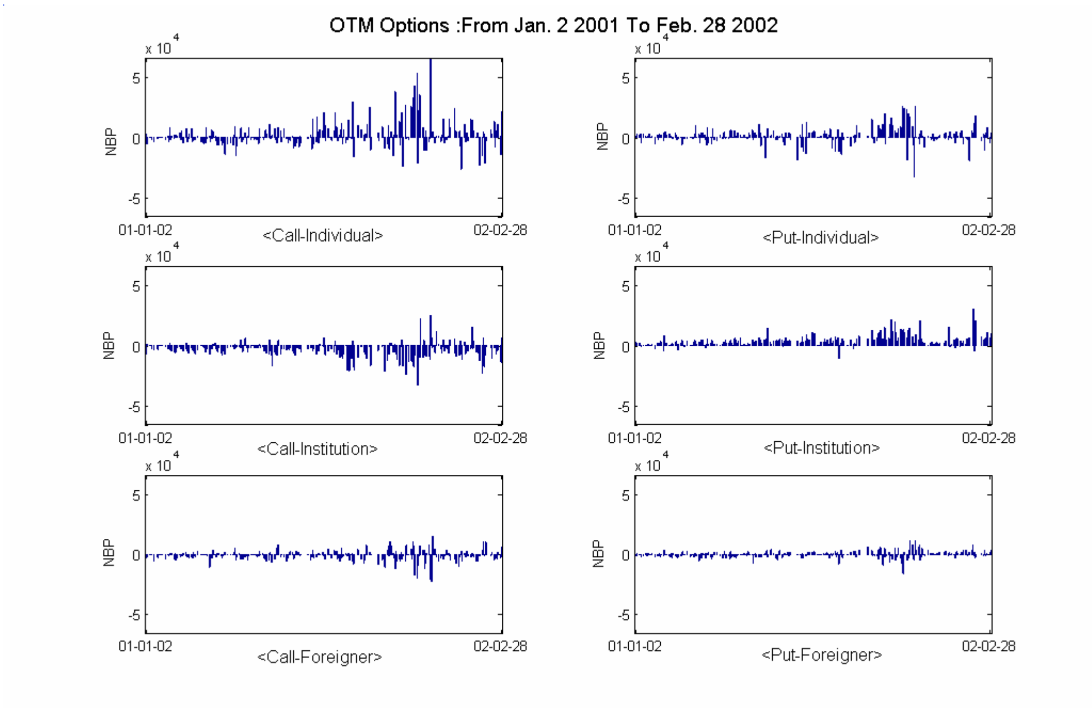
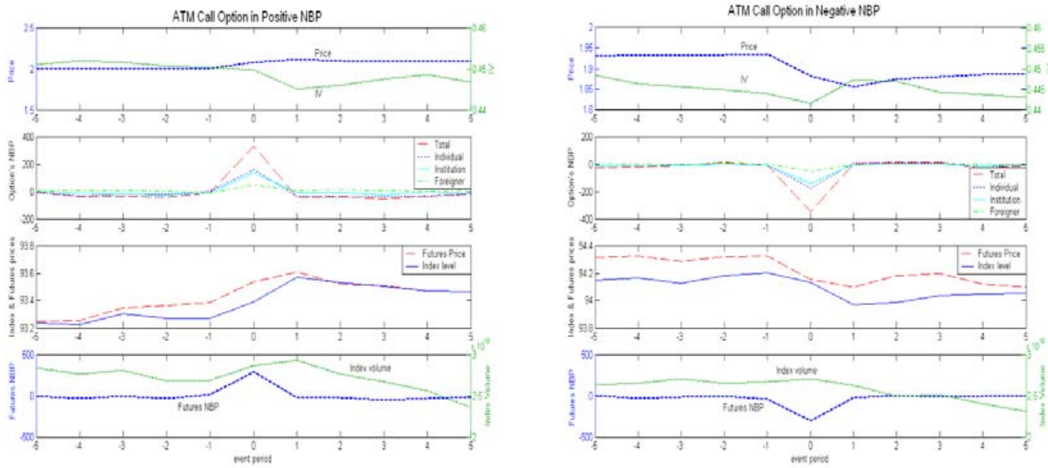


Figure 3
Impacts of the EXTREME_NBP on ATM options

Figures below show the movements of prices or net buying pressure around the event interval, where the event interval is defined as the interval where the absolute value of the net buying pressure of ATM options of interest lies out the two standard deviation from the average of 5-minute net buying pressure in our sample. The length of each interval is 5 minutes long. The sample period is from June 1,1998 to Feb 28, 2002.

Panel A. Impact on ATM Call options



Panel B. Impact on ATM Put options

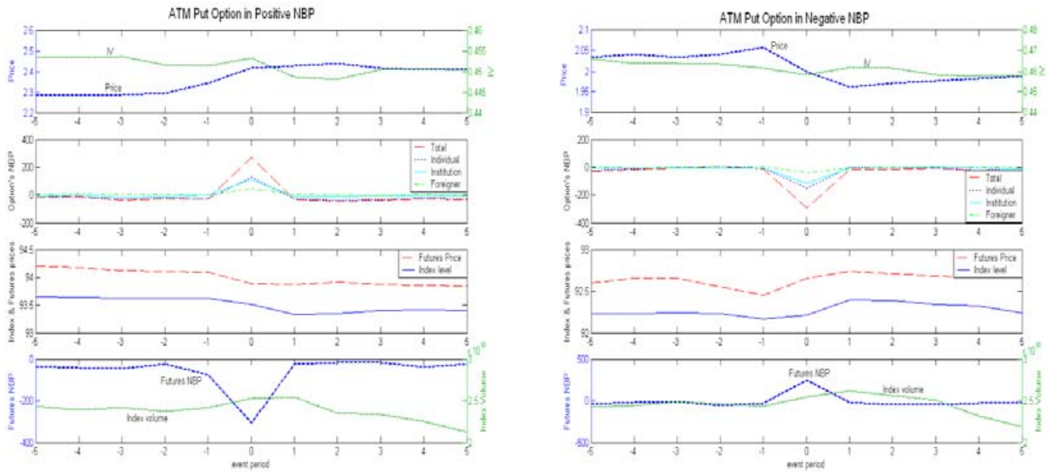
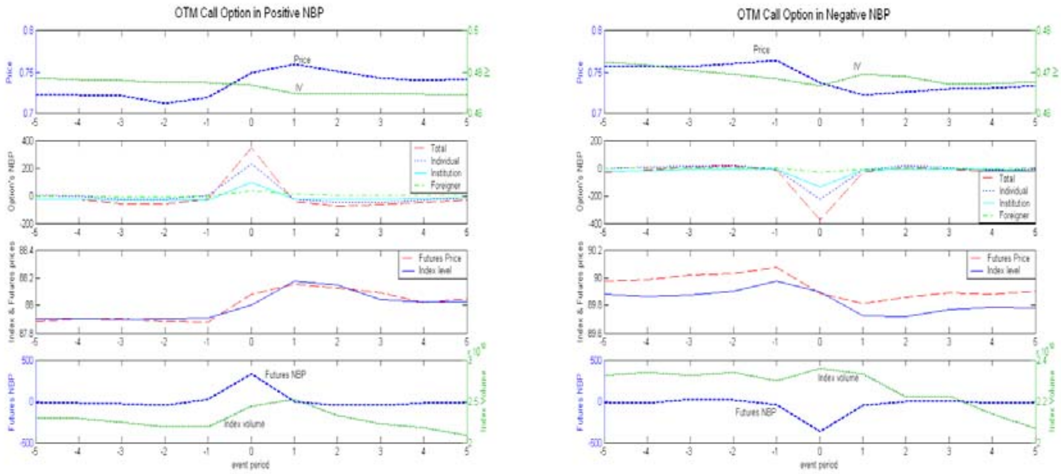


Figure 4
Impacts of the EXTREME_NBP on OTM options

Figures below show the movements of prices or net buying pressure around the event interval, where the event interval is defined as the interval where the absolute value of the net buying pressure of OTM options of interest lies out the two standard deviation from the average of 5-minute net buying pressure in our sample. The length of each interval is 5 minutes long. The sample period is from June 1,1998 to Feb 8, 2002.

Panel A. Impact on OTM Call options



Panel B. Impact on OTM Put options