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The Information Content of Option Prices: Evidence from S&P 500 Index Options

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ABSTRACT

This study addresses the question as to whether the option prices have useful predictive information on the direction of stock markets by investigating a forecasting power of volatility curvatures and skewness premiums implicit in S&P 500 index option prices traded in Chicago Board Options Exchange. We begin by estimating implied volatility functions and risk neutral price densities every minute based on non-parametric method and then calculate volatility curvature and skewness premium using them. The rationale is that high volatility curvature or high skewness premium often leads to strong bullish sentiment among market participants. We found that the rate of return on the signal following trading strategy was significantly higher than that on the intraday buy-and-hold strategy, which indicates that the S&P500 index option prices have a strong forecasting power on the direction of stock index market. Another major finding is that the information contents of S&P 500 index option prices disappear within one minute, and so one minute-delayed signal following trading strategy would not lead to any excess return compared to a simple buy-and-hold strategy.

Keywords: Risk Neutral Probability Density(RND), Volatility Curvature, Skewness Premium, S&P 500 Index Option, Signal Following Trading Strategy

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1. INTRODUCTION

The purpose of this study is to investigate whether it is possible to forecast the direction of stock indices using the information implicit in market prices of stock index options, and in turn make an excess rate of return by exploiting the information. We can classify the information retrieved from the option prices into two types. First, the moments such as implied volatility, skewness and kurtosis are of direct information we can easily retrieve from a set of market prices of options with either a cross section or time series format. Other information such as volatility curvatures and skewness premiums are a second type of information we can estimate from the implied volatility functions or risk neutral probability density functions which require more intensive computational efforts using market prices of options.

We estimate the implied volatility function and risk neutral probability density function using a non-parametric method based on intraday one minute market prices of S&P 500 index options traded in Chicago Board Options Exchange (CBOE) from October 2008 to October 2009, and then compute the volatility curvature from the implied volatility function and skewness premium from the risk neutral density function every minute from 8:31 AM to 3:10 PM, which is from one 1 minute after market open to five minutes prior to market close of each session. The volatility curvature and skewness premium respectively measure the degree to which the volatility function and density function are asymmetric. When the implied volatility of an out-of-the money (OTM) call is greater than that of an OTM put, the sign of volatility curvature becomes positive. When the length and area of right tail of the risk neutral density function is longer and fatter than those of left one, the sign of skewness premium becomes positive. Therefore when the volatility curvature or skewness premium increases (decreases), it reflects a strong bullish (bearish) sentiment among market participants who think the future price of stock index will increase (decrease).

We suggest two signal following trading strategies -volatility curvature and skewness premium following trading strategies. We then investigate as to how much forecasting powers volatility curvature and skewness premium contain for the direction of S&P 500. We compare the daily rate of return on our signal following trading strategies such that we buy (sell) a stock index when volatility curvature or skewness premium increases (decreases) by more than a pre-specified ratio (0.1%, 0.5%, 1%, 5%, 10%, and 20%) during one minute, with that of an intraday simple buy-and-hold strategy such that we buy a stock index on 8:31 AM and sell it on 3:10 PM of each session. We note that in our signal following trading strategy, we don't buy (sell) additional stock index when we already have long (short) position of stock index even if volatility curvature or skewness premium increases by more than a pre-specified ratio. We conduct this trading every single day when the stock and option markets are open between October of 2008 and October 2009.

What we find are as follows. First, the average daily rates of return on signal following strategies for the 272 trading days for the sample period are significantly greater than that of the buy-and-hold strategy. The average daily rate of return on the volatility curvature signal following strategy is 1.47%, whereas the buy-and-hold strategy records 0.05%. In addition, this volatility curvature following strategy dominates for 182 days of the total 272 days during the sample period, which indicates 67% of winning record. The skewness premium signal following trading strategy shows a similar performance. Second, when we delay signal following trades for 1 minute after receiving a bullish or bearish signal from volatility curvature or skewness premium, the excess rates of return on signal following strategies disappear. This indicates that the information implicit in the option prices may transfer to the stock market within one minute, and so the one-minute delayed signal following strategy would not outperform the simple buy-and-hold strategy any longer. Third, our sensitivity analysis shows that skewness premium has a broad sensitive information on the direction of stock market in a sense that any tiny change of rate as low as 0.1% as well as a huge change as high as 20% in skewness premium leads to consistent outperformance of the skewness premium signal following trading strategy over the simple buy-and-hold strategy. Volatility curvature, on the other hand, has sensitive information for the range of curvature change from 0.1% to 1%. Finally, the proposed following trading strategies may still provide a positive excess return even in the consideration of transaction costs such as taxes and brokerage commissions, but the trades should be conducted within one minute, otherwise the opportunity will vanish.

There is a lot of research dealing with the relationship between underlying prices and information implicit in option prices. Black (1975) and Easley, O'Hara and Srinivas (1998) argue that an informed trader would prefer to trade options to stocks because of options' leverage effect. Manaster and Rendleman (1982), Bhattacharya (1987), Amin and Lee (1997), Chan, Chung, and Fong (2002), Cao, Chen and Griffin (2005) and Pan and Poteshman (2006) find that some informed trades on options achieve excess rates of return and that option market quotes contain information about future stock returns. Meanwhile, Muravyev *et al*. (2013) provide compelling evidence that option prices do not contain any significant information that has not already been reflected in the stock prices. Some group of research focus on the lead-lag behavior between the option and stock markets using the econometric methodology. Ansi and Ben Ouda (2009) provide a nice literature review on the recent study of the group.

This research is different from the previous literature in that the latter depends mainly on cross section or time series analysis with lead-lag relationship in order to show any relevance between the prices of underlying asset and its option prices. However this article, based on the research methodology of Choi (2011), suggests trading strategies that extract and utilize volatility curvature or skewness premium from the option prices. Bhattacharya (1987) and Muravyev (2013) are the closest study to ours. They use a trading strategy in which the stock is bought (sold) when it is quoted below (above) the option-implied stock price by a specified threshold level, and the position is held open for 15 minutes until closed. Our research provides an evidence that the index option prices contain directional information about the future level of S&P 500 stock index by realizing an excess in a high- frequency trading regime. It is needless to say that the implied volatility function and risk-neutral probability densities of option prices have a wider range of information and a more predictive power than the volatility or spread of the stock index. This study shows that volatility curvature and skewness premium have sensitive information on the S&P 500 stock index market, considering that the signal following strategies based on these two variables produce excess rate of return. However, it turns out that earning an extra profit would be difficult if the signal following trading is delayed only for a minute, which implies that the CBOE is more efficient than the KOSPI market in Korea, considering the result of Choi (2011) that the information of option prices is transmitted to the stock market in three minutes.

The paper is organized as follows. In Section 2, we describe the estimation methods for implied volatility, volatility curvature, risk-neutral probability density and skewness premium which are presumed to have to do with option implied information. In Section 3, we explain the data used in this research, and in Section 4, we analyze the performances of two signal following trading strategies, and a simple buy-and-hold strategy. Finally we conclude in Section 5.

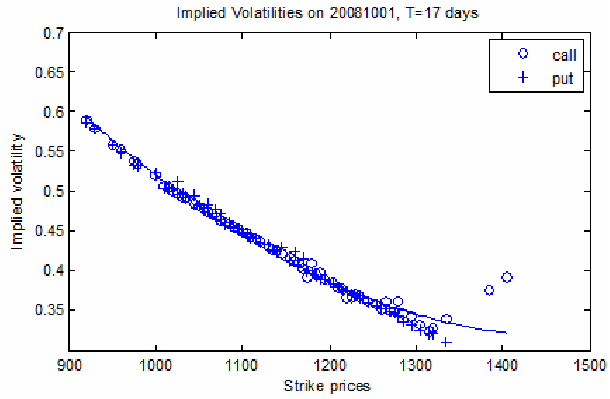
2. ESTIMATION OF VOLATILITY CURVATURE AND SKEWNESS PREMIUM

Volatility curvature and skewness premium are calculated from implied volatility functions and risk neutral density (RND) prices, respectively. We first explain how to derive implied functions and RND. Since the S&P 500 index option (SPX) is a European style option, the estimation of implied volatilities can easily be made using the closed formula of Black and Scholes (1973) using Newton-Raphson's method. After getting implied volatilities for all the options with different strike prices for every minute, we then estimate the implied volatility function with regard to strike price as a quadratic function using the least square curve fitting method as suggested by Shimko (1993). Given the implied volatility function, call and put prices are computed using the Black-Scholes formula for every strike price. The reason that we use the Black-Scholes formula is not because the RND follows the log-normal distribution assumption of Black and Scholes (1973), but because option prices are transformed into implied volatilities through the Black-Scholes formula. Finally the RND of the future prices of underlying assets can be derived by the second order finite difference method as proposed by Breeden and Litzenberger (1978). If we let C_i denote the call price with strike price K_i (for $i = 1, 2, \cdots, N$), transformed from the implied volatility function described before, then the risk neutral probability, $P(K_i)$, that the stock index at maturity will lie in $[K_i, K_{i+1}]$ is approximated as follows.

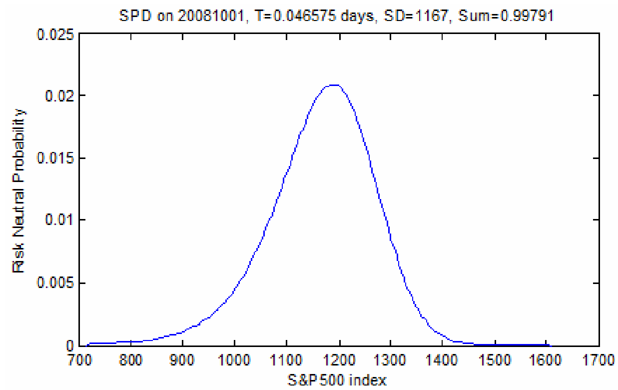
$$P(K_i) = \Pr(S_T \geq K_i) - \Pr(S_T \geq K_{i+1}) \qquad (1)$$
$$= \frac{C_{i-1} - C_{i+1}}{K_{i+1} - K_{i-1}} - \frac{C_i - C_{i+2}}{K_{i+2} - K_i},$$

where S_T is the underlying asset price at maturity.

Panel A in <Figure 1> illustrates the implied volatilities and its estimated curve from a set of call and put option prices with the same time to maturity but different strike price ranging from 900 to 1,400 points, observed at 2:30 PM on October 1, 2008. As shown in most developed and emerging option exchanges (Bakshi, *et al.* (2003), Bali and Hovakimian (2009), Gemmill (1996), and Yan (2011)), the implied volatility curve of S&P 500 index options reveals a volatility skew or volatility smile with respect to strike price. Panel B of <Figure 1> shows the RND estimated from the implied volatility function and option prices by following the methodology of Shimko (1993) and Choi (2011).



Panel A: Implied Volatility Curve



Panel B: Risk Neutral Probability Density

The figures represent implied volatility curve and risk-neutral probability density function respectively, extracted from S&P 500 index option prices observed at 2:30 PM on October 1st, 2008. SD denotes a spot price discounted by dividend yield.

Figure 1. Implied Volatility Curve and Risk-Neutral Probability density

There have been many attempts to retrieve useful information for the direction of stock movements from the diverse changes of implied volatility curves with respect to option's moneyness. For example, Bates (1991), Gemmill and Saflekos (2000), Cremers and Weinbaum (2008), Doran *et al.* (2007), Doran and Krieger (2010), Xing *et al.* (2010) discuss on the methods to measure volatility skew or smile. In this research, we estimate volatility curvature as in Gemmill (1996).

$$\text{Volatility curvature} = \left\{ \frac{\sigma_t(+x\%) - \sigma_t(-x\%)}{\sigma_t(+x\%)} \right\} \times 100, \qquad (2)$$

where $\sigma_t(+x\%)(\sigma_t(-x\%))$ denotes the implied volatility at the strike price x% greater(less) than the theoretical futures price. We use 4% in this research.

Another important indicator that shows the sentiment of market participants about the direction of the stock index is skewness premium, introduced by Bates (1991).

Skewness premium

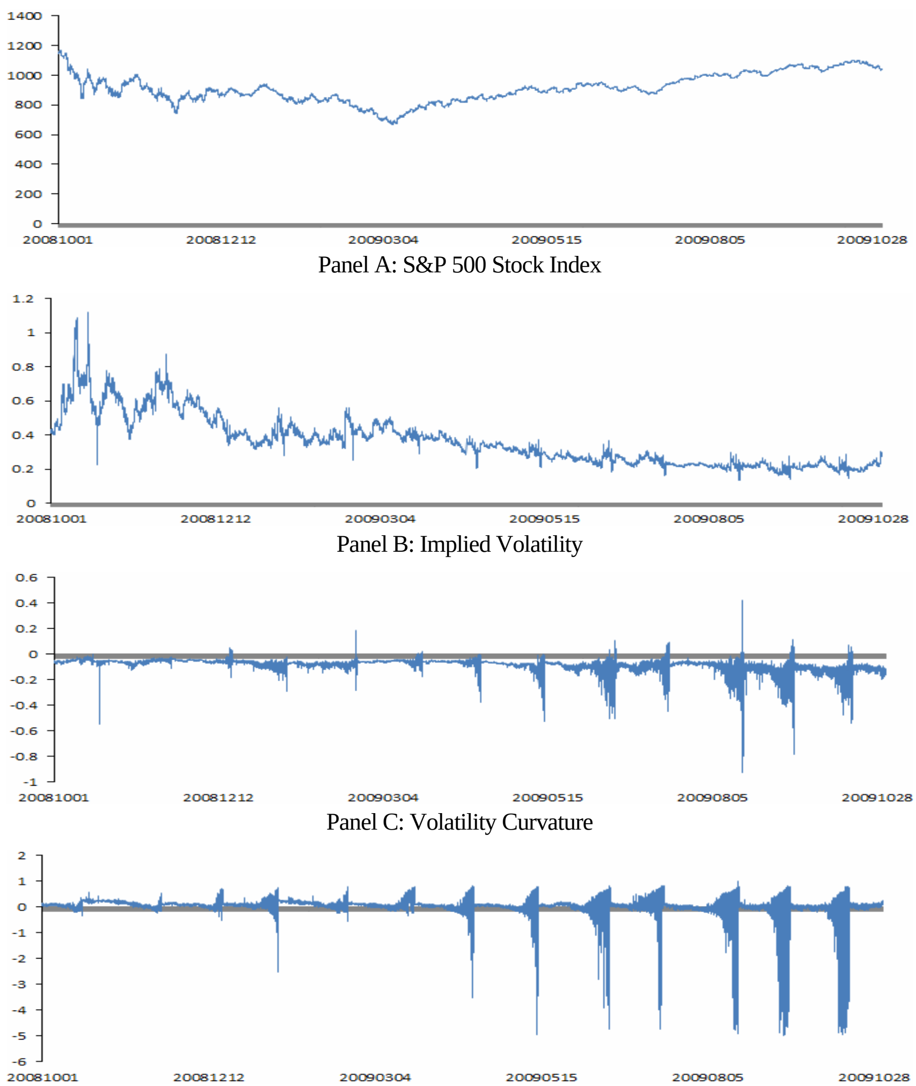
$$= \left\{ \frac{P(S > F_{+x\%}) - P(S < F_{-x\%})}{P(S > F_{+x\%})} \right\} \times 100 , \qquad (3)$$

where $P(S > k)$ is the risk neutral probability that the stock index at the expiration date is greater than k, $F_{+x\%}$ is the value which is x% greater than the current futures price, and $F_{-x\%}$ is the value which is x% less than the current futures price. Skewness premium will be zero if the shape of the RND is symmetric, and positive if the market participants believe the market will go up.

The Panel C and D of <Figure 2> show daily trends of volatility curvatures and skewness premiums estimated from minute by minute market prices of the index option from October 2008 to October 2009. It is worth mentioning that volatility curvature and skewness premium are more likely to be negative than positive, which has been a persistent trend after 1987 Black Monday crash. This reflects the sentiment among market participants that the stock price would decline sharply once again (Bates, 1991, 2000; Gemmill, 1996).

3. DATA

The sample of this analysis is minute by minute CBOE index option prices from October 2008 to October 2009. We obtain the market prices of S&P 500 index and index options (SPX) from Market Data Express, T-bill rate for three months from Federal Reserve System,



Panel A: S&P 500 Stock Index

Panel B: Implied Volatility

Panel C: Volatility Curvature

Panel D: Skewness Premium

The figures illustrate time series of S&P 500 index, implied volatility, volatility curvature, and skewness premium estimated based on the market prices at 3:10 PM every market opening day for the sample period between October 1, 2008 and October 31, 2009.

Figure 2. Time Series of Index, Implied Volatility, Volatility Curvature, and Skewness Premium

respectively. We only consider option prices with the nearest contract since the most of trading volume is concentrated in the options. We also do not exclude option prices which expire within one or two days since the trading volume is large and thus they convey many and useful information on the sentiments of the investors, though maturity effects may be present. However we exclude options with the minimum level of market prices (0.01 points) from this analysis since the market prices may not reflect the actual prices of the options. In addition, we apply some filtering rules shown below.

i) options with less than 100 trading volumes per day
ii) options with market price of 0.01 point
iii) $C(K_1) < C(K_2)$
iv) $P(K_1) > P(K_2)$
v) $C(K_1) - C(K_2) > K_2 - K_1$
vi) $P(K_2) - P(K_1) > K_2 - K_1$

where $K_1, K_2(K_2 > K_1)$ are exercise prices, and $C(K_i)$, $P(K_i)$ are call and put option price with exercise price $K_i (i = 1, 2)$, respectively. We don't exclude option prices that do not satisfy the put-call parity or convexity condition, since the arbitrage transactions may not be possible if transaction costs are added.

<Table 1> summarizes the basic statistics of minute by minute time series data of S&P 500 stock index, implied volatility of at-the-money(ATM) options, volatility curvature, and skewness premium, and <Figure 2> illustrates the daily trends of the four time series data.

Table 1. Descriptive Statistics

This table reports summary statistics for stock index, implied volatility of ATM option, volatility curvature, and skewness premium based on intraday 1 minute S&P 500 index, and index options for the sample period between October 2008 and October 2009. The number of data for the sample period is 101,130.

	S&P 500	implied volatility	volatility curvature	skewness premium
mean	912.577	0.363	-0.086	0.062
median	902.130	0.342	-0.075	0.066
min	666.880	0.132	-0.924	-4.979
max	1,166.560	1.120	0.426	1.000
std. dev.	96.351	0.150	0.043	0.295
kurtosis	-0.396	1.023	23.172	69.807
skewness	0.089	1.076	-3.103	-5.705

4. ANALYSIS

In this section we investigate whether information retrieved from the options data has significant signals for the direction of the stock index. To this purpose we compute volatility curvature and skewness premium every minute and if each value is increased (decreased) by greater than a pre-specified limit, we regard it as a signal that the stock index will move upward (downward) within a very short time. We can buy or sell the stock index as soon as a signal is detected or after a deliberate delay for from one to ten minutes. This delayed transactions examine how fast the proposed signal from the option market is delivered to the stock market. For each trading day during the sample period, from 8:31 AM, after 1 minute from market open to 3:10 PM, 5 minutes prior to market close of each session, we compute signal values of volatility curvatures and skewness premiums. If the value is increased by more than a pre-specified limit (0.1%, 0.5%, 1%, 5%, 10%, and 20%) compared to the value one minute before, we buy the S&P 500 stock index or sell (or short-sell) it if the value is decreased by more than a limit. If a selling (buying) signal is not detected till 5 minutes before the closing time for a long (short) position of the stock index, then the position would be liquidated at the closing time. The reasons why we liquidate all the positions before closing is to exclude any other effects such as overnight effect, which is presumed to have nothing to do with pure relationship between option and stock prices. For every single trading day during the sample period, we compare the daily return on each of these signal following trading strategies with that of the buy-and-hold strategy, which buys a stock index on 8:31 AM and sells it on 3:10 PM in the same day. We assume that the market allows short selling and there is neither margin nor trading fee.

4.1 Volatility Curvature Signal Following Trading Strategy

In this subsection we examine whether the volatility curvature has significantly useful information on the direction of the stock index. First of all, we compute the rate of return on the volatility curvature following trading strategy and the buy-and-hold trading strategy for every single day for the sample period from October 1, 2008 to October 30, 2009, based on S&P 500 intraday 1 minute option prices and stock index. In this analysis we use 1% sensitivity of volatility curvature, which means that if the value of volatility curvature is changed by more than ±1% compared to the value at one minute before, we regard it as a signal that the option prices contain new information about the market.

<Table 2> summarizes the performance of the strategies considered, such as mean, standard deviation, median, minimum, maximum, skewness, kurtosis, Sharpe ratio etc. The second column represents statistical information on the rate of return of the buy-and-hold trading strategy. The other columns from third to eighth represent information on the daily average rate of return on the volatility curvature trading strategy by varying the delay time. No delay means that we buy or sell a stock index as soon as a trading signal occurs, and 1 minute delay means trading occurs 1 minute later.

It is found, as we see from <Table 2>, that the volatility curvature signal following trading strategy without delay outperforms the buy-and-hold trading strategy

Table 2. Signal Following Trading Strategy

This table reports summary statistics for the average daily rates of return on buy-and-hold strategy, volatility curvature, and skewness premium signal following trading strategies during 13 months period from October, 2008. The threshold rate, over which the option is regarded to contain new information on the stock market, is 1%, and 0.1% for the volatility curvature and skewnes premium trading strategy, respectively. *** denotes significance at the 1% level.

Panel A: Volatility Curvature Signal Following Strategy

	Buy-and-hold strategy	Volatility curvature signal following strategy					
		No delay	1 min delay	2 min delay	3 min delay	5 min delay	10 min delay
mean	0.05%	1.47%***	0.16%	0.03%	0.05%	0.03%	-0.04%
median	0.21%	0.82%	0.10%	-0.07%	0.00%	0.06%	0.05%
min	-8.61%	-3.80%	-5.19%	-4.73%	-7.41%	-7.65%	-8.12%
max	7.99%	21.96%	10.32%	5.49%	7.82%	7.61%	10.91%
std dev	2.14%	2.76%	1.58%	1.53%	1.41%	1.63%	1.61%
kurtosis	2.70	13.23	7.96	1.99	6.84	5.99	10.29
skewness	-0.22	2.77	1.21	0.54	0.20	0.18	0.33
# obs	272	272	272	272	272	272	272
# win		182	125	125	125	123	127
win ratio		67%***	46%	46%	46%	45%	47%
Sharpe ratio	0.025	0.531	0.103	0.021	0.037	0.015	-0.028

Panel B: Skewness Premium Signal Following Strategy

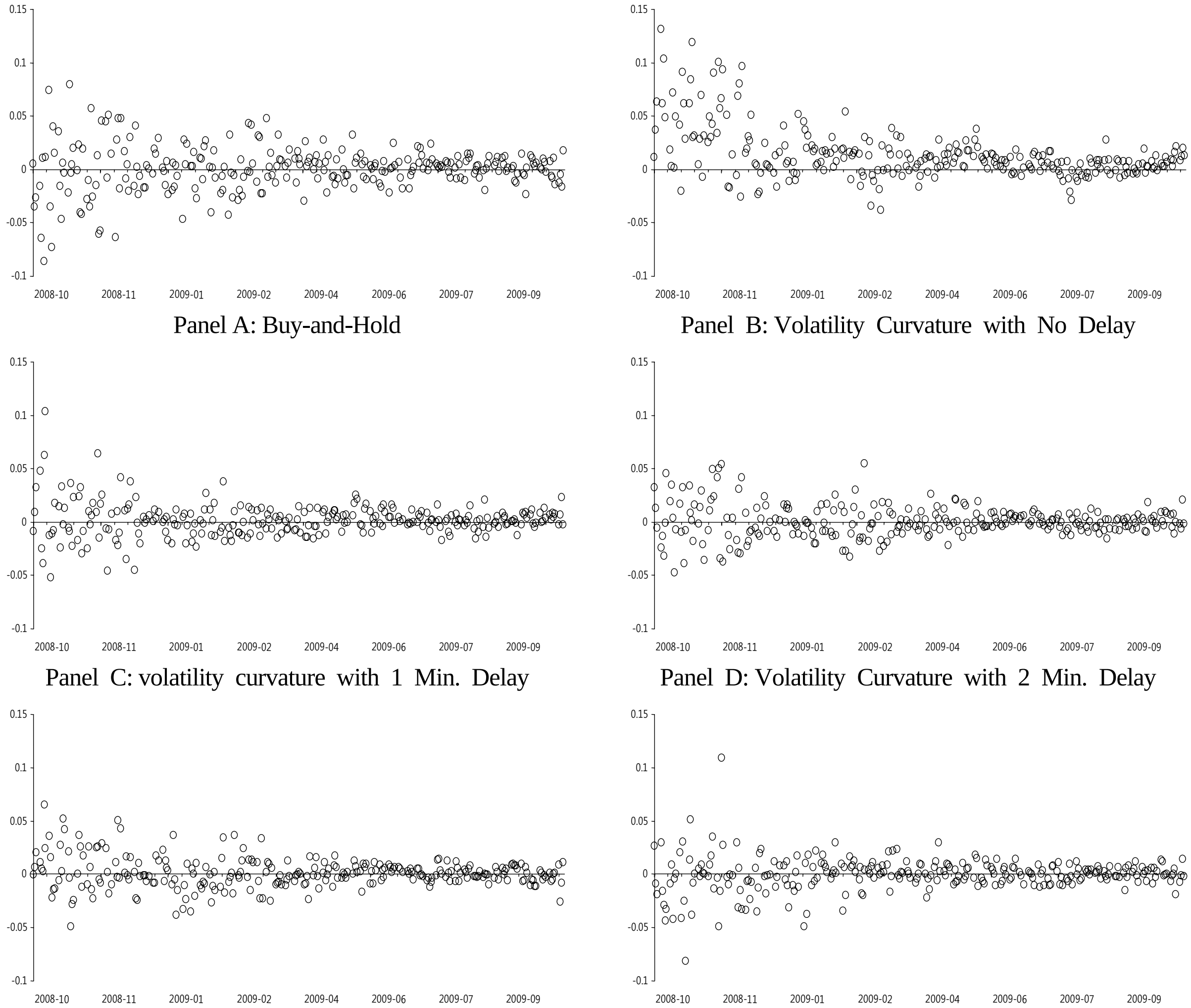
	Buy-and-hold strategy	Skewness premium signal following strategy					
		No delay	1 min delay	2 min delay	3 min delay	5 min delay	10 min delay
mean	0.05%	1.40%***	0.13%	0.08%	-0.02%	-0.03%	0.001%
median	0.21%	1.10%	0.19%	0.04%	-0.04%	-0.04%	0.08%
min	-8.61%	-5.88%	-5.30%	-5.78%	-7.75%	-7.57%	-12.07%
max	7.99%	14.23%	8.86%	5.41%	5.87%	8.79%	6.10%
std dev	2.14%	2.70%	1.44%	1.40%	1.38%	1.55%	1.65%
kurtosis	2.70	3.65	6.13	2.70	5.62	8.75	11.93
skewness	-0.22	1.00	0.59	0.08	-0.11	0.83	-1.54
# obs	272	272	272	272	272	272	272
# win		169	132	128	124	123	123
win ratio		62%***	49%	47%	46%	45%	45%
Sharpe ratio	0.025	0.518	0.087	0.055	-0.012	-0.019	0.0004

in that the average daily rate of return of the latter is 0.05%; meanwhile it is 1.47% on the former, nearly 28 times greater. Also the volatility curvature trading strategy surpasses the buy-and-hold one for 182 days during 272 trading days, which is a 67% winning ratio. The daily maximum rate of return on the volatility curvature trading is as much as 21.96% and the minimum rate is just 3.80%. A paired comparison test shows that the performance of the volatility curvature trading strategy is better than that of the buy-and-hold strategy, and their difference between two daily rates of return is statistically significant with 1% of significance level. In addition, the Sharpe ratio, which measures the risk adjusted rate of return, of the signal following trading strategy is better than that of buy-and-hold strategy.

However the performance of the volatility curvature trading strategy begins to deteriorate rapidly as we increase a delaying time from 1 minute to 10 minutes. For example if we delay one minute, the average rate of return on the volatility curvature trading strategy as shown in the fourth column of <Table 2> decreases to 0.16%, less than one tenth from that of trading strategy with no delay. When we increase the delay even further to two minutes or more, the average rate of return is less than that of the buy-and-hold strategy, though it is not statistically significant. The winning ratio also decreases to less than 50% even for one minute delay.

Thus we can conclude that the information on the direction of market contained in the volatility curvature retrieved from option prices would transmit to the stock market within one minute.

This can also be seen in <Figure 3> which illustrates a time series of daily rate of return of the buy-and-hold strategy in Panel A and the volatility curvature signal following trading strategies with no delay in Panel B, with 1 minute delay in Panel C, with 2 minutes delay in



Panel A: Buy-and-Hold

Panel B: Volatility Curvature with No Delay

Panel C: volatility curvature with 1 Min. Delay

Panel D: Volatility Curvature with 2 Min. Delay

Panel E: Volatility Curvature with 4 Min. Delay

Panel F: Volatility Curvature with 10 Min. Delay

The figures illustrate daily average rates of return on buy-and-hold and volatility curvature signal following trading strategy with 1% threshold rate with or without delay allowed for the sample period between Oct. 2008 and Oct. 2009.

Figure 3. Buy-and-Hold and Volatility Curvature Trading Strategy

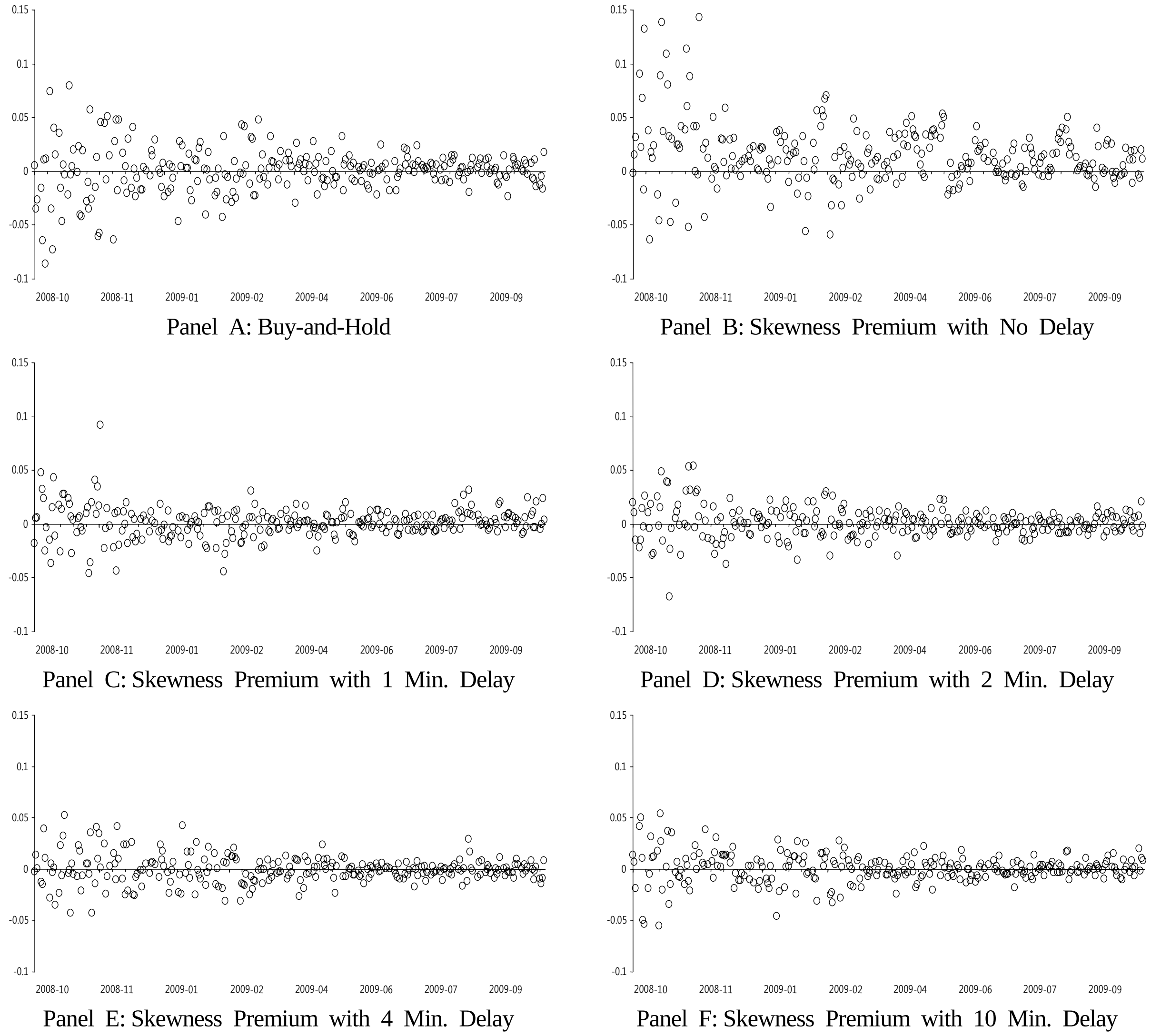
Panel D, with 4 minutes delay in Panel E, and with 10 minutes delay in Panel F, respectively. It is not so difficult to find that the daily rates of return on the buy-and-hold strategy is scattered evenly over the plane equally divided by the zero horizontal line; meanwhile the daily rates of return on the no delay volatility curvature trading strategy are more likely to be on the positive side. However if a delay is allowed at least for one minute, the scatter diagram seems to resemble that of the buy-and-hold strategy.

What is noticeable is that the greater the volatility of the index, the larger the daily rate of return on the volatility curvature trading strategy. For example, during the global financial crisis between mid 2008 and early 2009, the behavior of implied volatilities in Panel B in <Figure 2> is similar to the behavior of the daily rates of return of the volatility curvature trading with no delay in Panel B of <Figure 3>.

4.2 Skewness Premium Signal Following Trading Strategy

In this subsection we examine whether skewness premium has significantly useful information on the direction of S&P 500 stock index. First of all, we compute the daily rate of return on the skewness premium signal following trading strategy and the buy-and-hold trading strategy during the sample period. In this analysis we use 0.1% sensitivity of skewness premium.

Panel B of <Table 2> summarizes the performance of the considered strategies. The second column represents statistical information on the rate of return of the buy-and-hold trading strategy. The other columns from third to eighth represent information on the rate of return of the skewness premium trading strategy with various delaying times.



The figures illustrate daily average rates of return on buy-and-hold and skewness premium signal following trading strategy with 0.1% threshold rate with or without delay allowed for the sample period between Oct. 2008 and Oct. 2009.

Figure 4. Buy-and-Hold and Skewness Premium Trading Strategy

It is found that the skewness premium signal following trading strategy without delay outperforms the buy-and-hold trading strategy. More specifically, the average daily rate of return of the latter is 0.05%, whereas it is 1.40% on the former, nearly 27 times greater. The outperformance of the skewness premium trading strategy is observed for 169 days out of the total 272 trading days. The winning ratio is 62%. The daily maximum rate of return is as much as 14.23% and the minimum is just -5.88%. The paired comparison test again confirms that the performance of the skewness premium trading strategy is better than that of the buy-and-hold at the 1% of significance level. As in the case of the volatility curvature trading strategy, such a performance disappears if the delay time is present. See Panel B in <Table 3> which shows that one minute delay decreases the rate of return by 0.13%. We can make similar observations as in the volatility curvature trading strategy. Thus we can also conclude that the information contained in skewness premium would transmit to the stock market within one minute.

<Figure 4> represents a time series of daily rate of return on the buy-and-hold strategy in Panel A and skewness premium signal following trading strategies with no delay in Panel B, with 1 minute delay in Panel C, with 2 minutes delay in Panel D, with 4 minutes delay in Panel E, and with 10 minutes delay in Panel F, respectively. The observation made in the previous subsection still persist in this figure; the daily rates of return of no delay skewness premium trading strategy tend to be on the positive side, but it is impossible to realize excess returns over the buy-and-hold strategy if we allow one-

Table 3. Sensitivity Analysis

This table reports summary statistics for the average daily rates of return on volatility curvature and skewness premium signal following trading strategies with various threshold rates for the sample period between October 2008 and October 2009. *** denotes significance at the 1% level.

Panel A: Volatility Curvature

	Threshold rate					
	0.10%	0.50%	1%	5%	10%	20%
mean	1.47%***	1.48%***	1.47%***	0.92%	0.52%	0.13%
median	0.89%	0.89%	0.82%	0.50%	0.31%	0.05%
min.	-4.04%	-4.04%	-3.80%	-4.35%	-7.90%	-10.83%
max.	19.88%	19.49%	21.96%	19.92%	11.59%	7.70%
std dev	2.71%	2.76%	2.76%	2.41%	1.99%	1.44%
kurtosis	10.01	9.64	13.23	16.25	8.74	14.88
skewness	2.42	2.47	2.77	2.92	1.69	-1.33
# obs.	272	272	272	272	272	272
# win	180	181	182	157	156	138
win ratio	66%***	67%***	67%***	58%	57%	51%
# trade	295	282	265	160	95	43
Sharpe R.	0.544	0.536	0.531	0.381	0.260	0.093

Panel B: Skewness Premium

	Threshold rate					
	0.10%	0.50%	1%	5%	10%	20%
mean	1.40%***	1.45%***	1.42%***	1.39%***	1.19%***	0.88%***
median	1.10%	1.11%	1.03%	1.15%	0.77%	0.53%
min.	-5.88%	-6.33%	-6.33%	-5.79%	-6.57%	-6.89%
max.	14.23%	14.34%	16.29%	16.03%	18.85%	18.72%
std dev	2.70%	2.82%	2.85%	2.73%	2.65%	2.54%
kurtosis	3.65	4.40	4.92	4.29	10.23	8.78
skewness	1.00	1.17	1.19	1.07	1.89	1.41
# obs.	272	272	272	272	272	272
# win	169	172	168	171	164	157
win ratio	62%***	63%***	62%***	63%***	60%***	58%***
# trade	299	297	293	266	235	191
Sharpe R.	0.518	0.514	0.499	0.508	0.449	0.348

minute or longer delay.

4.3 Sensitivity Analysis

We conduct in this section a sensitivity analysis on trading signals. To this end, we investigate whether the proposed signal following trading strategies would earn excess rates of return over the buy-and-hold strategy under varying threshold rates of volatility curvature or skewness premium. We note that in the previous section, 1% and 0.1% values are used for the threshold rates for volatility curvature and skewness premium, respectively, while we consider various threshold rates (0.1%, 0.5%, 1%, 5%, 10%, and 20%) in this section.

<Table 3> summarizes the results. For such threshold rates as 0.1%, 0.5%, 1%, 5%, 10% and 20%, the volatility curvature trading strategy turns out to earn excess rates of return over the buy-and-hold strategy with 1% of significance level as shown in Panel A of the table. The winning ratios for those threshold rates achieve more than 64%, and Sharpe ratios are still reaching around 0.5, compared to 0.025 of the buy-and-hold strategy. However, under the other threshold rates, the performance deteriorates in terms of rate of return, winning ratio, and Sharpe ratio.

Panel B of <Table 3> represents similar results for the skewness premium trading strategy. Unlike volatility curvature, its performance dominates the buy-and-hold strategy in large threshold rates as well as small thresholds with 1% significance level. For example under a 20% threshold rate, though the average daily rate of return decreases to 0.88%, it is about 18 times larger than that of buy-and-hold. Thus it is concluded that the skewness premium shows better performances under various threshold levels than volatility curvature does.

4.4 Transaction Costs

Even though the primary purpose of this paper is to investigate whether the options have a useful predictive power on the direction of the stock market, it is worthwhile to explore how much excess return can be achieved using signal following trading strategies in practice so that we can examine whether the market is efficient or not.

We consider ETF (exchange-traded fund) based on S&P 500 presumably listed in an exchange as a proxy of S&P 500 stock index. There are two transaction costs in trading the ETF listed in exchanges: brokerage commission, and capital gains tax. Though brokerage fees range between $20 and $30 for online brokers, it is free for discount intermediaries. In addition, 35% of capital gains tax is required to pay for ETF in a short term and 15% in a long term trade. Since any short term loss is deducted from taxable incomes according to the U.S. tax law, we only need to subtract 35% tax from the total profit if the trader is a firm.[1)]

The proposed trading strategies with transaction costs still achieve far higher rates of return than the buy-and-hold strategy does. The volatility curvature signal following trading strategy earns 0.95% of daily average rate of return, and the skewness premium strategy earns 0.92% of daily average rate of return. However this opportunity will vanish if trades are delayed for one minute.

5. CONCLUSION

In this study, we examine whether the volatility curvature and skewness premium retrieved from the S&P 500 stock options has a predictable power on the direction of the stock market, based on minute by minute intraday market prices of options between October 2008 and October 2009. We find firstly that the previous finding (Black, 1975; Easley *et al*., 1998) that informed traders prefer options to stocks and are willing to make profits by trading options instead of stocks, still holds in the S&P 500 index option market. Secondly, volatility curvatures extracted from the implied volatility functions and skewness premiums extracted from the risk-neutral probability density respectively are found to possess valuable information on the market direction, which supports the finding of Choi (2011), but somewhat contradicts the finding of a previous study (Muravyev *et al*., 2013) that option prices do not contain economically significant information about future stock prices beyond what is already reflected in current stock prices. Thirdly, it seems that volatility curvature and skewness premium have sensitive information on the stock market considering that the signal following strategies based on these two variables produce excess rate of return when the sensitivity is even small value of 0.1%. Fourthly, the information implicit in the option prices is reflected to the stock prices within at least one minute, and so it turns out that it would be difficult to make an extra profit if the signal following trades are delayed for more than a minute, which implies that the CBOE is three times faster and so more efficient than the KOSPI market in Korea (Choi, 2011). Finally, the proposed signal following trading strategies may still provide a positive excess return even with transaction costs such as taxes and brokerage commissions, which allows us to examine the market efficiency of S&P 500 stock market in our future research. The current study has several limitations that call for caution in the interpretation of our findings. First, the data is confined to the most volatile period. Second, the proposed signal following strategies are examined in 1 minute data sample of option prices. Examining the proposed signal following strategies under expanding the sample period and reducing the time interval of sample data would be an interesting future research.

[1)] Although there is a distinction between long term and short term trading for a corporate trader, we set '60/40' principle for individual trader. If we follow that rule, the tax rate of capital gain for individual trader will be 0.27(= 0.6×0.35+0.4×0.15), where total profits are assumed to have 60 percent of long-term profit and 40 percent of short term.

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