Is it Useful to consider Options Volatility Spread, Risk-Neutral Skew and Kurtosis for Forecasting Distribution of Stock Return?

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Abstract

This paper examines whether the options volatility spread, risk neutral skew and kurtosis have information for predicting the distribution of the underlying asset. More specifically, we focus on the third and fourth moments of distribution, called skew and kurtosis, which contain important information for forecasting potential crash, spike upward and the fluctuations of stock index. The sample period covers from January 2002 to December 2006 with the closing price returns of KOSPI 200 Index and the KOSPI 200 options. The options volatility skews are estimated using method suggested by Cremers and Weinbaum(2010) and Xing, Zhang and Zhao(2010). And when estimating risk neutral skew and kurtosis of options, we use non-parametric method of Bakshi, Kapadia, and Madan(2003). We estimate and kurtosis of the underlying assets using Chen, Hong and Stein (2001) model and using stock returns during the past 1 month we calculate the historical 4th moments, called Physical kurtosis. Using statistical methodology such as VAR(vector autoregressive model), Granger causality test, impulse response and variance decomposition model, we investigate the response of higher moments of underlying asset to the change of options volatility skew and the implied risk neutral skew and kurtosis. Followings are the major findings and implications drawn from the empirical analysis of the Korean options market. First of all, options volatility skew has predictive information in forecasting the realized skew of the KOSPI200 index return. For the BKM skew and kurtosis, these implied risk neutral skew and kurtosis also provide some contents for predicting the third and fourth moments of KOSPI 200 index return.

Key words: Volatility skew, Risk-neutral distribution, VAR model, information flow, Lead-lag relationship

I. Introduction

The main interests of the stock market participants are how stock price will change and fluctuate in the future. In a perfectly functioning capital market, there should be complete simultaneity across markets. That is, any new information disseminating into one market would be reflected in other markets at the same time. However, if one market is more attractive than the others, then the market may thus be able to absorb new information more quickly and lead the others, which is interpreted as an indication of inter- market inefficiency.

A derivative market offers more advantages than a stock market such as reduction trading expense (Cox and Rubenstein, 1985), no restrictions on short selling (Diamond and Verecchia (1987)), and greater leverage effects (Black(1975), Manaster and Rendleman(1982)). Therefore, informed traders who have more information about future stock market movements than general investors would have incentive to mainly trade in derivative market rather than in stock market. As a result, the information about future stock price movements possessed by the informed investors would be reflected in the derivatives market earlier than stock market and it will be shown in any forms in derivatives market.

The inter-market inefficiency between options market and stock market have attracted the attention of researches, and there have been several studies underway with the presumption that it may be possible to discover lead-lag relationship between options market and stock market. i.e. [1] Researches on the relationship of the stock return and the trading volumes of the options market: Anthony (1988) , Stephan and Whaley (1990), Easley, O'Hara and Srinivas(1998), Chan, Chung and Fong(2002) [2] Researches on the relations between stock prices and the options price: Manaster, Rendleman(1982), Bhattacharya(1987), Stephen and Whaley(1990), Chan, Chung and Johnson(1993) , Chan, Chung and Fong(2002) [3] Researches on the relationship between stock price and implied volatility: Giot(2005), Banerjee, Doran, and Peterson(2006), Vijh(1990), Chakravary, Gulen and Mayhew(2004).

Most of the prior researches have conducted using the options trading volume, trading amount, option price, or implied volatility. However, recently, some researches try to examine the inter-market relations using options volatility skew. The volatility smile or volatility skew refers to the phenomenon that the value of implied volatility different across exercise price and has smiling shape or skewed shape, which is not consistent with constant volatility assumption in Black and Scholes(1973).

Previous researches argue that volatility skew is occurred due to the net buying pressure of options traders (see Garleanu, Pedersen, and Poteshman, 2009; Evans, Geczy, Musto, and Reed, 2005; Bollen and Whaley, 2004). They reflect the actual market situations that are different from the assumptions of Black and Scholes(1973) and conclude traders' future market expectation as well as their trading pattern affect volatility skew. On the other hand, other researches insist that the volatility skew phenomenon reflects the investors' crashophobia about the market crash.（Bates (1991, 2000), Bakshi, Cao and Chen(1997), Jackwerth(2000), Pan(2001)). They regard "jump premium" as the main reason of volatility skew. In specific, if the market becomes more volatile, investors become more concerned about a market crash and are willing to pay a higher premium to purchase put option due to "insurance" attribute of the option.

The relationship between volatility skew and future stock returns has received empirical supports. Doran and Kreiger (2010) shows that options volatility skew may influence on the future stock returns. They use five different measures on the basis of portion of the implied volatility skew and investigate how each skew measure can be used to forecast future equity returns. Xing, Zang and Zhao(2010) proves that the volatility skew has the cross-sectional predictive power about future stock returns, which persists for at least six month. Cremers and Weinbaum(2010) present strong evidence that option skew contain information not yet incorporated in stock prices and both levels and changes in volatility skew matter for future stock returns. Besides, Yan (2011) estimates jump risk premium defined to be the difference between the fitted implied volatilities of one-month-to-expiration put and call options with deltas equal to -0.5 and 0.5 respectively and shows that the jump risk premium that appears in individual stock options market in the U.S has the predictability about the future stock returns.

Furthermore, other researches investigate whether volatility skew can predict future market crash. Xing, Zang and Zhao(2010) find firms with the steepest volatility smirks have the worst earnings surprises. Doran, Peterson and Tarrant (2007) insist that the volatility skew has some predictive power for forecasting potential market crash, spike upward and the jumps of stock index. These researches can be interpreted that option volatility skew has some information on future stock movement related to the realized skew or fat-tailed traits.

Since the distribution of stock does not follow normal distribution and it has negatively skewed and has leptokurtic distribution, the higher moments perform important roles in explaining the stock return distribution. In particular, investors have preference toward higher moments on stock return. Harvey and Siddique (2000) claim that the unconditional return distributions cannot be fully explained by the mean and the variance alone and due to investors' preference toward skewness and thus skewness should also be considered to capture the asymmetric properties in realized returns. Scott and Horvath (1980) claimed that risk-averse investors have positive preference for the positive skew and negative preference for the negative skew and negative preference for kurtosis. Besides, the result of Golec and Tamarkin (1998) supports risk aversion and skewness preference for race bets and Garret and Sobel (1999), studying the data from horse race betting in the U.S, find theoretical and empirical evidence that skewness of prize distributions explains why risk adverse individuals may play the lottery.

In this perspective, information on the higher moments in stock market is valuable in that it can deliver information about future market crash and help investors to take optimal strategies according to the degree of their risk-aversion. Nevertheless, prior studies do not consider the fact that the volatility skew can provide useful information about higher moments of stock return.

Our study aims to investigate how the option volatility skew affects the higher moments of stock return distribution. Furthermore, we try to confirm whether the option volatility skew contains the predictive information about the future stock return in Korean market.

We add to the existing literature by using an unexplored dataset of emerging market and examining the price discovery role of the KOSPI 200 stock index options market in comparison with the other developed options markets. Our study proves the leading effect of option market to stock market in Korea, which is consistent with the study using U.S market data such as Doran, et al,(2007, 2010), Yan(2011), Cremers and Weinbaum(2010), and Xing, Zhang and Zhao(2010). Furthermore, the KOSPI 200 stock index options market has sufficient liquidity and thus is an appropriate one in which to study the price discovery associated with stock and options markets. Nam et al. (2006) argue that it is necessary to analyze the intraday patterns with a high frequency of derivatives markets with abundant liquidity to find out more apparent lead-lag relationship between markets. KOSPI200 stock index options market is ranked first in the world in terms of options trading volume, of which over 50 percent is by individual investors[1].

Also, we contribute to existing literatures by showing option skewness has influence on higher moments in stock distribution. Although most of the studies analyzing the effect of option skewness onto stock market limit their analyses to stock return, we go a step further investigating not only the effects of option skewness on stock return but also the effects on the higher moments. The information about the 3rd and 4th moments of stock index returns contain the information about market crash and investors have certain preference to higher moments based on their degree of risk aversion. Therefore, we expect that our study will help stock market participants to make their optimal investment decision. This paper is organized as follows. In section II, we introduce the variables which are used in this paper: CW volatility skew, XZZ volatility skew, BKM skew, BKM kurtosis, CHS skew, P kurtosis. In section III, we will explain samples and data and the statistical methodology used in this paper. In chapter IV, we will report and discuss the results empirical analysis. Lastly in chapter V, we briefly summarize the results of this research and suggest some alternatives for the future research.

II. Variables

[1] In 2006, the combined trading volume reached 2.4 billion contracts, which accounted for 22.4 percent of total contracts in the world.

1. Options volatility skew

In this section, we introduce how to estimate the options volatility skew. Two methods (CW, XZZ) are used to estimate the options volatility skew. There are some fundamental differences between the two methods in the way in which they define and recover the shape of the implied volatility.

Cremers and Weinbaum (2010)

Stoll (1969) proved that following equation should hold for European options on non-dividend-paying stocks in the perfect markets.

$$C - P = S - PV(K) \tag{1}$$

S : Stock price, *C* : Call price, *P* : Put price, *PV(K)* : Present value of strike price K

The Black-Scholes(1973) theorem always satisfies Put-call parity. Thus, following equation also holds.

$$\forall \sigma,\ C^{BS}(\sigma) + PV(K) = P^{BS}(\sigma) + S \tag{2}$$

C^{BS} : Black-Scholes call price, P^{BS} : Black-Scholes put price, σ : Volatility

By the equation (1) and (2),

$$\forall \sigma,\ C^{BS}(\sigma) - C = P^{BS}(\sigma) - P \tag{3}$$

IV^{call}, which refers to implied volatility on the call, is the value that satisfies the following equation.

$$C^{BS}(\mathrm{IV}^{call}) = C \tag{4}$$

And by substitute (4) into equation (3), we can get

$$P^{BS}(\mathrm{IV}^{call}) = P \tag{5}$$

This means that

$$\mathrm{IV}^{call} = \mathrm{IV}^{put} \tag{6}$$

Therefore, for European options, put-call parity model implies the equivalence of implied volatilities of call and put options with the same underlying assets, same maturities and exercise prices. If there are some differences between call options' implied volatility and put option's implied volatility, one option might be overpriced or underpriced compared to the other. High call implied volatilities relative to put implied volatilities suggest that calls are expensive relative to puts, and high put implied volatilities relative to call implied volatilities suggest the opposite. So we can compare the level of option price easily by following equation. We define this volatility skews as CW skew in our research.

$$\text{CW skew} = \text{VS}_{k,t} = \text{IV}_{k,t}^{call} - \text{IV}_{k,t}^{put} \tag{7}$$

VS : Volatility spread, k : Strike price, t : A point of time

Xing, Zhang and Zhao(2010)

We also estimated options volatility skew using method suggested by Xing, Zhang and Zhao (2010). They define implied volatility skewness for firm *i* at *t* as the difference between the implied volatilities of OTM puts and ATM calls. That is,

$$SKEW_{i,t} = VOL_{i,t}^{OTMP} - VOL_{i,t}^{ATMC} \tag{8}$$

$VOL_{i,t}^{OTMP}$: the implied volatility for an OTM put option

$VOL_{i,t}^{ATMC}$: the implied volatility for an ATM call option

In equation (8), $VOL_{i,t}^{OTMP}$ is chosen to catch the severity of the bad news and $VOL_{i,t}^{ATMC}$ is used as the benchmark of implied volatility.

Xing et al(2010) measure the SKEW on the basis of the demand-based option pricing model of Garleanu et al.(2009) who find end-user's demand for index option is positively related to option implied volatility and steepness of the implied volatility skew. If stock price is expected to go down, there will be high demand for put options for hedging purpose or speculative purpose. If investors are more likely to long the put than short the put, both the price and the implied volatility of the put would increase, which lead to steeper volatility skew in equation. For this reason, steep volatility skew is associated with bad news about future stock.

2. Risk –Neutral skew and kurtosis

Options implied risk-neutral distribution (RND) is the modified one of physical distribution by the pricing kernel. Since the pricing kernel can reflect the degree of the investors' risk averseness, the RND can also contain the investors' attitude of the risk. The implied risk-neutral skew is calculated under the assumption that there are no arbitrage or information differences between the options market and the stock market and they are estimated using various option series with different strike prices and maturities.

Bakshi, Kapadia, and Madan(2003)

We calculate options implied risk-neutral skew using Bakshi, Kapadia, and Madan(2003) model in which skew and kurtosis are estimated non-parametrically. Bakshi et al (2003) show that more negative risk-neutral skew leads to steeper slope of implied volatilities, under presumption everything are equal. They show that the risk-neutral skew can be expressed by the function of the prices of quadratic, cubic, and quartic contracts' payoff which are calculated by linear combination of OTM call and put option prices.
The skew and kurtosis of Bakshi et al (2003) can be calculated as follows.

$$\mathrm{Skew}(t,\tau)=\frac{E_t^q\left\{(\mathrm{R}(t,\tau)-E_t^q[\mathrm{R}(t,\tau)])^3\right\}}{\left\{E_t^q(\mathrm{R}(t,\tau)-E_t^q[\mathrm{R}(t,\tau)])^2\right\}^{3/2}}=\frac{e^{\gamma\tau}W(t,\tau)-3\mu(t,\tau)e^{\gamma\tau}\,\mathrm{V}(t,\tau)+2\mu(t,\tau)^3}{(e^{\gamma\tau}\,\mathrm{V}(t,\tau)-\mu(t,\tau)^2)^{3/2}} \tag{9}$$

$$\begin{aligned}\mathrm{Kurt}(t,\tau)&=\frac{E_t^q\left\{(\mathrm{R}(t,\tau)-E_t^q[\mathrm{R}(t,\tau)])^4\right\}}{\left\{E_t^q((\mathrm{R}(t,\tau)-E_t^q[\mathrm{R}(t,\tau)])^2\right\}^2}\\&=\frac{e^{\gamma\tau}W(t,\tau)-4\mu(t,\tau)e^{\gamma\tau}\,\mathrm{W}(t,\tau)+6e^{\gamma\tau}\mu(t,\tau)^2\,\mathrm{V}(t,\tau)-3\mu(t,\tau)^4}{(e^{\gamma\tau}\,\mathrm{V}(t,\tau)-\mu(t,\tau)^2)^2}\end{aligned} \tag{10}$$

where, $R(t,\tau)\equiv\ln[\mathrm{S}(t+\tau)/\mathrm{S}(t)]$ is the τ period return and *q* is the Risk-neutral probability.

The price of volatility contract is

$$\begin{aligned}\mathrm{V}(t,\tau)&\equiv E_t^q\left\{e^{-r\tau}R(t,\tau)^2\right\}\\&=\int_{S(t)}^{\infty}\frac{2(1-\ln[\frac{K}{S(t)}])}{K^2}C(t,\tau;K)dK+\int_0^{S(t)}\frac{2(1+\ln[\frac{S(t)}{K}])}{K^2}\mathrm{P}(t,\tau;K)dK\end{aligned} \tag{11}$$

And the prices of cubic and quadratic contract are defined as $\mathrm{W}(t,\tau)$ and $\mathrm{X}(t,\tau)$, respectively.

$$\mathrm{W}(t,\tau) \equiv E_t^q \left\{ e^{-r\tau} R(t,\tau)^3 \right\}$$

$$= \int_{S(t)}^{\infty} \frac{6\ln[\frac{K}{S(t)}] - 3(\ln[\frac{K}{S(t)}])^2}{K^2} C(t,\tau;K)dK - \int_{0}^{S(t)} \frac{6\ln[\frac{S(t)}{K}] + 3(\ln[\frac{S(t)}{K}])^2}{K^2} \mathrm{P}(t,\tau;K)dK \quad (12)$$

$$\mathrm{X}(t,\tau) \equiv E_t^q \left\{ e^{-r\tau} R(t,\tau)^4 \right\}$$

$$= \int_{S(t)}^{\infty} \frac{12(\ln[\frac{K}{S(t)}])^2 - 4(\ln[\frac{K}{S(t)}])^3}{K^2} C(t,\tau;K)dK + \int_{0}^{S(t)} \frac{12(\ln[\frac{S(t)}{K}])^2 - 4(\ln[\frac{S(t)}{K}])^3}{K^2} \mathrm{P}(t,\tau;K)dK \quad (13)$$

Finally, mean stock return is calculated as follows;

$$\mu(t,\tau) \equiv E_t^q \ln\left[\frac{S(t+\tau)}{S(t)} \right]$$

$$= e^{r\tau} - 1 - \frac{e^{r\tau}}{2}\ \mathrm{V}(\mathrm{t},\tau) - \frac{e^{r\tau}}{6}\ \mathrm{W}(\mathrm{t},\tau) - \frac{e^{r\tau}}{24}\ \mathrm{X}(\mathrm{t},\tau) \quad (14)$$

Although the skew and kurtosis of Bakshi et al (2003) have some advantages of being model-free moments, this method can be biased due to the discrete, not continuous, exercise prices and asymmetric number of observations of call options and put options when calculating using actual options data. So in this paper, using Black and Scholes(1973)' implied volatilities, we synthetically made continuous exercise prices by using interpolation-extrapolation method suggested by Jiang and Tian(2005) and then use these prices when calculating the price of quadratic, cubic, and quartic contracts in order to mitigate the biases caused by discreteness of options data.

3. Stock index return distribution

1) Skew

The skew of KOSPI200 returns distribution is found by the method suggested by Chen, Hong and Stein(2001). Chen et al (2001) suggest the following model.

$$CHSskew_t = -\left\{ (n(n-1)^{3/2} \sum R_t^3 \,/ \left[(n-1)(n-2) \sum R_t^2 \right]^{3/2} \right\} \quad (15)$$

R_t = daily log return at t, n = the number of daily log return

In this model, skewness is calculated by taking the negative of the third moment of daily returns divided by the standard deviation of daily returns raised to the third power. This measure reflects the convention that an increase in CHS skew corresponds to the stock which is more crash prone and has a more left-skewed distribution

3) Kurtosis(P kurtosis)

Physical kurtosis, which is historical kurtosis, is estimated using past 1 month of stock returns.
P kurtosis is equal to the kurtosis of the daily index returns over the past 1 month. The P kurtosis can be calculated as below:

$$P - kurt_t = \frac{1/n\sum(R_t - \bar{R})^4}{(1/n\sum(R_t - \bar{R})^2)^2} \qquad 16)$$

R_t = daily log return at t, $\bar{R}$ = sample mean

III. Data

We use data on KOSPI200 options. Despite its relatively short history, the KOSPI200 options market has become one of the largest options markets in the world. From 1998 to 2012, the KOSPI200 options market was ranked first among all options markets in the world in terms of trading volume. European-style options on the KOSPI200 index have been traded on the KRX since 1997. KOSPI200 index options have a contract size of KRW 100,000 per index point and a minimum price movement of 0.05 (when the premium is >3 index points) or 0.01 (when the premium is 3 index points or less) index point. Maturity dates and last trading days are the second Thursday of three consecutive near-term delivery months and one additional month from the quarterly cycle (March, June, September, and December).
We draw minute-by-minute transaction prices for KOSPI200 index options from the KRX from January 2002 to Dec 2006, which offers a fully automated trading system. The data for the empirical analysis were selected as follows. First, we use only the transaction prices reported no later than 2:50 p.m. each day to prevent non-synchronous trading effects. Second, we use only the data on options with the shortest maturity because the liquidity of the KOSPI200 options market is heavily concentrated in shortest-term contracts. Third, we use only those transaction prices greater than 0.02 point, to prevent the effect of price discreteness. Last, we exclude transaction prices which do not satisfy following option boundary condition.

$$C(t,\tau) \geq S(t) - \sum_{s=1}^{\tau} e^{-rs} D_{t+s} - K \times B(t,\tau) \tag{17}$$

$$\mathrm{P}(t,\tau) \geq K \times B(t,\tau) - S(t) + \sum_{s=1}^{\tau} e^{-rs} D_{t+s} \tag{18}$$

Where $B(t,\tau)$ is a zero-coupon bond that pays 1 in t periods from time *t*, D_t is daily dividend at time *t*, and r is the risk-free interest rate with maturity at time *t*. Besides, for consistency, and KOSPI200is used for variables in stock market and following Ahn et al. (2010), the 91-day certificate of deposit (CD) yield is used as the risk-free interest rate.

<Table 1> presents the average implied volatilities at each moneyness category. We use the five moneyness which grouped by the criteria based on delta(Δ) suggested by Bollen and Whaley(2004) instead of using simple definition of K/Se^{rt}. Simple definition of K/Se^{rt} is fairly intuitive but this definition ignores that exercising options relies not only on the volatility but also the time to maturity as well. Bollen and Whaley(2004) argue that options' delta can explain both volatility and time to maturity and thus delta can be interpreted as the risk-neutral probability that the option will be exercised.

<Table1> Descriptive Statistics 1

This table shows there is 'volatility smile' effect as to the degree of the moneyness. DOTM call and put have relatively higher value for the implied volatilities and the implied volatility gets lower values as the moneyness goes toward ATM and have the lowest implied volatility at the ATM. And then the implied volatility gets higher values as the moneyness get near ITM

IV. Model

In order to see whether there are lead-lag relationship between options market and stock market, we use VAR (vector auto regressive) model.

Sims (1980) first introduced the vector autoregression (VAR) models as an alternative to the large scale macroeconometric models. The VAR model is a natural extension of the univariate autoregressive model to dynamic multivariate time series and it is one of the most successful, flexible, and easy to use models for the analysis of multivariate time series. In the VAR model, all the variables are treated as endogenous. There is thus one equation for each variable as dependent variable and each equation has lagged values of all the included variables as dependent variables, including the dependent variable itself.

The VAR model is natural tools for forecasting. However, it can also be used to capture the linear interdependencies among multiple time series because they describe the joint generation mechanism of the variables involved. In particular, the VAR model has proven to be especially useful for describing the dynamic behavior of economic and financial time series.

VAR modeling does not require as much knowledge about the forces influencing a variable as do structural models with simultaneous equations: The only prior knowledge required is a list of variables which can be hypothesized to affect each other intertemporally.

When specifying a VAR, one first has to decide which variables to include into the model. Since one cannot include all variables of potential interest, one has to refer to economic theory or any a priori ideas when choosing variables. As our purpose is to investigate whether option skew has information on stock market distribution, we confine our variables to option skew and stock return or stock skew.

VAR model used in this research is as follows:

Option market equation investigates predictability of option market skewness to stock market distribution in order to verify the leading effects of the options market to the stock market.

Stock market equation

$$X_{k,t} = \alpha_k + \sum_{i=1}^{n} \beta_{k,i} \times X_{k,t\text{-}i} + \sum_{i=1}^{n} \gamma_{p,i} \times Y_{p,t\text{-}i} \quad 19)$$

Where, X_{kt} is KOSPI 200 return (k=1), CHS skew (k=2) and P kurtosis(k=3) and $Y_{p,t}$ indicates option skew such as CW skew (p=1), XZZ skew(p=2) and BMK skew(p=3).

If the volatility skew of options affects to future stock distribution just as the research results of Doran, et al (2007, 2010), Cremers and Weinbaum(2010), Xing, Zang and Zhao(2010), the coeifficients in the stock market equation ($\gamma_{p,i}$) would have significant values.

On the contrary, Option market equation investigates whether information about stock market movement can explain option skewness.

Option market equation

$$Y_{p,t} = \alpha'_p + \sum_{i=1}^{n} \beta'_{p,i} \times Y_{p,t\text{-}i} + \sum_{i=1}^{n} \gamma'_{k,i} \times X_{k,t\text{-}i} \quad 20)$$

In option market equation, the coeifficients ($\gamma'_{k,i}$) show whether information about stock market predicts option skewness. Table 2 reports summary statistics of variables in option and stock market using in this paper.

<Table 2> Descriptive Statistics of variables

As for the average values about each of the variables, CW skew has -0.0357, XXZ skew for 0.0584, -0.4024 for BKM skew, -0.1196 for CHS skew, and 0.7520 for P kurtosis. Positive CW skew value means call option implied volatility is higher than the put options' and thus the price of call options is high compared to put options which implies options market participants anticipate stock market will spikes up in the futures. As for the negative value of CW skew has opposite meaning in which put option implied volatility is higher than the call options' and there will be market crash near the future. The XXZ skew, the implied volatility for an OTM put option minus the implied volatility for an ATM call option, has positive value at average, indicating there exists high buying pressure for OTM puts compared to calls and there might be more bad news than good news in Korea. On the other hand, the implied risk-neutral skew, BKM skew, shows a big value compared to the realized skew of stock index return, which is consistent with Bakshi and Madan(2006), who conclude that risk neutral distribution has bigger value compared to the stock index distribution skew as it reflects the degree of risk-aversion of the investors[2].

The average values of stock index returns distribution was 0.008. Note that KOSPI200 return distribution has negative skewness(CHS skew: -0.0761), and leptokurtic properties (P kurtosis: 5.2662). In other words, the distribution of stock index returns does not follow normal distribution.

Figure1 shows that the process of each variable used in this paper. During the recession period in Korea called IMF, CW skew have relatively negative and more volatile value compared to the normal condition period. The negative value is due to the put option price will be more expensive than that of call option. XZZ skew in IMF recession period is also more volatile than the normal period and have relatively positive value. This result comes from the fact that during the recession period, the price of the put option in OTM might be expensive than the other options so XZZ skew defined by the difference between the implied volatilities of OTM puts and ATM calls will have positive value.

IV. Empirical Analysis

The first step for VAR model is to check for stationarity of individual variable. <Table 3>

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[2] As for the case of volatility, Jackwerth and Rubinstein(1996) insisted that implied volatility of options always shows greater value than realized volatility. This is consistent with negative volatility risk premium proved by Bakshi and Kapadia(2003).

presents the results of ADF(Augmented Dickey-Fuller) test and PP(Phillips-Perron) test to verify each variable follow stationary process.

<Table 3> Unit Root Test

Table 3 shows that the null hypothesis is rejected at 1% significant level for all variables, indicating all variables follow stationary process. Therefore, we can conduct the VAR (Vector Auto Regressive) model without considering cointegration test or VECM(Vector Error Correction Model).

First, we examine whether options volatility skew has the predictability about stock index returns at time point t. <Table 4> shows the result of VAR model analysis between option skew and KOSPI200 return.

<Table 4> VAR Results of Volatility Skew and Stock Index Return

When using CW skew and XZZ skew, the coefficients in option market equation (β_i) which indicating whether the option skew has predictive power for KOSPI200 return have significant values. In detail, the coefficient of CW skew is positive at time lag 1, while that of XZZ skew is negative at time lag 1 and both values are significant at 1% confidence level.

The fact that XZZ skew is negatively related to the stock return is consistent with the results of Conrad, Dittmar, and Ghysels (2007), Zhang (2005) and Xing et al(2010) who prove that lower skewness leads to higher return. XZZ skew is defined by the subtraction of implied volatility of ATM call from implied volatility of OTM put. If XZZ volatility skew is positive, price of the put option in OTM is expensive than the call options, which implies that informed trader expect the decrease in stock return. In contrast, if the value of XZZ skew is negative, then informed trader expect to the upward spikes in stock return. With this definition of XZZ volatility skew, positive XZZ skew can be related to decrease in stock return whereas negative XZZ skew can be related to the upward spikes in stock return. As a result, XZZ skew is negatively related with stock return.

Meanwhile, the coefficient of CW skew is positive. The opposite sign of CW skew which is differ from XZZ skew is plausible in that CW skew is calculated as ATM call option implied volatility minus that of the ATM put options and thus CW skew has negative correlation with XZZ skew. The results of granger causality test that reject the null hypothesis stating CW skew and XZZ skew does not Granger cause to KOSPI200 return support the option skew’s predictability on stock return.

Also, implied risk-neutral skew estimated by Bakshi, Kapadia, and Madan(2003) has significant impact on stock return at 10% confidence level. However, in comparison with options volatility skew such as CW skew and XZZ skew, the effect is marginal. Bakshi, Kapadia, and Madan(2003) shows that options volatility skew can be expressed as linear transformation of risk-neutral skewness and kurtosis.

Therefore, the thing that options volatility skew has stronger predictive power than risk-neutral skewness can be interpreted as the predictability of options volatility skew result from the risk-neutral kurtosis as well as the risk-neutral skewness.

On the other hand, the coefficients in option market equation ($\beta_i^{'}$) which indicate whether stock return has the leading effects to CW skew and XZZ skew are shown to be insignificant at time lag 1, which demonstrate the idea that information about future stock price movements is reflected in the derivatives market earlier than stock market.

When considering Granger causality test, the null hypothesis stating KOSPI200 return does not Granger cause to CW skew cannot be rejected. It means information stock index returns does not have predictability about CW volatility skew.

As for XZZ skew, the null hypothesis, XZZ skew does not Granger cause to stock return, is rejected at a 1% significance level which means options volatility skew estimated by XZZ model can have some predictable information about stock returns. This is similar result when testing using CW skew. Through this, we can conclude that XZZ skew also leads to the KOSPI200 return, for about 2 day.

For the direction of stock return to XZZ skew, Granger causality test result shows that stock return contains some predictive information of XZZ skew. So compared to the CW skew which affects to stock return only one direction, XZZ skew and stock return affects to each other bilaterally.

In sum, Table 4 shows that the option skew has predictability on stock return in Korea and the results are consistent with the result of Doran, et al,(2007, 2010), Yan(2011), Cremers and Weinbaum(2010), Xina, and Zhao(2010) who investigate the relationship between option skew and stock return using the U.S data.

<Figure 2> shows the impulse response analysis results conducted based on VAR model of option skew and KOSPI200 return[3]. Impulse response analysis is the forms of the impulse response by estimating coefficients of each process that results from decomposing each of the error terms of regression in VAR model by moving average (MA) process. In other words, the impulse that is added to a variable affects the present and future changes of other variables because the impulse that is delivered to a certain endogenous variable is transferred not only to corresponding variable but also to all other endogenous variables through dynamic structure of VAR. During this process, each of the error terms in the VAR model gets to have co-relation with one and other, and it is possible to find the form in which impulse

[3] The reaction about the stock onto stock return or stock skew itself lasts for a while in the positive (+) direction which infers that the stock index returns distribution lasts in a certain direction consistently for a long time. Also, the reactions about the shock onto option skew (CW skew, XZZ skew, BMK skew) itself last in a certain direction. However, since our purpose is to observe the lead lag relationship between option market and stock market, we do not report impulse response of variable to itself but they are available upon request.

is delivered to variables by estimating the coefficients of each moving average process during the process of clearing correlation through Choleski decomposition.

When considering the influence of CW skew onto KOSPI200 return, the effect of an unexpected 1 percentage point increase in CW skew on KOSPI200 return lasts in a certain positive way for about 2 days and disappeared. Moreover, the effect of an unexpected 1 percentage point increase in XZZ skew on KOSPI200 return lasts in a certain negative way for about 2 days and disappeared. These are consistent result with Table 5 which shows that the CW skew is positively related to stock return while XZZ skew is negatively related to stock return. The response of KOSPI200 return to the unexpected shock of BKM skew lasts about 1 day in negative (-) way but the magnitude of responses is marginal. On the other hand, for all option skew equations, the influence of KOSPI200 return onto option skew is somewhat slightly small and thus leading effect of option market is confirmed.

In sum, the impulse response results are consistent with the results of VAR test which concludes that KOSPI200 return does not have the predictability about the option skew while option skew has the information for KOSPI200 returns.

Scott and Horvath (1980) and Harvey and Siddique (2000) proves that investors have preference toward higher moments on stock return and thus the information about stock market skewness can help the investors construct optimal portfolios. For this reason, we investigate whether investors can predict the higher moments on stock market based on the information about option skewness.

<Table 4> shows the result of VAR model analysis between option skew (CW skew and XZZ skew) and stock skew (CHS skew).

For the case of CW skew and XXZ skew, the coefficients are significant at time lag 1. So we can conclude that the options volatility skew leads to the skew of the stock index return by explaining the extreme case of the stock return. This can be consistent result of Doran, et al (2007, 2010) who claimed that options volatility skew has the predictability for potential market crash, spike upward and the jumps of stock index.

In detail, CW skew has some predictability about CHS skew and it affects CHS skew as much as -0.3862 at time lag 1. On the other hand, Table 5 also shows the XXZ skew has the leading effects for CHS skew, the coefficient is positive and significant at time lag 1. Increase in CHS skew corresponds to the stock which is more crash prone and has a more left-skewed distribution. Meanwhile, if there are more bad news than good news, buying pressure for put option is higher compared to call, which lead XXZ skew to increase but CW skew to decrease. Therefore, the positive relationship between CHS skew and XZZ skew is consistent with the negative relationship between CHS skew and CW skew.

For the robustness check, we test using another option skew by Bakshi, Kapadia, and Madan(2003) The significant coefficient at time lag 1 shows that the BKM skew has the leading effects for CHS skew. Accordingly, it can be concluded that the implied risk neutral skew have information about the skew of KOSPI200 stock index returns distribution. .

In contrast, all the coefficients in option equation which show whether CHS skew has the leading effects to option skew(CW skew, XZZ skew, BMK skew) are turn out to be insignificant. That means the skew of KOSPI200 stock index returns does not have information effects to the volatility skew.

We also conduct the impulse response analysis in order to find out more details about dynamic interactions between the option skew (CW skew and XZZ skew) and the KOSPI200 skew (CHS skew) <Figure 3> shows the impulse response analysis results based on VAR model of option skew and stock skew[4]. First, the influence of CW skews onto CHS skew lasts in the negative way for about 10 days of period and the influence of XZZ skews lasts 6 days in positive way, which is in agreement with the VAR result in Table 6. In contrast, the influence of CHS skew onto option skew(CW skew, XZZ skew, BMK skew) is somewhat slightly small. Also, the influence caused by CHS skew onto BKM skew is marginal whereas the influence caused by BKM skew onto CHS skew lasts in the positive (+) direction for 7 days of period. This result supports the leading effect of option market, verifying option skew has the information for stock skew while that stock skew does not have the predictability about the option skew.

V. Robustness check: Information flow between implied risk-neutral kurtosis and P-kurtosis

This paper focus on examining lead-lag relations between the options volatility skew and the stock return and stock skewness. However, according to the Beber and Brandt (2006), the implied kurtosis of options risk neutral distribution decreases (increases) after bad (good) news for bonds, which tends to be good (bad) news for economy in the US Treasury bond futures options market. Similar to this, A¨ ijo¨ (2008) shows that the implied kurtosis of options risk neutral distribution increases (decreases) after good (bad) news in the FTSE-100 index options market. Through these researches, we can hypothesize that 4th moment can reflect the expectation of market participants about future stock index and their psychological status about future economy.

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[4] The reaction about the stock onto stock skew (CHS skew) itself lasts for a while in the positive (+) direction which infers that the skew of stock index returns distribution lasts in a certain direction consistently for a long time. Also, the reactions about the shock onto option skew (CW skew, XZZ skew, BMK skew) itself are similar. We can observe that it that the volatility skew also last in one direction for a long period of time. However, we do not report impulse response of variable to itself since our purpose is to observe the lead lag relationship between option market and stock market and they are available upon request.

Based on this, we try to examine whether the 4th moment of the options risk neutral distribution has some information about the realized kurtosis of the stock index return and how long the effect of options kurtosis on the 4th moment of the stock index return lasts.

<Table 7> shows the result of VAR test between BKM kurtosis and P kurtosis. The coefficients BKM kurtosis on the P kurtosis are significant at time 1 and 2, and specifically, it shows positive value at time 1, and negative value at time 2. This means that BKM kurtosis has the informational effects about P kurtosis and the effect of BKM kurtosis on the p kurtosis lasts for about 2 days.

Granger causality test results show that the null hypothesis stating that BKM kurtosis does not Granger cause to P kurtosis was shown to be strongly rejected at 1% significance level. Accordingly, it can be inferred that the kurtosis which is estimated from options non-parametrically has the predictability about the kurtosis of the KOSPI200 stock index return. So we can claim that not only the skew of the options but also the kurtosis of the risk neutral distribution contain the information about the higher moments of the stock return and the jumps of the underlying assets. So we suggest it might be useful analyzing the effect of the options risk neutral kurtosis on to the jumps of the stock as well.

And it can be understood that the influence caused by P kurtosis onto BKM kurtosis is light whereas the influence caused by BKM kurtosis onto P kurtosis lasts for 3 days of time in the positive (+) direction. Accordingly, It can be understood that the P kurtosis which is the stock index returns distributional kurtosis similar to VAR analysis through impulse response analysis, does not have the predictability about the BKM kurtosis which is the risk neutral distributional kurtosis of non-parametrically estimated options, whereas the BKM kurtosis has the predictability function about P kurtosis.

Ⅵ. Conclusion

Most of the prior researches that try to verify price discovery role or lead-lag relationship and information effects between stock market and derivatives market are only focused on predicting the future stock returns through the features of the options. However, to the investors who are interested not only in average trend of the stocks but also the jumps and rapid fluctuations of stock index, the skew which is 3rd and 4th moment of stock return can be important factor. Therefore as well as stock return, we focus on the higher moments in stock market which contain important information in predicting the jumps of stock return.

We use option skew which reflect net buying pressure of options traders and the investors' crashophobia about the market crash. If volatility skew precedes the return and skewness of KOSPI200 stock index returns, the investors can predict the movements about the stock price movement and obtain the information about the market crash or spikes.

In this perspective, this paper tries to examine whether options volatility skew has information for predicting the skewness of the stock index return. The sample period of the data covers from January 1998 to July 2006 with the closing price returns of KOSPI 200 Index and the KOSPI 200 options. The volatility skews are estimated by the methods suggested by Cremers and Weinbaum(2010) and Xing, Zhang and Zhao(2010) and the risk neutral skewness is estimated from non-parametric method of Bakshi, Kapadia, and Madan(2003). When estimating the skewness of the stock return, we employ Chen, Hong and Stein(2001) model. Our major empirical analysis results are as follows;

First, we prove that the volatility skew estimated from options leads the return of the KOSPI200 stock index. On the contrary, the skew of the KOSPI200 index return does not have the information effects about the implied volatility skew of options. Moreover, VAR results show that options volatility skew leads to the skew of the stock index return by explaining the extreme case of the stock return and impulse response analysis supports VAR result. Last, as not only the 3^{rd} moment but also 4^{th} moment can affect distribution of stock index return, we examine the relationship between option market kurtosis and stock market kurtosis and find the informational effects of option kurtosis about stock kurtosis.

References

Ahn, H., J. Kang, and D. Ryu, 2010, Information effects of trade size and trade direction: Evidence from the KOSPI 200 index options market, Asia-Pacific Journal of Financial Studies 39, pp. 301–339.

A¨ijo¨, J., 2008, Impact of US and UK macroeconomic news announcements on the return distribution implied by FTSE-100 index options, International Review of Financial Analysis 17, pp. 242–258.

Anthony, J. H., 1988, The Interrelation of Stock and Options Market Trading-Volume Data, *Journal of Finance*, 43(4), 949-964.

Amin, K. I., and Jarrow, R. A., 1992, Pricing Options on Risky Assets in a Stochastic Interest Rate Economy, *Mathematical Finance*, 2(4), 217-237.

Banerjee, R., Doran, J., and D. Peterson., 2006, Implied Volatility and Future Portfolio Returns, *Journal of Banking &Finance,* 31, 3183-3199.

Bakshi, G., Cao, C., and Chen, Z. (1997). Empirical performance of alternative option pricing models. *Journal of Finance*, 52(5):2003-2049.

Bakshi, G., Kapadia, N., and Madan, D., 2003, Stock Return Characteristics, Skew Laws, and Differential Pricing of Individual Equity Options, *Review of Financial Studies*, 16, 101–143.

Bakshi, G., D. Madan, and F. Zhang, 2006, "Investigating the Role of Systematic and Firm-Specific Factorsin Default Risk: Lessons From Empirically Evaluating Credit Risk Models," *Journal of Business,* 79(4).

Bates, A. W., 1991, Interactivity as a criterion for Media Selection in Distance Education, *Never Too Far*, 16, 5-9.

Bates, D., 2000, Post-'87 crash fears in the S&P500 futures options market, Journal of Econometrics 94, pp. 181–238.

Beber, A., and M. W. Brandt, 2006, The effect of macroeconomic news on beliefs and preferences: Evidence from the options market, Journal of Monetary Economics 53, pp. 1997–2039.

Bhattacharya, M., 1987, Price Changes of Related Securities: the Case of Call Options and Stocks, *Journal of Financial and Quantitative Analysis*, 22(1), 1-15.

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

Black, F., 1975, Fact and Fantasy in the Use of Options, *Financial Analysts Journal*, July-Aug.

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

Chan, K., 1992, A Further Analysis of the Lead-lag Relationship between the Cash Market and Stock Index Futures Market, *Review of Financial Studies*, 5(1), 123-152.

Carr, P., and Madan, D., 2001, Optimal Positioning in Derivative Securities, *Quantitative Finance*, 1, 19-37.

Conrad, J., R. Dittmar, and E. Ghysels (2007): "Skewness and the Bubble," Discussion Paper, University of Michigan and UNC.

Cox, J. C., and Rubinstein, M., 1985, Option Market. Prentice-Hall.

Cremers, M., and Weinbaum, D., 2010, Deviations from Put-Call Parity and Stock Return Predictability, *Journal of Financial and Quantitative Analysis*, 45, 335-367.

Chan, K., Chung, Y.P., and Fong, W., 2002, The Informational Role of Stock and Option Volume, *Review of Financial Studies*, 15(4), 1049-1075.

Chan, K., Chung, Y.P., Johnson, H., 1993, Why Option Prices Lag Stock Prices: a Trading Based Explanation, *Journal of Finance*, 48(5), 1957-1967.

Chakravarty, S., Gulen, H., and Mayhew, S., 2004, Informed Trading in Stock and Option Markets, *Journal of Finance*, 59(3), 1235-1257.

Chen, J., Hong, H., and Stein, J. C., 2001, Forecasting Crashes: Trading Volume, Past Returns and Conditional Skew in Stock Prices, *Journal of Financial Economics*, 61, 345-381.

Duan, J. C., 1995, The GARCH Option Pricing Model, *Mathematical Finance*, 5(1), 13-32.

Doran, J. S., and Krieger, K., 2010, Implications for Asset Returns in the Implied Volatility Skew, *Financial Analysts Journal*, 66, 65-76.

Diamond, D. W., and Verrecchia, R. E., 1987, Constraints on Short-selling and Asset Price Adjustment to Private Information, *Journal of Financial Economics*, 18, 277-311.

Doran, J. S., Peterson, D. R., and Tarrant, B.C., 2007, Is There Information in the Volatility Skew?, *Journal of Futures Markets*, 27, 921-959.

Evans, R., Geczy, C., Musto, D., and Reed, A., 2005, Failure is an Option: Impediments to Short Selling and Options Prices, *Review of Financial Studies*, 22, 1955-1980.

Easley, D., O' Hara, M., and Srinivas, P.S., 1998, Option Volume and Stock Prices: Evidence on Where Informed Traders Trade, *Journal of Finance*, 53(2), 431-465.

Giot, P., 2005, On the Relationships between Implied Volatility Indices and Stock Index Returns, *Journal of Portfolio Management*, 31(3), 92-100.

Garleanu, N., Pedersen, L., and Poteshman, A., 2009, Demand-based Option Pricing, *The Review of Financial Studies*, 22, 4259-4299.

Garrett, Thomas A. and Russel S. Sobel (1999): "Gamblers Favor Skewness, Not Risk: Further evidence from United States' Lottery Games," Economic Letters 63, 85-90.

Golec, Joseph and Maurry Tamarkin (1998): "Bettors Love Skewness, Not Risk, at the Horse Track," Journal of Political Economy 106, 205-225.

Goetzmann, William N., and Alok Kumar, "Equity portfolio diversification," *Review of Finance*, 12, 2008, 433-463.

Harvey, Campbell R., and Akhtar Siddique, "Conditional Skewness in Asset Pricing Models Tests," *Journal of Finance* 55, no.3 (June 2000), 1263–1295.

Heston, S., 1993, A Close Form Solution for Options with Stochastic Volatility, *Review of Financial Studies*, 6, 327-343.

Hull, J.., and White, A., 1987, The Pricing of Options on Assets with Stochastic Volatility, *Journal of Finance*, 42, 281-300.

Jackwerth, J. C., 2000, Recovering risk aversion from option prices and realized returns, Review of Financial Studies 13 (2), pp. 433-451.

Jackwerth, J. C. and M. Rubinstein, 1996, Recovering probability distributions from option prices, Journal of Finance 51 (5), pp. 1611-1631.

Jiang, G. J. and Y. S. Tian, 2007, Gauging the 'Investor Fear Gauge': Implementation problems in the CBOE's new volatility index and a simple solution, Journal of Derivatives 14 (3), pp. 35-60.

Kim, S., and Lee, G., 2010, Lead-lag Relationship between Volatility Skew and Returns: Evidence from KOSPI200 Intraday Options Data, Working paper, Hankuk University of Foreign Studies.

Kawaller, L., Koch, P., and Koch, T., 1987, The Temporal Price Relationship between S&P 500 Futures and S&P 500 Index, *Journal of Finance*, 42(5), 1309-1329.

Kumar, Alok, "Who gambles in the stock market?," *Journal of Finance*, 64, 2009, 1889-1933.

Manaster, S. and R. J. Rendleman, 1982, Option prices as predictors of equilibrium stock prices, Journal of Finance 37 (4), pp. 1043-1058.

Mitton, Todd, and Keith Vorkink, "Equilibrium under diversification and the preference for Skewness," *Review of Financial Studies* 20, 2007, 1255-1288.

Merton, R. C., 1973, Theory of Rational Option Pricing, *Journal of Economics and Management Science*, spring.

Merton, R. C., 1976, Option Pricing When Underlying Stock Return are Discontinuous, *Journal of Financial Economics*, 3, 125–144.

Madan, D. B., and Chang, E. C., 1996, Volatility Smiles, Skewness Premia and Risk Metrics: Applications of a Four Parameter Closed Form Generalization of Geometric Brownian Motion to the Pricing of Options, *Working Paper*, University of Maryland.

Manaster, S., and Rendleman, R. J., 1982, Option Prices as Predictors of Equilibrium Stock Prices, *Journal of Finance*, 37(4), 1043-1058.

Melino, A., and Turnbull, S. M., 1990, Pricing Foreign Currency Options with Stochastic Volatility, *Journal of Econometrics*, 45, 7-39.

Melino, A., and Turnbull S. M., 1995, Misspecification and the Pricing and Hedging of Long Term Foreign Currency Options, *Journal of International Money and Finance*, 14, 373-393.

O. N. Seung, Y. O. Seung and K. K. Hyun, "An Empiri- cal Analysis of the Price Discovery and the Pricing Bias in the KOSPI200 Stock Index Derivatives Markets," *In- ternational Review of Financial Analysis*, Vol. 15, No. 4-5, 2006, pp. 398-414.

Pan, J., 2002, The jump-risk premia implicit in options: Evidence from an integrated time-series study, Journal of Financial Economics 63 (1), pp. 3–50.

Stoll, H. R., 1969, The Relationship between Put and Call Option Prices, *Journal of Finance*, 24, 801–24.

Scott, L. O., 1987, Option Pricing When the Variance Changes Randomly: Theory, Estimation, and an Application, *Journal of Financial and Quantitative Analysis*, 22, 419-439.

Scott, R. C., and Horvath, P. A.,1980, On the Direction of Preference for Moments of Higher Order than the Variance, *Journal of Finance*, 35, 915-919.

Sims, C.A. (1980): Macroeconomics and Reality, *Econometrica*, 48, 1-48

Stein, E. M, and Stein, J. C., 1991, Stock Price Distributions with Stochastic Volatility: An Analytic Approach, *The Review of Financial Studies*, 4(4), 727-752.

Stoll, H. R., and Whaley, R. E., 1990, The Dynamics of Stock Index and Stock Index Futures Returns, *Journal of Financial and Quantitative Analysis*, 25(4), 441-468.

Stephan, J. A., and Whaley, R. E., 1990, Intraday Price Change and Trading Volume Relations in the Stock and Option Markets, *Journal of Finance*, 45(1), 191-220.

Vijh, A. M., 1990, Liquidity of the CBOE Equity Options, *Journal of Finance*, 45(4), 1157-1179.

Wiggins, J., 1987, Option Values Under Stochastic Volatility: Theory and Empirical Estimates, *Journal of Financial Economics*, 19, 351-372.

Xing, Y., Zhang, X., and Zhao, R., 2010, What Does Individual Option Volatility Smirk Tell Us About Future Equity Returns?, *Journal of Financial and Quantitative Analysis*, 45, 641-662.

Yan, S., 2011, Jump Risk, Stock Returns, and Slope of Implied Volatility Smile, *Journal of Financial Economics*, 99, 21

<Table 1> Descriptive Statistics

Table2 reports the implied volatilities calculated by inverting the Black-Scholes model separately for each moneyness category. The implied volatilities of individual options are then averaged within each moneyness category and across the days in the sample. Moneyness is categorized by delta(Δ) as definition by Bollen and Whaley(2004).

Type	Moneyness	IV	Type	Moneyness	IV
	DITM ($0.875<\Delta \leq 0.98$)	0.3824		DITM ($-0.98<\Delta \leq -0.875$)	0.4731
	ITM ($0.625<\Delta \leq 0.875$)	0.2853		ITM ($-0.875<\Delta \leq -0.625$)	0.3412
Call	ATM ($0.375<\Delta \leq 0.625$)	0.2692	Put	ATM ($-0.625<\Delta \leq -0.375$)	0.3035
	OTM ($0.125<\Delta \leq 0.375$)	0.3224		OTM ($-0.375<\Delta \leq -0.125$)	0.3189
	DOTM ($0.02<\Delta \leq 0.125$)	0.4451		DOTM ($-0.125<\Delta \leq -0.02$)	0.4114

<Table 2> Descriptive Statistics of variables

The sample period covers from January of 2002 to Dec of 2006. The options volatility skew was estimated by the methods suggested by Cremers and Weinbaum(2010) and Xing, Zhang and Zhao(2010). BKM skew is estimated by non-parametrical methods suggested by Bakshi, Kapadia, and Madan(2003). Besides, the CHS skew which is the KOSPI200 stock index distributional skew is calculated by the method suggested by Chen, Hong and Stein (2001).

Variable		Mean	Maximum	Minimum	Std	Skewness	Kurtosis	N
Option Market	CW skew	-0.0357	0.7773	-1.15	0.1416	-1.5903	11.4343	1237
	XZZ skew	0.0584	1.055	-0.6271	0.1243	1.6463	12.0165	1237
	BKM skew	-0.4024	1.2812	-2.4733	0.4317	-0.121	0.5298	1237
	BKM kurtosis	4.0669	24.5617	0.45	1.3628	5.5263	59.3478	1237
Stock market	Return	0.0008	0.085	-0.1202	0.0209	-0.0761	5.2662	1237
	CHS skew	-0.1196	2.9721	-2.8548	0.8767	0.1527	-0.2312	1237
	P kurtosis	0.752	15.5397	-0.9752	1.9555	4.6592	23.3423	1237

<Table 3> Unit Root Test

This Table reports the Unit-Root test results for each variable. I use augmented Dicky-Fuller(ADF) test and Phillips and Perron(PP) test to check whether a variable has a unit root. Constant terms (1) is the result including constant term and trend line(2) is the result including both constant terms and trend lines. P-values are MacKinnon(1996) one-sided p-values

Variables		Option market				Stock market		
		CW skew	XZZ skew	BKM skew	BKM kurt	Return	CHS skew	P kurtosis
ADF	Constant Term	-11.11** (<.0001)	-12.88** (<.0001)	-10.86** (<.0001)	-16.45** (<.0001)	-18.51** (<.0001)	-8.09** (<.0001)	-4.52** (-0.0003)
	Trend Line	-11.15** (<.0001)	-12.89** (<.0001)	-13.42** (<.0001)	-17.68** (<.0001)	-18.51** (<.0001)	-8.09** (<.0001)	-4.53** (-0.0014)
PP	Constant Term	-368.643** -0.0001	-466.613** -0.0001	-12.72** (<.0001)	-19.79** (<.0001)	-1837.54** (-0.0001)	-8.22** (<.0001)	-4.76** (-0.0001)
	Trend Line	-15** (<.0001)	-17.17** (<.0001)	-15.87** (<.0001)	-21.3** (<.0001)	-42.41** (<.0001)	-8.21** (<.0001)	-4.77** (-0.0005)

<Table 4> VAR Results of Volatility Skew and Stock Index Return

Table5 reports VAR(Vector auto regression) test result using volatility skew and the KOSPI 200 stock index return. Optimal lags of the repressors are determined by the AIC. The options volatility skew was estimated by the methods suggested by Cremers and Weinbaum(2010), Xing, Zhang and Zhao(2010) and Bakshi, Kapadia, and Madan(2003). R_t denotes KOSPI200 stock index return at t.

Stock market equation ($X_t = \alpha + \sum_{i=1}^{n} \beta_i \times X_{t-i} + \sum_{i=1}^{n} \gamma_i \times Y_{t-i}$)				Option market equation ($Y_t = \alpha' + \sum_{i=1}^{n} \beta_i' \times Y_{t-i} + \sum_{i=1}^{n} \gamma_i' \times X_{t-i}$)			
X_t	Stock return			Y_t	CW skew	XZZ skew	BMK skew
Y_t	CW skew	XZZ skew	BMK skew	X_t	Stock return		
α	0.00008 (0.14)	0.0008 (1.27)	0.0009 (1.37)	α'	-0.0042* (-1.66)	0.009*** (3.37)	-0.0365*** (-5.11)
X_{t-1}	0.0359 (1.33)	0.0383 (1.41)	0.0869*** (3.91)	Y_{t-1}	0.4159*** (15.57)	0.4372*** (16.30)	0.6317*** (28.71)
X_{t-2}	-0.0301 (-1.12)	-0.0358 (-1.32)	-0.0264 (-1.18)	Y_{t-2}	0.1605*** (5.58)	0.1318*** (4.53)	0.1144*** (4.38)
X_{t-3}	-0.0136 (-0.50)	-0.0403 (-1.48)	-0.0113 (-0.50)	Y_{t-3}	0.0891*** (3.12)	0.0929*** (3.25)	0.0583** (2.22)
X_{t-4}	0.0081 (0.30)	0.0138 (0.51)	-0.0157 (-0.70)	Y_{t-4}	0.0962*** (3.41)	0.0676*** (2.39)	-0.0174 (-0.66)
X_{t-5}	-0.0223 -(0.83)	-0.0458* (-1.69)	-0.0508*** (-2.27)	Y_{t-5}	0.1082*** (3.86)	0.0938*** (3.33)	0.0388 (1.48)
X_{t-6}			-0.0067 (-0.30)	Y_{t-6}			0.0849*** (3.89)
Y_{t-1}	0.0275*** (4.45)	-0.0257*** (-4.00)	0.0032* (1.50)	X_{t-1}	0.0723 (0.62)	0.1755 (1.55)	-1.0851*** (-4.66)
Y_{t-2}	-0.0202*** (-3.04)	0.0151** (2.18)	0.0026 (1.04)	X_{t-2}	-0.2639** (-2.26)	0.3728*** (3.29)	0.9331*** (3.98)
Y_{t-3}	-0.0021 (-0.32)	-0.0019 (-0.28)	-0.0051*** (-2.02)	X_{t-3}	-0.1151 (-0.99)	0.1205 (1.06)	0.0958 (0.40)
Y_{t-4}	-0.0042 (-0.65)	0.0054 (0.80)	-0.0023 (-0.92)	X_{t-4}	0.0372 (0.32)	0.0071 (0.06)	0.0582 (0.24)
Y_{t-5}	0.0012 (0.19)	0.0021 (0.32)	0.0021 (0.85)	X_{t-5}	0.0854 (0.74)	0.005 (0.04)	0.5330** (2.27)
Y_{t-6}			0.0006 (0.30)	X_{t-6}			0.8835*** (3.81)
Granger (p-value)	25.45*** (0.00)	19.62*** (0.00)	10.00* (0.07)	Granger (p-value)	7.32 (0.29)	15.72** (0.015)	48.35*** (0.00)

<Table 5> VAR Results of Volatility Skew and Stock Index skew

Table6 reports VAR(Vector auto regression) test result using volatility skew and the KOSPI 200 stock index skew. Optimal lags of the repressors are determined by the AIC. The options volatility skew was estimated by the methods suggested by Cremers and Weinbaum(2010), Xing, Zhang and Zhao(2010) and Bakshi, Kapadia, and Madan(2003). The CHS skew which is the KOSPI200 skew is calculated by the method suggested by Chen, Hong and Stein (2001).

Stock market equation ($X_t = \alpha + \sum_{i=1}^{n} \beta_i \times X_{t-i} + \sum_{i=1}^{n} \gamma_i \times Y_{t-i}$)				Option market equation ($Y_t = \alpha' + \sum_{i=1}^{n} \beta'_i \times Y_{t-i} + \sum_{i=1}^{n} \gamma'_i \times X_{t-i}$)			
X_t	CHS skew			Y_t	CW skew	XZZ skew	BMK skew
Y_t	CW skew	XZZ skew	BMK skew	X_t	CHS skew		
α	-0.0135 (-1.34)	-0.0180 (-1.58)	-0.00205 (-0.21)	α'	-0.0054** (-2.09)	0.0114*** (4.10)	-0.03348** (-4.57)
X_{t-1}	0.9106*** (34.18)	0.9304*** (34.78)	0.96684*** (44.17)	Y_{t-1}	0.4157*** (15.87)	0.4298*** (16.34)	0.63571** (29.08)
X_{t-2}	-0.0145 (-0.40)	-0.0170 (-0.47)	-0.02816 (-0.93)	Y_{t-2}	0.1475*** (5.20)	0.1122*** (3.92)	0.09017** (3.47)
X_{t-3}	0.0354 (0.98)	0.0016 (0.05)	-0.01959 (-0.64)	Y_{t-3}	0.0756*** (2.71)	0.0843*** (3.01)	0.06156** (2.36)
X_{t-4}	0.0175 (0.49)	0.0373 (1.02)	0.04613 (1.52)	Y_{t-4}	0.0972*** (3.52)	0.0674*** (2.44)	-0.01204 (-0.46)
X_{t-5}	-0.0334 (-0.93)	-0.0243 (-0.67)	-0.02192 (-0.72)	Y_{t-5}	0.1125*** (4.09)	0.0948*** (3.44)	0.02015 (0.78)
X_{t-6}	-0.0180 (-0.68)	-0.0324 (-1.21)	-0.01135 (-0.37)	Y_{t-6}	0.0085 (0.33)	0.0191 (0.75)	0.04939 (1.90)
X_{t-7}			-0.00014 (-0.00)				0.01701 (0.66)
X_{t-8}			0.00664 (0.30)				0.05608** (2.57)
Y_{t-1}	-0.3862*** (-3.78)	0.2922*** (2.70)	0.12021*** (4.14)	X_{t-1}	0.0000 (0.01)	-0.0021 (-0.32)	-0.00647 (-0.39)
Y_{t-2}	-0.1490 (-1.35)	-0.0128 (-0.11)	-0.08200** (-2.38)	X_{t-2}	-0.0029 (-0.32)	0.0039 (0.44)	0.00493 (0.21)
Y_{t-3}	0.1347 (1.23)	0.0765 (0.66)	-0.04149 (-1.20)	X_{t-3}	-0.0112 (-1.22)	0.0143 (1.61)	0.02066 (0.90)
Y_{t-4}	0.1748* (1.62)	-0.0896 (-0.79)	0.00906 (0.26)	X_{t-4}	0.0025 (0.27)	-0.0024 (-0.27)	-0.05212** (-2.27)
Y_{t-5}	0.0522 (0.49)	-0.1124 (-0.99)	0.02994 (0.87)	X_{t-5}	0.0100 (1.09)	-0.0109 (-1.23)	-0.00331 (-0.14)
Y_{t-6}	0.0957 (0.95)	-0.0431 (-0.41)	-0.06133 (-1.78)	X_{t-6}	-0.0054 (-0.80)	0.0043 (0.66)	0.03163 (1.38)
Y_{t-7}			-0.02685 (-0.78)				-0.01366 (-0.60)
Y_{t-8}			0.06599** (2.28)				0.01253 (0.76)
Granger (p-value)	24.48*** (0.00)	10.86* (0.09)	26.82*** (0.00)	Granger (p-value)	8.97 (0.17)	12.63** (0.04)	11.13 (0.19)

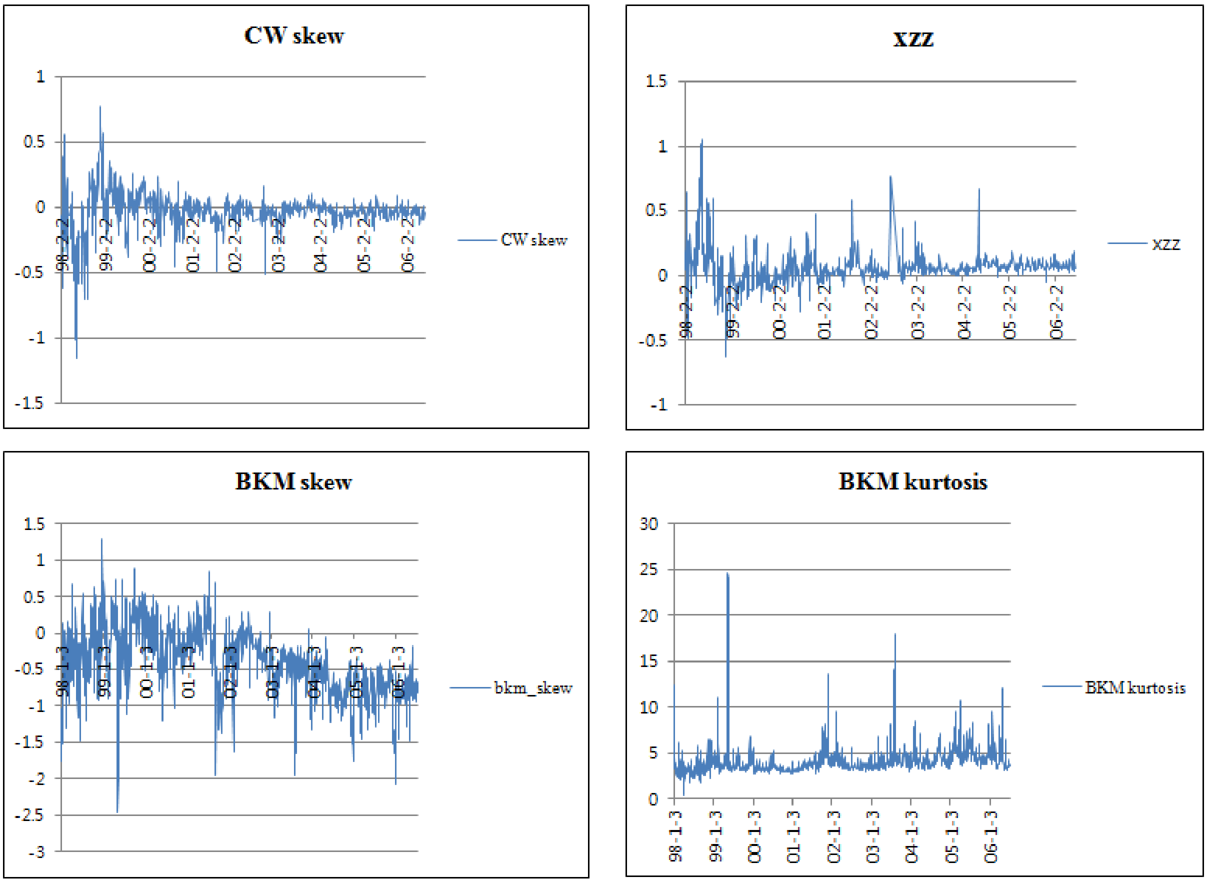
<Table 6> VAR Results of BMK Kurtosis and P- Kurtosis:

BKM kurtosis is estimated by non-parametrical methods suggested by Bakshi, Kapadia, and Madan(2003).

Stock market equation ($X_t=\alpha+\sum_{i=1}^{n}\beta_i\times X_{t-i}+\sum_{i=1}^{n}\gamma_i\times Y_{t-i}$)		Option market equation ($Y_t=\alpha'+\sum_{i=1}^{n}\beta_i'\times Y_{t-i}+\sum_{i=1}^{n}\gamma_i'\times X_{t-i}$)	
X_t	P kurtosis	Y_t	BMK kurtosis
Y_t	BMK kurtosis	X_t	P kurtosis
α	0.00968 (0.26)	α'	0.94534** (11.24)
X_{t-1}	0.88686** (40.76)	Y_{t-1}	0.64866** (29.94)
X_{t-2}	0.06934** (2.38)	Y_{t-2}	0.05025 (1.95)
X_{t-3}	0.03757 (1.29)	Y_{t-3}	-0.01031 (-0.40)
X_{t-4}	-0.02947 (-1.01)	Y_{t-4}	0.04918 (1.89)
X_{t-5}	0.02500 (0.86)	Y_{t-5}	-0.06708** (-2.60)
X_{t-6}	-0.00986 (-0.46)	Y_{t-6}	0.09233** (4.33)
Y_{t-1}	0.02759** (2.93)	X_{t-1}	0.00877 (0.18)
Y_{t-2}	-0.04970*** (-4.43)	X_{t-2}	-0.03205 (-0.48)
Y_{t-3}	0.01870 (1.66)	X_{t-3}	0.00390 (0.06)
Y_{t-4}	0.00432 (0.38)	X_{t-4}	0.06363 (0.95)
Y_{t-5}	-0.00072 (-0.06)	X_{t-5}	-0.04055 (-0.61)
Y_{t-6}	0.00136 (0.15)	X_{t-6}	0.01935 (0.39)
Granger (p-value)	20.15*** (0.00)	Granger (p-value)	5.81 (0.44)

<Figure 1: Process of Variables>

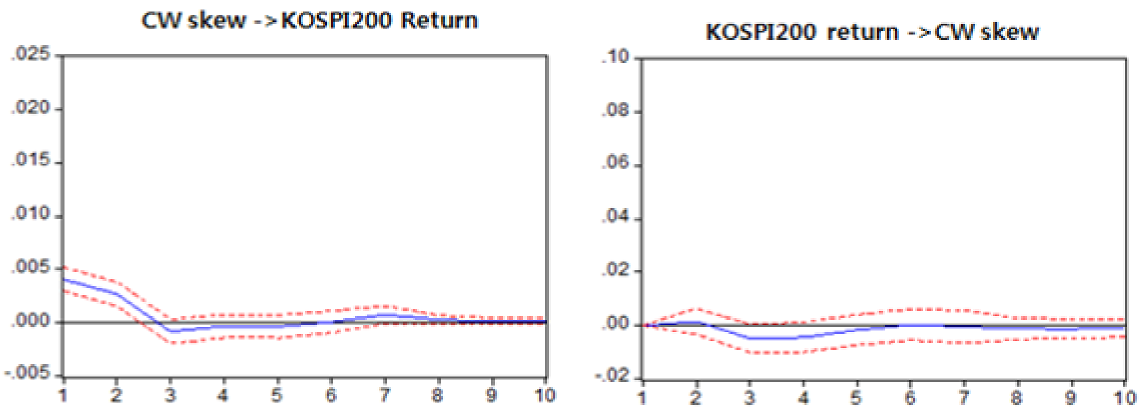
The Figure shows the process of each variable used in this paper. The sample period is from January of 1998 to June of 2006. The volatility skew was estimated by the methods suggested by Cremers and Weinbaum(2010) and Xing, Zhang and Zhao(2010). The implied risk-neutral skew and kurtosis are estimated by the methods suggested by Bakshi, Kapadia, and Madan(2003).



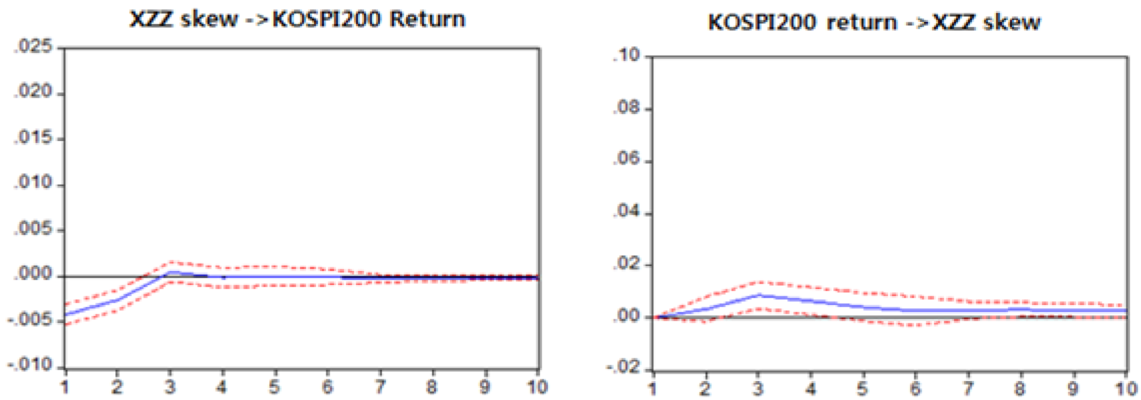
<Figure 2> Impulse response analysis: option skew and stock return

This Figure shows the result of impulse response analysis using option skew(CW skew, XZZ skew, BMK skew) and stock return (KOSPI200).

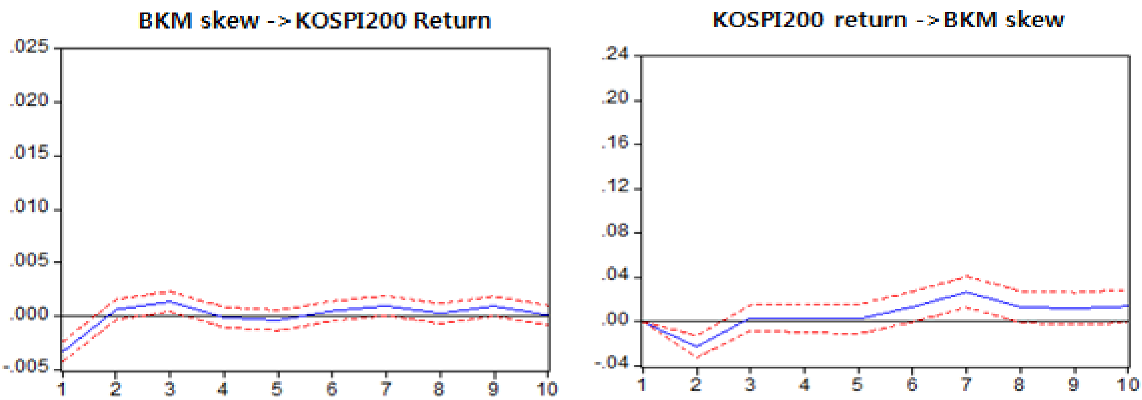
A. CW skew – Stock return



B. XZZ skew – Stock return



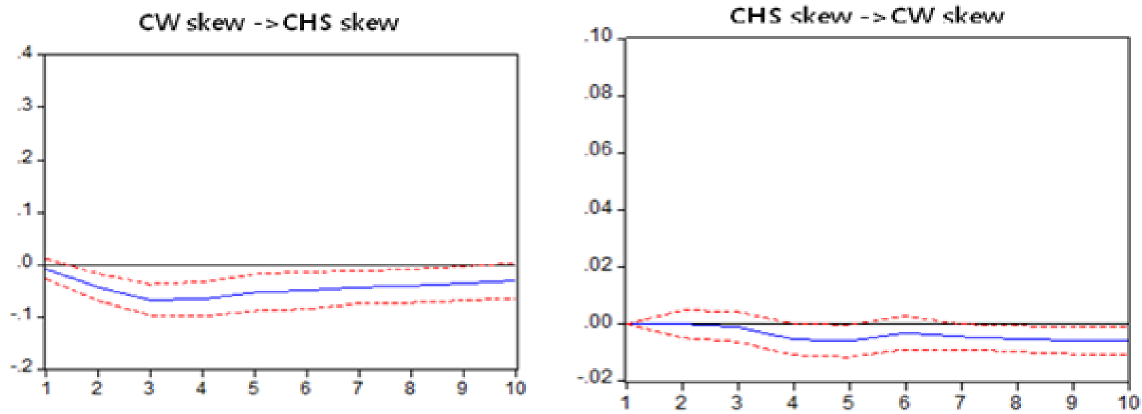
C. BMK skew – Stock return



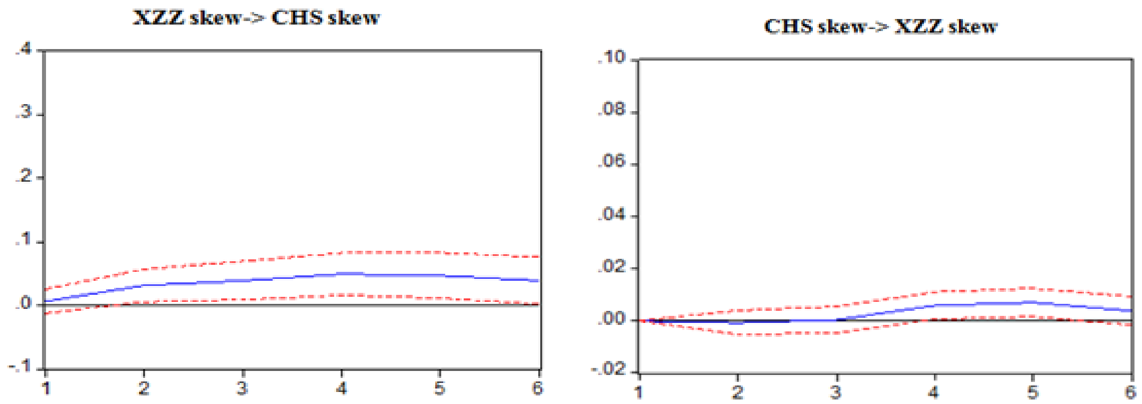
<Figure 3> Impulse response analysis: option skew and stock skew

This Figure shows the result of impulse response analysis using option skew(CW skew, XZZ skew, BMK skew) and stock skew(CHS skew).

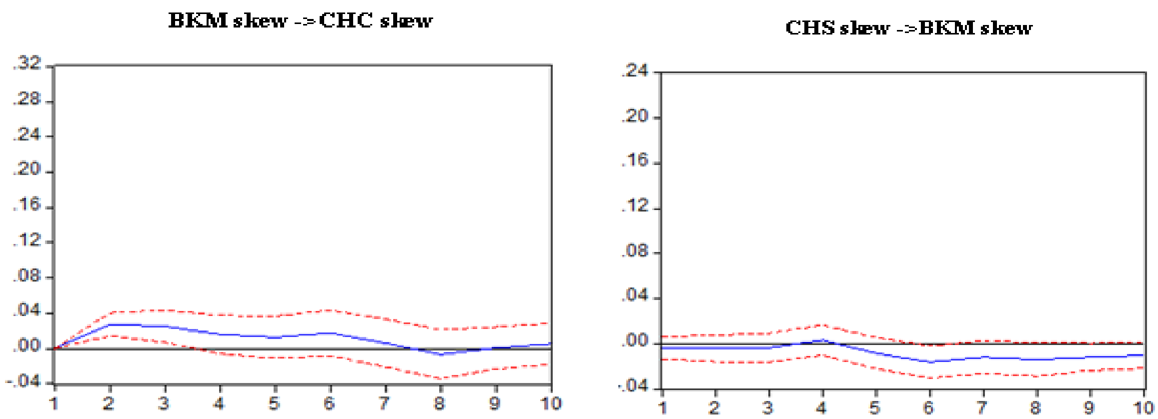
A. CW skew – CHS skew



B. XZZ skew- CHS skew



C. BMK skew- CHS skew



<Figure 4> Impulse response analysis results of BKM kurtosis and P kurtosis

This Figure shows the impulse response analysis results conducted based on VAR model of BKM skew and P skew.