Is Stochastic Volatility Always Priced on Index Options ?

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Abstract

The negative volatility risk premium implied on index options is a common concept to explain the difference of the historical volatility and the implied volatility. Since the volatility of an underlying index becomes higher as the market moves down, holding both an underlying asset and the option induces a hedging effect against significant market declines. In a circumstance, however, in which each market is dominated by different investors, such an explanation may not be reliable anymore. This study proves the argument via KOSPI 200 index options. The KOSPI 200 index market is mainly driven by institutional investors and foreign investors, whereas its related options market is dominated by individual investors. We shows that the volatility risk is not priced on KOSPI 200 index option, using the delta-hedged gains on a portfolio of a long position in a call, hedged by a short position in the underlying asset (Bakshi and Kapadia (2003)). Rather, jump fear influences in determining KOSPI 200 option prices. The results are consistent with extant literatures that have shown that the Korean derivatives market is dominated by directional traders, thus questioning the existence of hedging demands on option trades. In this research, no specifications are imposed on the stochastic processes of the underlying asset, volatility, and jumps, consequently freeing the results from misspecification errors.

JEL classification: G12; G13

Keywords: KOSPI 200 index; KOSPI 200 index option; volatility risk premium; stochastic volatility/jump diffusion; risk-neutral skewness; risk-neutral kurtosis

1 Introduction

Since the seminal works of Black and Scholes (1973) and Merton (1976), a large number of option pricing models have been proposed to explain empirical regularities such as the volatility smile/smirk which could not be interpreted by Black-Scholes model (hereafter BS model). These endeavors can be classified into three groups:

- the deterministic volatility model: Cox and Ross (1976), Rubinstein (1994), Dupire (1994), and Derman and Kani (1994)
- the stochastic volatility model: Hull and White (1987), Stein and Stein (1991), Heston (1993), and Heston and Nanci (2000)
- the jump/diffusion model: Merton (1976), Bates (1991), and Pan (2002).

Bakshi et al. (1997), Dumas et al. (1998), Bates (2000), and Jackwerth and Rubinstein (1998) compare the empirical performances of these three alternative option pricing models. According to their results, although the BS model is dominated by deterministic models as well as by stochastic models, both pricing and hedging errors are too large to judge the superiority of the models.[1] However, Bakshi et al. (2000), and Buraschi and Jackwerth (2001) suggest the possibility of existence of an additional risk factor in S&P 500 index options market, which can at least reject the deterministic volatility models.

The stochastic volatility is one of the most typical risk factors among possible candidates. The stochastic volatility enables to capture time-varying volatility, and its negative risk premium can explain the discrepancy of the historical volatility and the implied volatility.[2] The negative risk premium on volatility risk corresponds to a hedging effect against significant market declines. Since the volatility of the underlying index becomes higher as the market moves down, holding both an underlying asset and the option induces a hedging effect against significant market declines (French, Schwert, and Stambaough (1987) and Glosten, Jagannathan, and Runkle (1993)). Given

[1] Furthermore, the alternative models do not appear to fully explain both the underlying market and the options market, as shown in Ait-Sahalia, Wang, and Yared (2001), Anderson, Benzoni, Lund (2002), and Chernov and Ghysels (2000).

[2] The BS implied volatilities are higher than the historical volatilities of the underlying asset in the S&P index options markets (Jackwerth and Rubinstein (1996)).

that option values are proportional to the volatility of the underlying asset, option buyers are ready to pay a premium for protecting against market depreciation.

Is such an explanation, however, still reliable in a circumstance in which the underlying market and the options market are dominated by different investors? Should an option buyer always pay a premium for market declines, even though they do not possess any positions in the underlying asset? The KOSPI 200 index options market is the only and the best market affordable for testing the argument. As shown in Table 1 and Table 2, the KOSPI 200 index market is dominated by non-individual investors, whereas the KOSPI 200 index options market is mainly driven by individual investors. Over 50 percent of the trades in the KOSPI 200 index options market are composed of trades by individual investors, far higher than those in other markets.[3] Given the suitability of the KOSPI 200 index options market, the present goal of this paper is to investigate empirically whether volatility risk requires a premium in the KOSPI 200 index options market.

There are two types of approaches which we can adopt in our research. One is to choose the specification of a model and to estimate its parameters both under physical and risk-neutral measures. The difference between the parameters under the two measures infers the risk premia implied on option prices. Chernov and Ghysels (2000), Anderson et al. (2002), and Benzoni (2002) estimate a variety of the models with stochastic volatility and support the existence of the negative volatility risk premia in the S&P 500 index options market. The other approach is the non-parametric approach based on the hedging performance. Hedging performance reflects the compensation for bearing other risks in addition to stock price risk. This kind of study does not usually depend on the choice of models and is free from the misspecification errors. By examining the sign and size of delta-hedged gains, for instance, Bakshi and Kapadia (2003) determine an additional risk factor of the volatility risk in the S&P index options market. Delta-hedged gains on a portfolio of a long position in a call, hedged by a short position in the underlying asset, are systematically and consistently negative, which supports a negative risk premium in S&P 500 index options market.

[3] In Japan, individual investors account for 12% of customer trading (excluding inter-dealer transactions) in Nikkei 225 futures and 8% in options, while their share in the more heavily traded TOPIX contracts is essentially zero. Comparable data for the United States and Europe do not exist, but all of the available evidence suggests that individual investors account for only a small proportion of derivatives trades. (BIS Quarterly Review (2005))

Our empirical study adopts the nonparametric approach of Bakshi and Kapadia (2003). The discrete delta-hedged gains are used to test for the existence of volatility risk premia. This approach does not impose any specification on the pricing kernel and the volatility process, thereby making the results free from misspecification errors.[4] We set a portfolio of a long position in a call option, daily-hedged by a short position in the stock. The portfolio is not hedged for any risk factors other than market risk, and the gain on the portfolio is termed "delta-hedged gains." If volatility is deterministic or if it is stochastic but not compensated, the delta-hedged gains will be zero. Otherwise, the gains are skewed subject to the sign and magnitude of the risk premium.

The empirical results of our study provide evidence supporting the following arguments:

- The delta-hedged gain on the portfolio of buying the ATM call, hedged by the underlying stock (KOSPI 200 index), is not far from zero.
- There appears to be no relation between the delta-hedged gains and option vega in KOSPI 200 options market.
- These mean that the volatility risk is not priced, as the driving force of KOSPI 200 index options market differs from that of KOSPI 200 index market.
- A jump risk is a more important factor in the KOSPI 200 index options market.[5]

The remainder of the paper is organized as follows. Section 2 represents the properties of the delta-hedged gains, and shows how the risk-neutral skewness and kurtosis are retrieved from option

[4]The parametric approach suffers from misspecification errors. For example, Chernov and Ghysels (2000), Anderson et al. (2002), and Benzoni (2002) support the negative risk premium. On the other hand, Pan (2002) estimates the stochastic volatility/jump diffusion model, and concludes that the volatility risk premia are not significantly different from zero but rather the jump size risk requires a considerable premium. The different choice of models induces the different results for the risk premia, and the erroneous specification of models can thereby lead to incorrect conclusions.

[5]This appears to be contrary to the results of the extant literature (Kim and Kim (2004)). Kim and Kim (2004) compare the empirical performance of alternative option pricing models in terms of hedging and forecasting under the risk-neutral measure in the KOSPI 200 index options market, and conclude assuming only the stochastic volatility is better than assuming both the stochastic volatility and the jump component on the risk-neutral distribution implied in options prices. Their results, however, are not linked to the physical process; hence, they do not apply to the volatility risk premium.

prices. In Section 3, the KOSPI 200 index options market and the criteria used in screening the dataset are described. Included is the method of calculating the volatility. Section 4 documents the empirical results associated with the delta-hedged gains. Delta-hedged gains are tested as to whether they are far from zero statistically, and whether this can be interpreted using the option vega, moneyness, and maturities. Section 5 explores the jump effect on option prices. Lastly, Section 6 concludes and discusses future research issues.

2 Theoretical Background

This section gives a simple description of the theoretical backgrounds of this paper, as well as related testable implications. Based on the results of Bertsimas, Kogan, and Lo (2000), Bakshi and Kapadia (2003) develop the properties of the "delta-hedged gains," when the volatility is stochastic. Bakshi, Kapadia, and Madan (2003) formalize a means of retrieving risk-neutral skewness and kurtosis from out-of-the-money options as a proxy of the jump fears. These theoretical foundations are the cornerstones of the empirical analysis of this study.

2.1 Delta-Hedged Gains and Risk Premium

The stock price and its volatility are denoted by S_t and σ_t, respectively, whose processes are as follows:

$$\frac{dS_t}{S_t} = \mu_t(S,\sigma)dt + \sigma_t dZ_t^1, \tag{1}$$
$$d\sigma_t = \theta_t(\sigma)dt + \eta(\sigma)dZ_t^2, \tag{2}$$

where the correlation between two Brownian motions is ρ.

Let $C(t,\tau;K)$ represent the price of a European call maturing in τ periods from time t with exercise price K; $\Delta(t,\tau;K)$ indicates the corresponding option delta. The delta hedged gains, $\Pi_{t,t+\tau}$, on the hedged option portfolio are given by

$$\Pi_{t,\tau} = C_{t+\tau} - C_t - \int_t^{t+\tau} \Delta_u dS_u - \int_t^{t+\tau} r\left(C_u - \Delta_u S_u\right)du, \tag{3}$$

where S_t is the underlying stock price at the time t and r is the riskfree rate at time t.

Under a BS economy with constant volatility, the gains on a portfolio that is continuously hedged will be zero over every horizon. Even if it is discretely hedged, the distribution of the gains converges to zero asymptotically (Bertsimas, Kogan, and Lo (2000)). Here, for an option portfolio, hedged discretely N times over the life of options, the delta-hedged gains are represented as

$$\pi_{t,t+\tau} = C_{t+\tau} - C_t - \sum_{n=0}^{N-1} \Delta_{t_n} \left(S_{t_{n+1}} - S_{t_n}\right) - \sum_{n=0}^{N-1} r_n \left(C_t - \Delta_{t_n} S_{t_n}\right) \frac{\tau}{N}, \tag{4}$$

where $t_0 = t, \quad t_N = t + \tau$.[6] Bertsimas, Kogan, and Lo (2000) derived the asymptotic distribution of the discrete delta-hedged gains, and showed that the delta-hedged gains are distributed around zero regardless of the rebalancing frequency.

Similarly, consider the economy wherein volatility is stochastic. According to Bakshi and Kapadia (2003), the delta-hedged gains would be satisfied by the following relationships, given the volatility risk premia, λ.[7]

- The delta hedged-gains, $\Pi_{t,t+\tau}$, are given by

$$E_t \left[\Pi_{t,t+\tau}\right] \;=\; \int_t^{t+\tau} E_t \left(\lambda_u \frac{\partial C_u}{\partial \sigma_u}\right) du, \tag{5}$$

  where $\lambda_t = -\text{cov}\left(\frac{dm_t}{m_t}, d\sigma_t\right)$, and m_t is the pricing kernel.

- If the volatility risk does not require the premia, the discrete delta-hedged gains, $\pi_{t,t+\tau}$, are, on average, zero with the order of $O(1/N)$.

$$E_t \left(\pi_{t,t+\tau}\right) = O(1/N) \tag{6}$$

In consequence, if the volatility is stochastic and its risk is offset, the delta-hedged gains are affected by the volatility risk premia, λ_t, and the option vega, $\partial C_t / \partial \sigma_t$. Such a relationship was applied to the KOSPI 200 index options to find evidence of the volatility risk premia.

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[6] This portfolio gain (4) does not satisfy the self-financing strategy, as $\int r_u C_u du$ is approximated into $\sum_{n=1}^{N} r_n C_t \frac{\tau}{N}$. Thus it is calculated again with self-financing portfolio, but the results do not change. The reported results, hereafter, are based on the self-financing portfolio gains.

[7] Rigorous proof of the above relationships is reported in Bakshi and Kapadia (2003). Out of space consideration, it is not included here.

2.2 Risk-Neutral Skewness and Kurtosis as a Proxy of Jump Component

Jump risk is another factor that can induce the underperformance of delta-hedged gains (Bakshi and Kapadia (2003)). In this section, the theoretical mechanism of how jump risk influences the delta-hedged gains as well as how the extent of jump risk is measured are simply described.

The linkage between jump fears and delta-hedged gains is somewhat complicated. To comprehend the impact of jump fears on delta-hedged gains, a simple jump-diffusion model for a stock process is considered (Bates (1991, 1996, 2000), and Pan (2002)).

$$\frac{dS_t}{S_t} = (\mu_t - \Lambda\mu_J)\,dt + \sigma_t dZ_1 + J_t dq_t, \tag{7}$$

$$d\sigma_t = -\kappa\sigma_t dt + \nu dZ_2, \tag{8}$$

$$\mathrm{Cov}\,(dZ_1, dZ_2) = \rho dt, \tag{9}$$

$$\mathrm{Prob}\,(dq_t = 1) = \Lambda dt, \tag{10}$$

$$\ln(1 + J_t) \sim N(\ln(1+\mu_J) - \frac{1}{2}\delta^2, \delta^2), \tag{11}$$

where σ_t represents the instantaneous return volatility at time t, q is a Poisson process with intensity Λ, and J_t is the random percentage jump conditional on a jump occurring at time t.

Under the consideration of the jump risk, the delta-hedged gains are given by

$$\begin{aligned} E_t\left[\Pi_{t,t+\tau}\right] \;=\; & \int_t^{t+\tau} E_t\left(\lambda_u \frac{\partial C_u}{\partial \sigma_u}\right) du + \mu_J^* \Lambda^* \int_t^{t+\tau} E_t\left[\frac{\partial C_u}{\partial S_u} S_u\right] du \\ & -\Lambda^* \int_t^{t+\tau} \int_{-\infty}^{\infty} \left(C_u(S_u(J+1)) - C_u(S_u)\right) prob^*(J) dJ du \\ & +\Lambda \int_t^{t+\tau} \int_{-\infty}^{\infty} \left(C_u(S_u(J+1)) - C_u(S_u)\right) prob(J) dJ du, \end{aligned} \tag{12}$$

where $prob(J)$ is the physical density represented by (11), and $prob^*(J)$ is the risk-neutral density. The jump risk premia Λ/Λ^* and $\mu_J - \mu_J^*$ reflect the compensation required for bearing the systematic jump risk. Assume that jumps occur only in the stock market and that the representative agent has a constant relative risk aversion (CRRA) utility. When average jumps are negative, the risk-neutral jump frequency and the risk-neutral average drop size are likely to exaggerate the downside jump risk: $\Lambda^* > \Lambda$, $\mu_J^* < \mu_J$ (Bates (1991, 2000)). The first term in (12) reflects the effect of a volatility risk premium, and the other terms reflect the effect of the jump risk.

When $\lambda_u = 0$, the sign of the delta-hedged gains is indefinite.[8] The delta-hedged gains depend on all $\Lambda, \Lambda^*, \mu_J, \mu_J^*$, $\partial C_u/\partial S_u$, and $\Delta C(\cdot)$. In particular, the risk-neutral jump density Λ^* and μ_J^* are related to the marginal utility of nominal wealth for the representative investor, which is not easily defined in empirical studies. Only assuming that the third term and the fourth term are comparable, the delta-hedged gains are determined mainly by the second term, and are therefore negative.

The risk-neutral skewness and kurtosis are adopted as a proxy for jump fears (Bakshi, Kapadia, and Madan (2003)).[9] This step relies on the possibility of using only OTM calls and puts. No specific structure is imposed on the jump process, leaving the results free from misspecification errors.

Specifically, the cubic contract, which is a specific position simultaneously involving a long position in OTM calls and a short position in OTM puts, can quantify the return asymmetry. For example, when the risk-neutral distribution is left-skewed, the cost of holding puts is larger than that of holding calls, thereby reflecting the degree of the skewness. Similarly, the price of quartic contract can be transformed to the kurtosis.

According to Bakshi et al. (2003), the τ-period risk-neutral return skewness is given by

$$\begin{aligned} \mathrm{SKEW}(t,\tau) &\equiv \frac{E_t^*\left[(R_{t,t+\tau} - E_t^*[R_{t,t+\tau}])^3\right]}{\left\{E_t^*\left(R_{t,t+\tau} - E_t^*[R_{t,t+\tau}]\right)^2\right\}^{3/2}} \\ &= \frac{e^{r\tau}W(t,\tau) - 3\mu(t,\tau)e^{r\tau}V(t,\tau) + 2\mu(t,\tau)^3}{\left[e^{r\tau}V(t,\tau) - \mu(t,\tau)^2\right]^{3/2}}. \end{aligned} \tag{13}$$

The risk-neutral kurtosis is given by

$$\mathrm{KURT}(t,\tau) \equiv \frac{E_t^*\left[(R_{t,t+\tau} - E_t^*[R_{t,t+\tau}])^4\right]}{\left\{E_t^*\left(R_{t,t+\tau} - E_t^*[R_{t,t+\tau}]\right)^2\right\}^2}$$

[8] Bakshi and Kapadia (2003) assert that delta-hedged gains are negative if the mean jump size is negative and if only a jump size is priced. This is supported by the following argument: $\int_{-\infty}^{\infty} C_u(S_u(J+1))prob^*(J)dJ - \int_{-\infty}^{\infty} C_u(S_u(J+1))prob(J)dJ$ is positive. Under $\Lambda^* > \Lambda$, and $\mu_J^* < \mu_J$, however, the integral term is likely to be negative rather than positive to call options. Thus the total delta-hedged gains, represented by equation (24) on page 538 of Bakshi and Kapadia (2003), may possibly be positive albeit very small. Therefore, it is hard to say that negative mean jumps result in negative delta-hedged gains *absolutely*.

[9] Alternatively, Bates (1991, 2000)'s skewness premium measure can also be employed as a proxy. The skewness premium is also free from any specification error.

$$= \frac{e^{r\tau}X(t,\tau) - 4\mu(t,\tau)e^{r\tau}W(t,\tau) + 6e^{r\tau}\mu(t,\tau)^2V(t,\tau) - 3\mu(t,\tau)^4}{[e^{r\tau}V(t,\tau) - \mu(t,\tau)^2]^2}, \tag{14}$$

where $V(t,\tau)$, $W(t,\tau)$, and $X(t,\tau)$ are the prices of the volatility contract, the cubic contract, and the quartic contract, respectively. The expected rate of returns from t to $t+\tau$, $\mu(t,\tau)$, are obtained by the Taylor expansion. To compute above equations from finite option data, the Riemann integral should be approximated discretely, as in Bakshi and Madan (2006).

$$V(t,\tau) = \int_{S_t}^{\infty} \frac{2\left(1-\ln(K/S_t)\right)}{K^2}C(t,\tau;K)dK + \int_0^{S_t} \frac{2\left(1+\ln(S_t/K)\right)}{K^2}P(t,\tau;K)dK, \tag{15}$$

$$\begin{aligned} W(t,\tau) &= \int_{S_t}^{\infty} \frac{6\ln(K/S_t) - 3\left(\ln(K/S_t)\right)^2}{K^2}C(t,\tau;K)dK \\ &\quad - \int_0^{S_t} \frac{6\ln(S_t/K) + 3\left(\ln(S_t/K)\right)^2}{K^2}P(t,\tau;K)dK, \end{aligned} \tag{16}$$

$$\begin{aligned} X(t,\tau) &= \int_{S_t}^{\infty} \frac{12\left(\ln(K/S_t)\right)^2 - 4\left(\ln(K/S_t)\right)^3}{K^2}C(t,\tau;K)dK \\ &\quad + \int_0^{S_t} \frac{12((\ln(S_t/K))^2 + 4\left(\ln(S_t/K)\right)^3}{K^2}P(t,\tau;K)dK, \end{aligned} \tag{17}$$

$$\mu(t,\tau) \simeq e^{r\tau} - 1 - \frac{e^{r\tau}}{2}V(t,\tau) - \frac{e^{r\tau}}{6}W(t,\tau) - \frac{e^{r\tau}}{24}X(t,\tau). \tag{18}$$

In summary, risk-neutral higher moments are used as a proxy for jump fears. If jump fears are implied on options prices, this factor tends to drive the delta-hedged gains to be negative on average.

2.3 Testable Implications

This section includes three testable implications related to delta-hedged gains.

- First, if the volatility risk premium is nonzero, the delta-hedged gains for ATM options will also be nonzero.

From equation (5), the delta-hedged gains reflect the sign and magnitude of the volatility risk premium, given a fixed vega. To fix the option's vega, only a fixed maturity of ATM options are employed. The gains for ATM options are most sensitive to a risk premium. Moreover, the ATM options are known to be most unrelated to market friction. Thus, the ATM option prices are slightly contaminated while the ATM-based-results are reliable.

- Second, if the volatility risk requires the premia, the magnitude of absolute delta-hedged gains (loss) coincides to the level of option vega with respect to moneyness.

To confirm the first hypothesis that holds that volatility risk is offset in KOSPI 200 index options, the relationship between the delta-hedged gains and option vega is investigated. Since delta-hedged gains are determined by the risk premium, λ_t, and the option vega, $\frac{\partial C}{\partial \sigma}$, the difference in the option vega induces the difference in the delta-hedged gains.

According to the Ito-Taylor expansion of delta-hedged gains shown in Bakshi and Kapadia (2003), the delta-hedged gains, $E_t(\Pi_{t,t+\tau})$, are related to the current underlying asset, the level of volatility, and the parameters governing the option vega, here maturity and moneyness. For a broad class of option pricing models, option prices are homogeneous of degree one in the stock price, S_t, and the exercise price, K (Merton (1973)). Therefore the option vega, $\partial C_t / \partial S_t$, is also linearly correlated with the stock price, given a fixed moneyness and maturity. According to *Lemma 1* of Bakshi and Kapadia (2003), the delta-hedged gains can be rewritten as

$$E_t\left[\Pi_{t,t+\tau}\right] = S_t \times g_t(\sigma_t, \tau, y; \lambda_t), \tag{19}$$

where $g(\cdot)$ is the model specific function of volatility, σ_t, time to maturity, τ, and moneyness, y, given the risk premium λ_t. $E_t\left[\Pi_{t,t+\tau}\right]/S_t$ varies with the physical volatility in the time series and with the option moneyness in the cross section.

Hence, such a relationship can be applied to a cross-sectional analysis. Once σ_t is fixed, the delta-hedged gains change according to the option vega, which varies with moneyness.[10] The option vega is maximized for at-the-money, and as are the delta-hedged losses (gains) for at-the-money strikes. On the other hand, the vega and the losses (gains) are minimized for the away-from-the-money. If these relationships are found between delta-hedged gains and moneyness, it is possible to reject the hypothesis that states that the volatility risk premium is zero.

- Third, if jump fears are implied on option prices, the coefficients of risk-neutral skewness and/or kurtosis in the regression are significant.

Jump fears can induce the under-or-over performance of delta-hedged gains. A jump fear can dichotomize the risk-neutral distribution from the physical distribution, thereby changing the delta-hedged gains even without a volatility risk premium (Bates (2000), and Pan (2002)). Usually,

[10] It is important to fix σ, because the option price is nonlinear in σ_t for away-from-the-money strikes.

the risk-neutral distribution is more volatile, more left-skewed and more leptokurtic compared to the physical distribution (Rubinstein (1994), Jackwerth (2000), and Bakshi, Kapadia, and Madan (2003)). The mean jump size governs the risk-neutral skewness, while the jump intensity determines the risk-neutral kurtosis. Thus, higher-order risk-neutral moments, retrieved using a position in out-of-money calls and puts, are applied as a proxy of the jump fears.

3 Data Description

3.1 KOSPI 200 Index Options Market

The dataset used is the KOSPI 200 index and its related options. The KOSPI 200 is a market-capitalization-weighted index composed of 200 major stocks in the Korea Stock Exchange (KSE). It reflects nearly eighty percent of the total market capitalization. KOSPI 200 index options are written on the KOSPI 200 index. Introduced on July 7 1997, the KOSPI 200 options market has become the most active options market in the world in terms of the trading volume, despite its short history. Table 3 shows the top three exchange-traded options in terms of the trading volume from 2001 to 2006. The trading volume of KOSPI index options reached to 2,837 million contracts at 2003, which is over twenty times higher than that of secondly liquid index options.

Three consecutive near-term delivery months and one additional month from the quarterly cycle (March, June, September and December) make up four contract months. The expiration day is the second Thursday of each contract month. An option contract per each month has at least five strike prices. The number of strike prices may, however, increase according to the price movement. Trade in KOSPI 200 index options is European and thus contracts can be exercised only on the expiration date. The KOSPI 200 index options market opens at 9:00 and trades continuously until 15:05. Prior to 9:00 and from 15:05 to 15:15, options are traded on a single price, and the trade closes at 15:15. On the other hand, the underlying market closes at 15:00.

3.2 Screening Criteria

Daily observations are employed on KOSPI 200 index options. To avoid the synchronizing problem that could occur when selecting the index and corresponding options, both prices are captured at

14:50 on every trading day.[11]

The options used are screened by the following criteria. First, only the option data from January 1 1999 to July 31 2006 are used. Until the 1990s, the Korean interest rate was very high while the average stock returns were not. This causes a negative excess return for a certain period. More importantly, since January 1, 1999, the Korea Stock Exchange (KSE), has excluded Saturday in addition to Sunday as trading days, thereby having 250 trading days a year.[12] To avoid the negative excess return and the change in the number of trading days, the data prior to 1999 are eliminated. Second, the options that violate following arbitrage bounds are deleted.

$$S_t e^{-d\tau} \geq C_{t,\tau} \geq S_t e^{-d\tau} - e^{-r\tau}K, \tag{20}$$

$$e^{-r\tau}K - S_t e^{-d\tau} \geq P_{t,\tau} \tag{21}$$

Third, the options with maturities less than 10 (trading days) and longer than 40 (trading days-two months) are excluded due to the very low trading volume. Fourth, the options whose implied volatilities are less than 5 % or more 95% were also eliminated to reduce the impact induced by mispriced data. Fifth, the deep-in-the-money options (with prices higher than 15p or moneyness (S/K) higher than 1.1) are deleted, as are deep-out-of-the-money options (with prices lower than 0.03p or moneyness (S/K) lower than 0.9). The number of option samples satisfying above criteria are 19,987 calls and 20,088 puts.

Index dividend yields are obtained from the KSE website.[13] In addition, the call rate[14] are used as the risk-free rate.

3.3 The Historical Volatility

For robustness, two volatility estimates for KOSPI 200 index returns are adopted: the GARCH (1,1) model and the sample standard deviation (Bakshi and Kapadia (2003)).

[11] Various sampling times (2:00, 2:30, and others) are adopted, but the results are similar regardless of the sampling time.

[12] For reference, the total trading days before 1999 were approximately 290.

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

[14] The short-term interbank interest rate offered by the Bank of Korea

- GARCH (1,1)

$$\begin{aligned} R_{t-1,t} &= \overline{R} + \epsilon_t, & (22)\\ \sigma_t &= a_0 + a_1\epsilon_{t-1}^2 + a_2\sigma_{t-1}^2 & (23)\\ \epsilon_t &\sim \text{i.i.d} \quad N(0,\sigma_t) & (24)\\ \text{VOL}_t &= \sqrt{\frac{250}{\tau}\sum_{n=t-\tau}^{t}\hat{\sigma_n^2}}, & (25)\end{aligned}$$

where the τ-period return is defined as $R_{t,t+\tau} \equiv \log(S_{t+\tau}/S_t)$; σ_t is the conditional volatility; $\hat{\sigma_n}$ is the evaluated value by the GARCH estimation.

- Sample standard deviation

$$\text{VOL}_t = \sqrt{\frac{250}{\tau}\sum_{n=t-\tau}^{t}\left(R_{n-1,n} - \overline{R}\right)^2} \tag{26}$$

where $\overline{R}$ is the average daily return for a nonoverlapping period.

4 Empirical Results

In Section 4.1, the empirical and statistical properties of delta-hedged gains on a KOSPI 200 call option portfolio are documented. In Section 4.2, using the relationship between the delta-hedged gains and option vega, the existence of a volatility risk premium is investigated cross-sectionally.

4.1 Delta-Hedged Gains and Risk Premium

As shown in equation (4), delta-hedged gains for each call option are calculated by a long position in each call at date t, daily-hedged by a short position in the underlying asset equal to the option delta, $\partial C/\partial S$, until the maturity date $t + \tau$.

For tractability, a delta-hedge ratio, Δ_{t_n}, is implemented as the BS hedge ratio, $N(d_1)$, where $N(d_1)$ is the cumulative normal distribution and

$$d_1 = \frac{\log(S_t/K) + \left(r_n + \frac{1}{2}\sigma_{t,t+\tau}^2\right)\tau_n}{\sigma_{t,t+\tau}\sqrt{\tau_n}}. \tag{27}$$

Under the allowance of time-varying volatility, BS delta will bias the delta-hedged gains if the volatility is correlated with the stock return. As proven through the simulation by Bakshi and

Kapadia (2003), however, the bias resulting from the usage of the BS delta is negligible.[15] They show for 30-day options, the mean π/S is -0.0018% with the stochastic volatility hedge ratio versus 0.0022% with the BS hedge ratio. Thus, the use of the BS hedge ratio as the delta-hedge ratio is feasible.

The volatilities needed to compute the BS delta are calculated via the two alternative methods of the GARCH (1,1) and the sample standard deviation, as reported in Section 3.3. As both estimates move together very closely, only the results based on the GARCH (1,1) volatilities are reported.[16]

Table 4 presents descriptive statistics of the delta-hedged gains on the KOSPI 200 index call option portfolio, classified by moneyness and maturity.[17] The reported numbers are the average delta-hedged gains $\pi_{t,\tau}$, the delta-hedged gains scaled by the index level $\pi_{t,t+\tau}/S_t$, and delta-hedged gains scaled by the call price $\pi_{t,t+\tau}/C_t$. Panel A shows the gains over the total sample period 1999:01-2006:07. Over both entire ranges of moneyness and maturities, the delta-hedged strategy loses money by a maximum of approximately 0.38, which can be translated to 0.4 percent of the index level. Roughly speaking, the delta-hedged losses for ATM options are not higher, and determining a pattern with regard to maturities and moneyness consistent to a volatility risk premium is difficult. This is contrary to the results for S&P 500 index options shown in Bakshi and Kapadia (2003). Under the existence of volatility risk premia, the absolute delta-hedged gains for at-the-money and large maturities options should be higher due to the relationship with option

[15]Branger and Schlag (2004) investigate the impact of discrete trading and the use of the BS delta through a simulation. They show that discrete trading and model misspecification may cause the standard test to yield unreliable results under the stochastic volatility model. For a hedging interval of one day, however, discretization errors are negligible; thus, all of the error in the test procedure is due to the choice of the mis-specified delta. Even for mis-specification errors, the errors by the BS delta are very small over the range of time-to-maturity (shorter than 2 month), volatility level (approximately 0.3), and excess return (approximately 0.1), which is consistent with the option sample, as shown in Branger and Schlag (2004). Moreover, during the sample period, the correlation between the stock return dynamics and the volatility dynamics is much lower compared to the parameter value (-0.65) set in Branger and Schlag (2004). This relatively low correlation increases the validity of the BS delta. Therefore, the results based on delta-hedged gains do not lose reliability.

[16]Over the total sample period, the mean and standard deviation of the volatilities estimated by the sample standard deviation method are 32.1% and 10.79% respectively, while those of the volatilities estimated by the GARCH (1,1) are 30.59% and 12.71%.

[17]The results for put options are similar to those for call options. To save a space, they are not reported here.

vega. To guarantee that such results are not caused by extreme values, the last column, $1_{\pi<0}$ statistic, which measures the frequency of negative delta-hedged gains, is additionally included. The frequency of negative delta-hedged gains is comparable to the trend of the average losses; thus the results are not due to extremes.

Panel B presents, for robustness, the mean delta-hedged gains for subsamples: Set 1 and Set 2 over 1999:01 - 2002:12 and the 2003:01 - 2006:07 sample periods, respectively. As shown in Panel B, no pattern with respect to moneyness or maturities consistent to the volatility risk premium is found. The only unusual item is the apparent difference of the mean delta-hedged gains between subsample periods. The losses on Set 1 are twice or three times as high as those on Set 2. Without the volatility risk premium, one possible explanation for this phenomenon is jump fears proportional to the return volatility. When the intensity of jump occurrence increases in the level of volatility, the delta-hedged gains are magnified because the second, third and fourth terms in equation (12) are proportional to the volatilities.[18]

In reality, going through the Asian financial crisis with the subsequent IMF (International Monetary Fund) relief loan in the late 1990s, the Korean financial market was destabilized until the early 2000s. There was ample bad news as well as good news. Korean financial market was very volatile and appeared risky. Furthermore, immediately after overcoming the crisis, the collapse of the KOSDAQ market induced the critical depression of financial markets, which albeit were trivial compared to the market crash of October '87. As such, jump fears are likely to become an important risk factor in Korean financial markets, as other financial markets have experienced (Jackwerth and Rubinstein (1996), Bates (2000), Chernov and Ghysels (2000), and Anderson et al. (2002)). A more detail analysis for jump fears on KOSPI 200 index options follows in a later Section.

Next, whether the delta-hedged gains are far from zero statistically is investigated. If the volatility risk requires a risk premium, the delta-hedged gain for, as a minimum, ATM options should not converge to zero and its sign should have same to that of the volatility risk premium. ATM options are not only highly sensitive to the volatility risk premium, but are also known to be unaffected by market imperfections, such as transaction costs or asymmetric pricing errors. Results

[18]To support this argument, it is found that the delta-hedged losses for ATM options increase in the level of the volatility regime, but this is not reported. Furthermore, the volatility of Set 1 is approximately twice as high as that of Set 2, according to Table 7.

based on ATM thereby are uncontaminated by other pricing errors.[19]

Table 5 presents the mean delta-hedged gain and statistics for ATM calls with fixed maturities of 20, 30, and 40 trading days. For 20, 30, and 40 day calls, the mean gains are $\pi = -0.11$, -0.19, and -0.0079, which correspond to t-statistic values of -1.56, -2.16, and -0.07. Only for options with a maturity of 30 days, the delta-hedged gains are statistically significant at 95% significance level. Even the delta-hedged gains for 30 day calls are insignificant, once the data during the former subsample period (especially 1999 and 2000) are omitted.

For robustness, an alternative method that use the standard deviation of discrete delta-hedged gains is additionally adopted. Under a BS economy in which the expected return and volatility are constant, the standard deviation of delta-hedged gains is found in Bertsimas, Kogan, and Lo (2000). As such, first, $\widetilde{\pi}_{t,t+\tau}$ is derived by standardizing each $\pi_{t,t+\tau}$ by the corresponding standard deviation. Second, the t-statistic is computed as $\sum \widetilde{\pi}_{t,t+\tau}/\sqrt{N}$, where N is the number of observations. With the historical values of $\mu = 0.128$ and $\sigma = 0.34$, the t-statistics are -0.17, -0.30, and -0.05. For other mean and volatility values, the hypothesis that states that the delta-hedged gains are zero cannot be rejected, as shown in Table 5-B.[20] It is important to note that this method starts with the assumption of a BS economy, and that these results may be inconsistent with the true process with time-varying volatilities. When daily-updated GARCH volatilities are implemented, however, the bias will decrease and the results will be reliable (Bakshi and Kapadia (2003)).

In summary, the hypothesis proposing that the delta-hedged gains are zero cannot be rejected through two alternative test-statistics based on ATM options with a fixed maturity. This implies that, in the KOSPI 200 index options market, the volatility risk is likely to be unpriced. Alternatively, even if priced, its magnitude is very small.

4.2 Delta-Hedged Gains and Option Vega in the Cross Section

In the former section, the hypothesis proposing that delta-hedged gains are zero statistically could not be rejected. This somewhat implies the absence of the volatility risk premium. In this section,

[19]Kim, et al. (1994) and Hentchel (2003) show that ITM and OTM options experience asymmetric pricing errors, which can generate a volatility smile/smirk.

[20]For reference, this method is sensitive to the volatility of the underlying asset. For volatile markets including Korea Stock Exchange, this standardized method has a low testing power.

to ensure the above hypothesis, the possibility of a cross-sectional relationship between delta-hedged gains and the option vega is explored. As is shown in Section 2.3, if volatility risk is priced, the delta-hedged gains should be correlated with option vega given a fixed σ_t; hence, the level of absolute delta-hedged gains should coincide with the level of the option vega. As such, the existence of the volatility risk premia can be tested implicitly. The specification adopted is as follows:[21]

$$\text{GAIN}_t^i = \Psi_0 + \Psi_1 \text{VEGA}_t^i + \epsilon_t^i, \qquad i = 0, \cdots, I, \tag{28}$$

where $\text{GAIN}_t^i \equiv \pi_{t,t+\tau}/S_t$ and VEGA_t^i is the option vega.

To regress the gains on the option vega as in (28), a proxy for VEGA must be specified. For robustness of the estimation, two option vegas are adopted as in Bakshi and Kapadia (2003):

$$\text{VEGA} = \begin{cases} \exp\left(-d_1^2/2\right) & \text{BS vega,} \\ |y-1| & \text{Absolute moneyness,} \end{cases} \tag{29}$$

where d_1 is as presented in equation (27). Since the BS vega reaches a maximum at nearest-the-money, a negative volatility risk premium corresponds to $\Psi_1 < 0$, and the magnitude of $\Psi_0 + \Psi_1$ approximates the mean delta-hedged gains for ATM options. On the other hand, the absolute moneyness as a proxy of the option vega reaches a minimum at nearest-the-money, and hence a negative volatility risk premium corresponds to $\Psi_0 < 0$ and $\Psi_1 > 0$, and Ψ_0 approximates the mean delta-hedged gains for ATM options.

For each estimation of equation (28), it is necessary to fix the volatility. To do this, the total sample is divided into several volatility regimes with intervals of 5%. Each sample includes the data observed at dates at which volatility is within one of these intervals. The reported results are based on the options with maturities of 20 and 30 trading days. With two vega proxies, 36 distinct panels are used in these tests.

When the regressions (28) are implemented, merging the data observed at several dates to one panel makes it non-trivial. It is possible that day-specific components exist in the delta-hedged gains, and that they can lead to erroneous conclusions. This economic issue can be resolved by the fixed effect model or the random effect model (Greene (1997)). The fixed effect model adopts

[21] For an easy comparison with the results for S&P index options market by Bakshi and Kapadia (2003), identical notations to those used in Bakshi and Kapadia (2003) are used here as much as possible.

dummy variables equal to the number of included days, while the random effect model classifies the disturbance term into the date-specific component and the white noise. The random effect model will be biased if the day-specific component is correlated with regressors, but it is more efficient compared to the fixed effect model otherwise. To prove that there is no correlation among them, the Hausman test is used for the fixed effect model versus the random effect model. The following results are, therefore, based on the random effect model, in which coefficients are estimated by Feasible Generalized Least Square panel regression (FGLS).

Table 6 presents the coefficient values estimated by a random effect panel regression, which do not support the existence of a risk premium, as conjectured in Section 4.1. For 20-day options, only two coefficients Ψ_1 among eight volatility regimes are significant at the significance level of 95% with respect to the BS vega. More importantly, their signs are opposite to those expected by a negative volatility risk premium. For 30-day options, three coefficients are significant, but their signs are also not clear: two are negative, whereas the other is positive. In addition, the hypothesis that states that the mean delta-hedged gain is zero, $\Psi_0 + \Psi_1 = 0$, can not be rejected by the Wald test-statistic in most panels. These are opposite to those of S&P 500 options, as in Bakshi and Kapdai (2003), in which the sign of Ψ_1 is significantly negative, thus supporting the negative volatility risk premium. The use of absolute moneyness as a proxy for option vega also has similar implications. For each panel with a maturity of 20-day and 30-day, just two coefficients, Ψ_1, are significant. Moreover only three coefficients Ψ_0, which indicate the mean delta-hedged gains, are significant among 16 panels. Therefore, the results here do not support the existence of the volatility risk premium with respect to both proxies of option vega.

4.3 Interpretation

The main participant of KOSPI 200 index options are different from those of the underlying asset, and thus there is no reason for the presence of hedging demands in KOSPI 200 index options market. The absence of a risk premium on volatility risk is a possible evidence of no hedging demands for market declines.

Individuals, the main driver of KOSPI 200 index options market, tend to prefer contracts that involve smaller cash outlays, and usually do not have large and well-diversified portfolios to reduce the idiosyncratic risk, hence the low level of open interest. Under these circumstances, it is not feasible to expect a hedging effect, i.e., a negative volatility risk premium. That is, a considerable proportion of the extremely large trading volume is likely to be the results from directional traders rather than hedgers (BIS Quarterly Report (2003)). This is also supported by Kang and Park (2007), which show that the KOSPI 200 index options market is driven by directional traders rather than by volatility traders (hedgers), using the information contents of net-buying pressure.

The fact that volatility risk is not priced is consistent with the similarity of levels between the historical and the implied volatility. The BS implied volatilities of ATM (at-the-money) options on KOSPI 200 index are not apparently higher than the realized volatilities of the underlying asset.[22] In a sample from 1999:01 to 2006:07, the mean (standard deviation) implied volatilities and historical volatilities of at-the-money options are 30.57% (12.74%) and 30.36% (10.73%), respectively. That is, ATM KOSPI 200 index options are consistently and systematically not overpriced than the BS model prices.

Additionally, the excess skewness and kurtosis of the KOSPI 200 index distribution to the normal distribution are relatively small, compared to those of developed countries' indices. As shown in Table 7, physical skewness and kurtosis for daily returns on the KOSPI 200 index from 1999:01 to 2006:07 are approximately -0.3 and 5.6, respectively.[23] In contrast, distributions of the S&P index are severely left-skewed and fat-tailed (Anderson, Benzoni and Lund (2002)). The relatively low level of the higher moments of KOSPI index returns is likely to reduce the ability to hedge against the underlying asset's downward movements by holding related options.

5 The Effects of Jump Fears

Although no evidence for the volatility risk premium is found on KOSPI 200 options, the delta-hedged gains tend to be negative in the majority of moneyness and maturities as shown in Table 5. In particular, this is evident for out-of-the-money options. Thus, the reason for the negative

[22] As mentioned in Jackwerth and Rubinstein (1996), and Bakshi and Kapadia (2003), the BS implied volatilities of ATM S&P 500 index options are consistently and systematically higher than the realized volatilities.

[23] This phenomenon may be due to the existence of price limits in the KSE, which tends to restrict extreme price changes. Thus, it is likely to decrease the excess skewness and kurtosis of the return distribution.

delta-hedged gains is traced. One possible reason is fears of a market crash, such as the crash that occurred in October of 1987. The delta-hedged gains reflect not only the volatility premium but also the effect of a tail event (Jackwerth and Rubinstein (1996)). For instance, the difference of delta-hedged gains between subsample 1 and subsample 2 in Tables 5 and 6 supports the jump fears implied in option prices. According to Bates (2000), Pan (2002), and Eraker, Johannes, and Polson (2003), if a jump process is dependent on the level of volatility, the delta-hedged gains are also dependent. The rate of returns for subsample 1 are more volatile than those for the subsample 2 and the losses are over twice as much as those for subsample 2.[24]

5.1 A Proxy of Jump Fears: Risk-Neutral Skewness and Kurtosis (Bakshi, Kapadia, and Madan (2003))

Jump fears can dichotomize the risk-neutral distribution from a physical distribution. Usually, the risk-neutral distribution is more volatile, more left-skewed, and more leptokurtic compared to the physical distribution. Thus, under the absence of the volatility risk premium, the risk-neutral skewness and kurtosis can approximate the jump fears embedded in option prices (Jackwerth and Rubinstein (1996), Bates (2000), Bakshi and Kapadia (2003), and Bakshi, Kapadia, and Madan (2003)). Generally, the frequency of asymmetric jumps is captured by the (risk-neutral) skewness, and the severity of jumps is captured by the (risk-neutral) kurtosis.

The risk-neutral skewness and kurtosis are based on the model-free approach of Bakshi et al. (2003), in which the risk-neutral higher moments are retrieved using out-of-the-money calls and puts. Using such proxies for jump fears, the effect of jump fears on option prices is examined. The

[24]Although it is conjectured that subsample 1 is more exposed to jump risk, the difference in the physical kurtosis levels among subsamples is small. However, it is important to note that movements caused by jumps are usually captured first by the volatility, and second by kurtosis. The volatility level of subsample 1 is higher than that of subsample 2, and hence the indifference in kurtosis levels is not peculiar.

following specification is adopted:[25]

$$\text{Gain}_t = \Omega_0^* + \Omega_1^* \text{Gain}_{t-1} + \Omega_2^* \text{SKEW}_t^* + \Omega_3^* \text{KURT}_t^* + \epsilon_t, \tag{30}$$

where $\text{Gain}_t \equiv \pi_{t,t+\tau}/S_t$ is the option closest to at-the-money, SKEW^* is the risk-neutral skewness, and KURT^* is the risk-neutral kurtosis. To correct the serial correlation of the residuals, a lagged variable is included in the regression specification. The coefficients are estimated by OLS.

Before conducting the regression (30), the mean risk-neutral higher moments was compared with the physical higher moments. Table 8 presents the mean risk-neutral skewness and kurtosis implied on OTM options with maturities of 20, 30, and 40 trading days. The option implied distribution is more left-skewed and more leptokurtic than the physical distribution. This difference is likely to be seen as indirect evidence of jump fears in the KOSPI 200 options market.

Table 9 presents the coefficients estimated from the specification (30) for at-the-money calls and puts with maturities of 20, 30, and 40 trading days: Panel A is for calls and Panel B is for puts. For calls, the coefficients of the risk-neutral skewness are statistically significant in seven of nine estimations; they range between -0.0057 and -0.0234 with significant value. Even the panels with insignificant coefficients do not lose significance once subsample 2 is omitted. On the other hand, the risk-neutral kurtosis is likely to be insignificant for calls. Only three panels have significance.

One interesting item is the sign of the coefficient Ω_2^* estimated from (30) for calls. As shown in Table 9-A, the sign is consistently negative in all estimates, which implies that the more negative skewed the risk-neutral distribution is, the higher the delta-hedged losses are. This is contradictory to the results on S&P index options (Bakshi and Kapadia (2003)).[26]

To understand this, the delta-hedged gains (12) is taken into account. The sign of the coefficient depends on which term dominates in equation (12). If the delta-hedged gains are dominated by

[25]The specification adopted differs slightly from that adopted in Bakshi and Kapadia (2003). Bakshi and Kapadia (2003) examine whether a volatility risk premium (assumed to proportional to the volatility) loses its significance under the consideration of jump fears, while this study examines as to whether jump fears can solely explain the delta-hedged gains (option prices) without the volatility risk premium. This difference generates the change of specifications.

[26]Furthermore, in the S&P 500 index options market, risk-neutral skewness loses significance once volatility and kurtosis are omitted. On the other hand, in the KOSPI 200 index options market skewness is solely significant without any other variables in all estimations.

the second term $\mu_J^* \Lambda^* \int_t^{t+\tau} E_t\left[\frac{\partial C_u}{\partial S_u} S_u\right] du$ which is usually negative, the coefficient of the risk-neutral skewness will be positive. On the other hand, if they are dominated by the third term $-\Lambda^* \int_t^{t+\tau} \int_{-\infty}^{\infty} (C_u(S_u(J+1)) - C_u(S_u))\, prob^*(J) dJ du$ which is usually positive, the coefficient will be negative. In consequence, the negative coefficients estimated from the KOSPI 200 options are consistent with the dominance of third term.

This may be due to the effect of directional traders rather than hedgers. The hedging traders, who hold a call and hedge it by a short position in the underlying asset, are relatively less sensitive, because the direction of gains in both positions are opposite. On the other hand, the directional traders not hedging by the underlying asset will be sensitive to jump fears. This over-anxiety for jumps enlarges the price change of options $C_u(S_u(J+1)) - C_u(S_u)$ under *the risk-neutral measure*, hence causing the third term in (12) to be prominent.

Table 9-B presents the coefficients for puts. The coefficients of risk-neutral higher moments for puts are more significant compared to those for calls. Similar to calls, the skewness coefficients are significant for 7 of 9 panels, and their signs are all positive (opposite to calls) as expected. This implies that the negative skewness reduces the delta-hedged gains. The signs of the kurtosis coefficients are consistently positive; thus, the increase in kurtosis raises the delta-hedged gains. One interesting item is that the coefficients of the risk-neutral kurtosis for puts are significant in all panels except one, contrary to the results for calls. This discrepancy between calls and puts reflects the importance of left-tail events. The left-tail event influences puts more directly than it does calls, since it increases the probability for puts to be in-the-money. This is consistent with the fact that investors are severely averse to large downward losses.

In conclusion, it is shown that jump fear rather than volatility premium plays an important role in explaining the underperformance of the delta-hedging strategy. As shown in Table 5, the delta-hedged losses caused by jump risk are nearly $15,000$ won. This implies that call prices with consideration of jump fears are more expensive by as much as $15,000$ won compared to those without consideration of jump fears. Given the extremely large trading volume of the KOSPI 200 call options of nearly 2500 million per a year, the total amount impacted by the overvaluation of calls is as high as 37.5 trillion won, which amount to 37.5 billion US dollors.

6 Conclusion

This paper has explored whether or not the hedging effect exists in a circumstance in which the main stakeholder of the underlying market differs from that of its related options market. The KOSPI 200 market is the only and the best market affordable for testing the argument. The KOSPI 200 index market is dominated by non-individual investors, whereas its related options market is mainly driven by individual investors. From the study for KOSPI 200 index options market, we show that the volatility risk cannot be priced in some cases. The hypothesis that delta-hedged gains for at-the-money options are statistically zero is not rejected. Moreover the delta-hedged gains are not connected to vega. They imply the irrelevance of KOSPI 200 index option with the volatility risk premium. Rather, jump fears influence KOSPI 200 option prices clearly.

This study is, however, not free from limitations. Since the processes of the underlying asset, volatility and jumps are not specified explicitly, the results cannot be applied to predicting the option prices. Only this study enables to tell as to how option pricing models should be developed in the KOSPI 200 index options market: Considering jump fears above all is important on option pricing models for the KOSPI options market. As such, a natural extension of this study would be to specify the exact processes of all components including jumps, and to develop an option pricing model consistent with the dynamics of the KOSPI 200 index.

Additionally, one interesting feature of the KOSPI 200 index options market is the amazingly higher portion of individual investors who participate in derivatives trading. Such a high composition is likely to be due to the presence of a e-trading-system. In Korea, e-trading systems are very well facilitated and individuals can complete most trading by e-trading systems. It offers individuals greater opportunity to contact with the trade-exchange directly, thus increasing the trading fraction of individuals. At present, e-trading systems can span the entire globe. This trend will change the composition of international derivatives markets; hence, studies concerning the Korean derivative market may portend possible changes in the other financial markets.

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Table 1: Foreign Ownership of the Korea Stock Exchange (KSE) by the type of investors

year	Individual	institution	foreigner	else
1999	25.9%	16.7%	21.9%	35.5%
2000	20.0%	15.4%	30.2%	34.4%
2001	22.3%	15.8%	36.6%	25.3%
2002	22.3%	16.0%	36.0%	25.7%
2003	19.7%	16.7%	40.1%	23.5%
2004	18.0%	18.0%	42.0%	22.0%
2005	18.4%	18.3%	39.7%	23.6%
2006	18.0%	22.0%	37.3%	23.7%

Table 1 shows the ownership structure of the companies listed on the KSE. The first column presents the individual ownership in terms of the market capitalization. The second column and third column are the ownerships by institutional investors and foreign investors, respectively. All figures are expressed in percentages and are calcualted at the end of each year. Foreign investors in Korea must register with the SSB and obtain an ID number before they can start trading stocks. The group of "else" consists of a juridical company and government related funds. Data are obtained from Korea Excahnge (www.krx.co.kr).

Table 2: The compositions of KOSPI 200 index options market by the types of investors

	Call				Put			
Year	individual	institution	foreigner	else	individual	institution	foreigner	else
1999	51.82m	20.29m	1.56m	1.39m	61.40m	20.44m	2.09m	0.86m
	(69.03%)	(27.03%)	(2.09%)	(1.85%)	(72.41%)	(24.11%)	(2.47%)	(1.02%)
2000	158.01m	51.11m	10.99m	4.13m	116.60m	34.52m	9.45m	2.81m
	(70.46%)	(22.80%)	(4.90%)	(1.84%)	(71.36%)	(21.13%)	(5.79%)	(1.73%)
2001	652.80m	196.69m	56.34m	15.62m	536.76m	127.68m	46.91m	13.74m
	(70.84%)	(21.35%)	(6.11%)	(1.70%)	(74.03%)	(17.61%)	(6.47%)	(1.90%)
2002	1360.55m	575.57m	151.96	19.90m	1127.47m	399.69m	127.85m	16.62m
	(64.54%)	(27.30%)	(7.21%)	(0.94%)	(67.45%)	(23.91%)	(7.65%)	(0.99%)
2003	1612.80m	991.31m	323.10m	37.12m	1496.72m	875.67m	304.36m	34.33m
	(54.41%)	(33.40%)	(10.90%)	(1.25%)	(55.21%)	(32.30%)	(11.23%)	(1.27%)
2004	1321.66m	991.23m	294.91m	22.58m	1196.38m	891.01m	306.59m	18.72m
	(50.25%)	(37.68%)	(11.21%)	(0.86%)	(49.59%)	(36.93%)	(12.71%)	(0.78%)
2005	1182.95m	1065.15m	350.32m	22.41m	989.48m	1064.88m	379.31m	15.86m
	(45.14%)	(40.64%)	(13.37%)	(0.86%)	(40.39%)	(43.47%)	(15.49%)	(0.65%)
2006	921.54m	1127.13m	353.86m	13.80m	885.07m	1102.01m	410.39m	15.00m
	(38.14%)	(46.65%)	(14.64%)	(0.57%)	(36.69%)	(45.68%)	(17.01%)	(0.62%)
Total	7262.15m	5018.52m	1543.07m	136.99m	6409.92m	4515.94m	1586.98m	117.97m
	(50.62%)	(35.95%)	(11.05%)	(0.98%)	(50.75%)	(35.75%)	(12.56%)	(0.93%)

Table 2 shows the composition of trading volume of the KOSPI 200 index options by the types of investors. The trading volume is the number of contracts traded, including both sales contracts and purchase contracts. 'm' means the unit of million. The number in parenthesis indicates the percentage share of each group among total contracts. All data presented in Table are collected from Korea Stock Exchange, www.krx.co.kr.

Table 3: The top 3 index options by the trading volume

Rank	2001		2002		2003	
1	KOSPI 200 Index Options	823	KOSPI 200 Index Options	1,890	KOSPI 200 Index Options	2,837
2	CAC 40 Index Options	107	CAC 40 Index Options	84	CAC 40 Index Options	74
3	DAX Options	44	DAX Options	44	DJ Euro Stoxx 50 Options	62

Rank	2004		2005		2006	
1	KOSPI 200 Index Options	2,522	KOSPI 200 Index Options	2,535	KOSPI 200 Index Options	2,414
2	DJ Euro Stoxx 50 Options	71	DJ Euro Stoxx 50 Options	91	DJ Euro Stoxx 50 Options	150
3	CAC 40 Index Options	63	S&P 500 Index Options	72	S&P 500 Index Options	104

Table 3 illustrates the top 3 index options in terms of trading volume from 2001 to 2006. In each year, the first column is the name of derivatives product and the second column is the trading volume in million of contracts. Data is available from the annual volume survey of FIA (Futures Industry Association, www.futuresindustry.org).

Table 4: Delta-hedged gains for calls written on KOSPI 200 index

Panel A: Full sample period, 1999:01 - 2006:07

Moneyness		π (in 100,000 Won)			π/S (in percent %)			π/C (in percent %)			$1_{\pi<0}$
y-1	N	10-20	20-40	All	10-20	20-40	All	10-20	20-40	All	%
-10% to -7.5%	2537	-0.2609	-0.3816	-0.3369	-0.29	-0.40	-0.36	-56.18	-30.40	-39.94	66.69
		(0.026)	(0.0267)	(0.0194)	(0.03)	(0.03)	(0.02)	(6.05)	(3.44)	(3.12)	
-7.5% to -5%	2956	-0.3506	-0.3782	-0.3679	-0.35	-0.38	-0.37	-61.25	-19.93	-35.35	65.79
		(0.0256)	(0.0255)	(0.0186)	(0.03)	(0.03)	(0.02)	(4.91)	(1.97)	(2.24)	
-5% to -2.5%	2999	-0.3553	-0.2631	-0.2976	-0.35	-0.27	-0.30	-29.37	-6.34	-14.97	63.48
		(0.0272)	(0.0271)	(0.0198)	(0.03)	(0.03)	(0.02)	(2.55)	(1.15)	(1.21)	
-2.5% to 0%	2815	-0.2536	-0.1942	-0.2163	-0.27	-0.23	-0.24	-9.33	-1.41	-4.36	61.10
		(0.027)	(0.0298)	(0.0212)	(0.03)	(0.03)	(0.02)	(1.1)	(0.74)	(0.62)	
0% to 2.5%	2692	-0.1207	0.003	-0.0432	-0.15	-0.05	-0.09	-1.89	2.63	0.94	55.49
		(0.0275)	(0.0308)	(0.0219)	(0.03)	(0.03)	(0.02)	(0.67)	(0.62)	(0.46)	
2.5% to 5%	2437	-0.0571	0.0687	0.0196	-0.09	0.02	-0.03	-0.25	2.98	1.72	52.31
		(0.0295)	(0.0349)	(0.0242)	(0.03)	(0.04)	(0.03)	(0.56)	(0.55)	(0.40)	
5% to 7.5%	2044	-0.025	0.0855	0.0415	-0.05	0.05	0.01	0.34	2.39	1.58	50.83
		(0.0345)	(0.0376)	(0.0265)	(0.04)	(0.04)	(0.03)	(0.48)	(0.48)	(0.35)	
7.5% to 10%	1507	-0.0519	0.1167	0.0497	-0.06	0.09	0.03	0.00	2.17	1.31	49.83
		(0.0414)	(0.0438)	(0.0311)	(0.04)	(0.05)	(0.03)	(0.50)	(0.48)	(0.35)	

Panel B: Delta-hedged gains across the 1999:01-2002:12 and 2003:01-2006:07 subsamples

Moneyness			π (in 100,000 Won)			π/S (in percent %)			π/C (in percent %)			$1_{\pi<0}$
y-1	Sample	N	10-20	20-40	All	10-20	20-40	All	10-20	20-40	All	%
-10% to -7.5%	Set 1	1302	-0.3978	-0.4834	-0.451	-0.46	-0.54	-0.51	-28.05	-8.56	-15.94	71.81
	Set 2	1235	-0.1096	-0.2772	-0.2167	-0.09	-0.25	-0.19	-87.27	-52.81	-65.25	61.29
-7.5% to -5%	Set 1	1322	-0.4673	-0.5148	-0.4969	-0.54	-0.57	-0.57	-23.32	-8.89	-14.35	70.49
	Set 2	1634	-0.2538	-0.2692	-0.2636	-0.20	-0.23	-0.22	-92.70	-28.73	-52.34	61.99
-5% to -2.5%	Set 1	1334	-0.4377	-0.3761	-0.3995	-0.49	-0.41	-0.44	14.89	-2.42	-7.17	65.36
	Set 2	1665	-0.2873	-0.1741	-0.216	-0.23	-0.17	-0.19	-41.31	-9.44	-21.23	61.98
-2.5% to 0%	Set 1	1233	-0.4184	-0.4085	-0.4122	-0.46	-0.44	-0.44	-10.10	-2.55	-5.37	65.28
	Set 2	1582	-0.124	-0.028	-0.0636	-0.12	-0.07	-0.09	-8.73	-0.53	-3.57	57.83
0% to 2.5%	Set 1	1169	-0.3155	-0.223	-0.2581	-0.34	-0.23	-0.27	-5.13	1.11	-1.26	61.84
	Set 2	1523	0.0334	0.1732	0.1217	0.00	0.09	0.05	0.68	3.77	2.63	50.62
2.5% to 5%	Set 1	1108	-0.2648	-0.1638	-0.2038	-0.28	-0.16	-0.21	-2.73	1.96	0.10	58.574
	Set 2	1329	0.121	0.259	0.2058	0.07	0.16	0.12	1.88	3.82	3.08	47.10
5% to 7.5%	Set 1	982	-0.2336	-0.0746	-0.1397	-0.24	-0.09	-0.15	-1.73	1.84	0.38	57.33
	Set 2	1062	0.1784	0.2283	0.2089	0.13	0.17	0.16	2.37	2.89	2.69	44.82
7.5% to 10%	Set 1	761	-0.2093	-0.0574	-0.1207	-0.22	-0.07	-0.13	-1.32	1.23	0.16	55.06
	Set 2	746	0.1249	0.2833	0.2234	0.11	0.24	0.19	1.49	3.07	2.47	44.50

Table 4 presents the delta-hedged gain on a portfolio of a long position in a call, hedged by a short position in the underlying stock, which satisfies a self-financing strategy. The option delta is computed as the Black-Scholes hedge ratio based on the GARCH volatility. The rebalancing frequency is set to 1 day. We report (i) the delta-hedged gains ($\pi_{t,t+\tau}$), (ii) the delta-hedged gains normalized by the index ($\pi_{t,t+\tau}/S_t$), and (iii) the delta-hedged gains normalized by the option price ($\pi_{t,t+\tau}/C_t$). The moneyness of options are defined as $y = S/K$. The standard error, shown in parentheses, is computed as the sample standard deviation divided by the square roor of the number of observation. $1_{\pi<0}$ is the proportion of delta-hedged gains with $\pi < 0$, and N is the number of computed options. Subsample: set 1 corresponds to 1999:01-2002:12; Subsample: set 2 corresponds to 2003:01-2006:07.

Table 5: Mean delta-hedged gains and statistics for ATM calls with a fixed maturity of 20, 30, and 40 trading days

A. t-statistics

	ATM: [-2,5%, 2.5%]		
	20 days	30days	40 days
N	192	213	173
Mean delta-hedge gains	-0.1116	-0.1973	-0.0079
Standard errors	0.0715	0.0913	0.1089
t-statistics	-1.5614	-2.162	-0.0726

B. Bertsimas, Kogan, and Lo (2000)'s t-statistics

	ATM: [-2,5%, 2.5%]		
	20 days	30days	40 days
N	192	213	173
(i) $\mu = 12.8\%$, $\sigma = 34\%$ (historical values)			
t-statistics	-0.17	-0.30	-0.05
(ii) $\mu = 12.8\%$, $\sigma = 23\%$			
t-statistics	-0.29	-0.53	-0.07
(iii) $\mu = 12.8\%$, $\sigma = 12\%$			
t-statistics	-0.97	-1.75	0.31

Table 5 presents the statistics for at-the-money calls with a fixed maturity of 20, 30, and 40 trading days. Panel A indicates the simple t-statistic, while Panel B indicates the t-statistic of the gains, normalized by the standard deviation derived by Bertimas, Kogan, and Lo (2000). The delta-hedged gains are based on the volatility estimated by GARCH.

Table 6: Cross-sectional results with respect to option vega on Delta-hedged gains for KOSPI 200 calls by volatility regimes

	20 trading day options					30 trading day options				
		Vega: $\exp(-d_1^2/2)$		Vega: $\lvert y-1\rvert$			Vega: $\exp(-d_1^2/2)$		Vega: $\lvert y-1\rvert$	
VOL^h	N	Ψ_0	Ψ_1	Ψ_0	Ψ_1	N	Ψ_0	Ψ_1	Ψ_0	Ψ_1
< 15	77	-0.000432	0.001918*	0.001549	-0.022017*	41	0.000437	0.005931*	0.007852*	-0.085613*
		[-0.327]	[2.19]	[1.29]	[-2.00]		[0.20]	[2.62]	[5.68]	[-3.22]
15-20	96	0.000342	0.000517	0.001	-0.007474	149	0.002518	-0.001116	0.001608	0.002100
		[0.25]	[0.41]	[0.83]	[-0.57]		[1.54]	[-0.69]	[1.26]	[0.16]
20-25	147	0.002492	-0.003359	-0.000915	0.020531	167	0.005126	-0.007455	-0.001970	0.023555
		[0.80]	[-1.53]	[-0.32]	[1.18]		[1.25]	[-1.79]	[-0.75]	[0.94]
25-30	83	0.00354	-0.005349	-0.001717	0.020895	84	0.001741	0.001339	0.004078	-0.024655
		[0.94]	[-1.43]	[-0.68]	[0.91]		[0.30]	[0.25]	[1.09]	[-1.07]
30-35	91	-0.001980	0.001795	0.000523	-0.020403	105	0.013403	-0.022847*	-0.010435*	0.071512*
		[-0.41]	[0.39]	[0.16]	[-0.95]		[1.49]	[-2.43]	[-2.95]	[2.24]
35-40	63	-0.014421	0.019530*	0.006432	-0.077389*	62	-0.020379	0.016583	-0.006457	0.032779
		[-1.75]	[2.26]	[1.84]	[-2.41]		[-0.91]	[0.70]	[-1.13]	[0.56]
40-45	52	0.01105	-0.022303	-0.011296	0.045955	56	0.028828	-0.036919	-0.009467	0.077470
		[0.75]	[-1.47]	[-1.88]	[0.96]		[1.51]	[-1.92]	[-1.29]	[1.78]
>45	86	0.031587*	-0.04533*	-0.013337	0.056346	81	0.040935	-0.049848*	-0.006025	-0.013645
		[2.23]	[-3.09]	[-3.33]	[1.62]		[1.66]	[-2.01]	[-0.88]	[-0.34]

Table 6 presents the estimates of a FGLS random effect panel regression of delta-hedged gains on the Vega:

$$\begin{aligned} \text{GAIN}_t^i &= \Psi_0 + \Psi_1 \text{Vega}_t^i + \epsilon_t^i \\ \epsilon_t^i &= u_t + \omega_t^i \end{aligned}$$

where $\text{GAIN}_t^i = \pi_{t,t+\tau}^i / S_t$. Two proxies for the option vega are used. One is $\exp(-d_1^2)$, where $d_1 = \frac{log(S/K)+(r+\frac{1}{2}\sigma^2)\tau}{\sigma\tau}$, the other is the absolute level of moneyness, $|y-1|$. The data consists of monthly call options with maturity of 20 and 30 trading day over 1999:01-2006:07. Since the estimation method is not least squares, the coefficient of determination is omitted. N is the number of observation. Numbers in square brackets show the z-statistics [Greene (1997)]. An asterisk * is attached when the coefficient is significant at 5% significant level.

Table 7: Summary statistics for daily KOSPI 200 index returns

Panel A: Full range of Sample (1999:01:01-2006:07:31)

Annual. Mean	Std. Dev.	Skewness	Kurtosis	Autocorr.	Min	Max	JB-statistics
12.80%	34.00%	-0.2996	5.6041	0.0322	-3184%	2104%	550.09

Panel B: Subsample 1 (1999:01:01-2002:12:31)

Annual. Mean	Std. Dev.	Skewness	Kurtosis	Autocorr.	Min	Max	JB-statistics
5.28%	40.66%	-0.2455	4.5574	0.0267	-3184%	2104%	108.88

Panel C: Subsample 2 (2003:01:01-2006:07:31)

Annual. Mean	Std. Dev.	Skewness	Kurtosis	Autocorr.	Min	Max	JB-statistics
21.3%	24.4%	-0.3053	4.1355	0.006	-1517%	1259%	60.17

Table 7 presents summary statistics for daily return of KOSPI 200 index from 1999:01:01 to 2006:07:31. Data set is also classified into two subsample panels: Panel B includes the observations from 1999:01:01 to 2002:12:31 ,while Panel C includes the observation from 2003:01:01 to 2006:07:31. Annualized return is calculated as $\log(P_t/P_{t-1}) \times 250$, where P_t is the KOSPI 200 index price. JB-statistics refer to Jarque-Berra test statistics.

Table 8: The risk-neutral skewness and kurtosis from OTM calls and puts

Maturity (τ)	Sample	mean risk-neutral skewness*	mean risk-neutral kurtosis*
20 days	Full	-0.54	4.76
	set 1	-0.31	3.28
	set 2	-0.81	6.42
30 days	Full	-0.57	4.30
	set 1	-0.36	3.12
	set 2	-0.81	5.59
40 days	Full	-0.59	3.64
	set 1	-0.44	2.65
	set 2	-0.75	4.68

Table 8 presents the risk-neutral skewness and kurtosis, implied in out-of-the-money calls and puts with a maturity of 20, 30, 40 trading days. Set 1 corresponds to 1999:01-2002:12; Set 2 corresponds to 2003:01-2006:07.

Table 9: Effect of jumps on delta-hedged gains for ATM calls and puts

Panel A: ATM Calls

Maturity (τ)	Sample	Ω_0^* ($\times 10^{-2}$)	Ω_1^*	Ω_2^* ($\times 10^{-2}$)	Ω_3^* ($\times 10^{-2}$)	R^2
20	Full	-0.68	-0.0069	-0.37	0.09	7.08
days		[-1.73]	[-0.07]	[-1.22]	[0.94]	
	Set 1	-2.8*	-0.10	-1.35*	0.74*	30.97
		[-3.61]	[-0.80]	[-2.70]	[3.23]	
	Set 2	-0.14	0.10	0.02	0.02	0.88
		[-0.25]	[0.56]	[0.06]	[0.25]	
30	Full	-0.61	0.14	-1.43*	-0.04	29.57
days		[-1.94]	[1.79]	[-5.40]	[-0.49]	
	Set 1	-1.10*	0.10	-2.34*	0.15	36.19
		[-2.30]	[1.02]	[-4.88]	[1.10]	
	Set 2	-0.91*	0.29*	-0.68*	0.08	33.13
		[-2.43]	[2.34]	[-2.61]	[0.98]	
40	Full	-0.85*	0.0363	-0.70*	0.12*	10.27
days		[-3.07]	[0.35]	[-2.75]	[3.08]	
	Set 1	-0.88*	0.01	-0.90*	0.15	8.32
		[-2.12]	[0.09]	[-2.00]	[1.91]	
	Set 2	-1.20*	0.26	-0.57*	0.20*	26.51
		[-2.69]	[1.83]	[-2.24]	[2.06]	

Panel B: ATM Puts

Maturity (τ)	Sample	Ω_0^* ($\times 10^{-2}$)	Ω_1^*	Ω_2^* ($\times 10^{-2}$)	Ω_3^* ($\times 10^{-2}$)	R^2
20 days	Full	-0.69*	-0.05	1.16*	0.18*	18.45
		[-3.13]	[-0.56]	[3.95]	[3.75]	
	Set 1	-1.55*	-0.03	0.85	0.43*	15.71
		[-2.50]	[-0.22]	[1.47]	[2.40]	
	Set 2	-0.61*	0.02	1.20*	0.17*	44.93
		[-2.47]	[0.10]	[4.78]	[4.76]	
30 days	Full	-0.55*	0.13	1.38*	0.18*	30.17
		[-2.34]	[1.62]	[5.88]	[4.05]	
	Set 1	-0.41	0.10	1.55*	0.14*	30.83
		[-1.14]	[0.86]	[4.34]	[1.72]	
	Set 2	-0.67*	0.32*	0.93*	0.17*	39.13
		[-2.93]	[2.77]	[3.13]	[3.92]	
40 days	Full	-1.09*	0.30*	1.66*	0.42*	35.25
		[-3.70]	[3.30]	[3.96]	[4.52]	
	Set 1	-1.25*	0.31*	2.09*	0.59*	36.12
		[-2.27]	[2.38]	[3.23]	[2.43]	
	Set 2	-1.19*	0.24	0.86*	0.30*	29.84
		[-3.30]	[1.75]	[2.04]	[3.19]	

We apply the risk-neutral skewness and kurtosis as proxies for jump fear. Table show the regression results based on the following specification between delta-hedged gains and the higher-order moments of the risk-neutral return distribution.

$$\text{Gain}_t = \Omega_0^* + \Omega_1^* \text{Gain}_{t-1} + \Omega_2^* SKEW_t^* + \Omega_3^* KURT_t^* + \epsilon_t,$$

where $\text{Gain}_t \equiv \pi_{t,t+\tau}/S_t$ of puts closest to at-the-money. To correct the serieal correlation of the residuals, a lagged variable is included in thee regression specification. Table includes the estimates, test-statistics (t-statistic) in square brackers, the R^2. An asterisk * is attached when the coefficient is significant at 5% significant level. Panel A corresponds to ATM call options, while Panel B corresponds to ATM put options. Full sample is from total sample periods: 1999:01 to 2006:07. Set 1 refers to the subsample of 1999:01 to 2002:12, while Set 2 refers to the subsample of 2003:01 to 2006:07. All results are tested for options with a fixed maturity of 20 days, 30 days, and 40 days (trading days).