

THE TRADING EFFICIENCY ON OPTIONS MARKET:

ESSAYS ON STOCK OPTIONS MARKET

BY

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ABSTRACT**THE TRADING EFFICIENCY ON OPTIONS MARKET:****ESSAYS ON STOCK OPTIONS MARKET****By Yan Feng****Advisor: Professor Christos Giannikos**

F. Black (1975) in his seminal paper “Fact and Fantasy in the use of options” mentioned a number of fantasies that widely spread in the options markets. Since Black’s (1975) paper was published, there were significant changes and innovations in the options markets. The purpose of this paper is to address some of the pricing and trading aspects in the options markets.

The first paper studies the impact of option liquidity on the level of implied volatility function for equity and stock index options. Option liquidity is measured by percentage bid-ask spread, option trading volume and open interest. The study finds a significant negative effect of percentage bid-ask spread on implied volatility level, as well as positive effect of trading volume and open interest on implied volatility level. After adjusting for the underlying asset’s total risk, the option percentage spread still has significant negative effect on the level of option excessive volatility. Among several firm specific variables, beta coefficient and systematic risk proportion have significant effects on the slope of excessive implied volatility function. The Fama-MacBeth regressions are used to test the hypotheses for eight moneyness categories separately. This paper explains the implied volatility function from the viewpoint of option market efficiency, and proves that the illiquidity premium documented in stock and bond market is also significant in stock options market.

In The second paper, risk-neutral Skewness derived from stock options market is used to test the information role of options price in predicting stock returns after earnings announcements. The result shows that risk-neutral skewness before earnings announcement day contains information about stock returns during earnings announcement period. Less negative options risk-neutral skewness and the positive change of skewness predict higher abnormal return after earnings announcement. In addition, it is the individual risk-neutral skewness and idiosyncratic risk that play more important role in predicting the abnormal return.

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1. Implied volatility and options market liquidity

1.1 Introduction

This paper studies the impact of options liquidity on the shape of implied volatility functions for both equity options and index option. The traditional option pricing model assumes that the market is frictionless, but more and more evidences from various markets have proved that liquidity is one of the important determinants of the assets return. In the stock market, it has been documented that the market liquidity is related to the stock return. In an earlier study, Amihud and Mendelson (1986) studied the effects of bid-ask spread on asset pricing, their result shows that expected stock return is an increasing and concave function of the spread. Since then, studies on different market prove the liquidity impact on asset pricing. Recently, there are researches on derivative markets concerning the liquidity effects. Derivative markets have difference market micro-structure; therefore the liquidity may play different role on asset pricing. Deuskar, Gupta and Subrahmanyam (2010) find that unlike stock and bond markets, there is liquidity discount, instead of premium, in the OTC market for interest rate derivative market. Brenner (2001) confirm that the non-tradable currency options in Israel are priced at discount compare with exchanged-traded options. These found suggest that in derivative market, the liquidity impact depends on the characteristic of a specific market. This motivates the study of options liquidity in the equity and index stock options markets.

Ever since the publishing of Black-Scholes model, empirical studies in the derivative literature have provided numerous evidences of “implied volatility smile”. The implied volatility of index option was found to have negative relationship with exercise prices, and the implied volatility across exercise prices for equity stock option appeared to be more like a smile. Previous research mostly focused on the implied volatility smile of Index options. More recently, there have been

papers studying the cross-sectional effect on the individual stock implied volatilities. A group of researchers use risk-neutral distribution derived from option data to explain the implied volatility. Among them, Maryland, Kapadia and Madan (2003) explain the differential pricing of individual stock options by using the risk-neutral return skew, and find that individual risk-neutral distributions are far less negatively skewed than index, which is used to explain the more negative slope of implied volatility function for index option, whereas less negative slope for individual stock option implied volatility functions. Duan and Wei (2009) demonstrate the impact of systematic risk on the prices of individual stock options, showing a positive effect of systematic risk on both the level and the slope of the implied volatility curve. Other researchers focus on the non-market maker's net demand for options. Bollen and Whaley (2004) find that net buying pressures of options have significant impact on changes in implied volatilities for both index option and individual stock options, with higher impact of put option net buying pressure on index option volatility change, and higher impact of call option net buying pressure on individual options' volatility change. Garleanu, Pedersen and Poteshman (2009) demonstrate that the demand pressure contributes to the expensiveness and skew of index option as well as individual stock options.

In the stock options market, the bid-ask spread is higher for ITM options and lower for OTM options. However, since the options prices are higher for ITM options and lower for OTM options, after scaling the bid-ask spread by midpoint of the bid ask quotes, the scales spread increases from ITM options to OTM options. This brings the question that whether the option bid-ask spread is related to the implied volatility level, and whether the effects are different across different moneyness categories.

This paper is inspired by the above-mentioned studies on option implied volatility and the liquidity effect on asset pricing. In this paper, I study the relationship between options liquidity and implied volatilities of options on both equity options and index options. Daily options data are separated into eight groups according to their moneyness. Following the literature, the options liquidity is measured by the option percentage spread, option trading volume and open interest. The study finds statistically significant evidence that the implied volatility can be explained by the liquidity of the options. The result shows a negative relationship between the scaled spread and the implied volatility across all moneyness categories. This suggests that the illiquid options, with high percentage spread, have lower implied volatility, and therefore higher return. The positive effect of trading volume and open interest on implied volatility generates the same conclusion. As such, one can conclude that the liquidity premium documented in the stock market also exist in the individual stock options market.

Dennis and Mayhew (2001) investigate various stock characteristics and find that firm specific factors are important in explaining the risk-neutral skew for individual stocks.

Among these variables, they find significant effects of firm size and trading volume. Following their paper, I use firm size, stock trading volume and leverage as control variables. The negative effect of the percentage spread is still statistically significant after controlling the firm specific variables.

Based on the above, it is of interest to investigate at whether the liquidity premium still exists for the excessive volatility once we control the historical volatility. Following Duan and Wei (2009), by using the GARCH volatility calculated with stock return, I estimate the average level of excessive volatility for each moneyness category. After controlling the firm specific

characteristics, there is still negative effect of the percentage spread on the level of excessive volatility. These results prove the existence of liquidity premiums in stock options market.

This paper contributes to the literature from several aspects. First, it explains the volatility level from the view point of market efficiency. Second, it studies both the level of implied volatility and excessive implied volatility for both stock options and index options. Third, it explains the impact of stock characteristics on the total and excessive implied volatility.

This paper is organized by four parts. The first section present the empirical hypothesis testing procedure and data used for testing. In the second section the empirical result of Fama-MacBeth regression is presented. In the Third section the regression is used to test the impact of options liquidity on index options. And the conclusion is presented in the fourth section.

1.2 Hypothesis testing procedure

In order to find the impact of options liquidity on the implied volatility, two null hypotheses need to be test:

Hypothesis I: The level of the total implied volatility is unrelated to the option liquidity.

Hypothesis II: The level of the excessive implied volatility is unrelated to the option liquidity.

The first hypothesis testing can be done by running the regressing option implied volatility on the option liquidity measures.

$$\sigma_{it}^{imp} = \gamma_{0i} + \gamma_{1i}L_{it} \quad (1)$$

In the above equation, the σ_{it}^2 stands for the implied volatility for stock i at time t, whereas the independent variable L_{it} stands for option liquidity measurement for stock i at time t. First, the

Fama_Macbeth (1973) regression is run cross-sectionally, and then the Newy-West heteroscatetic standard error is calculated for the time serial's average. Hypothesis I is rejected if γ_{li} is statistically significant. Therefore one can say the option liquidity has significant impact on the implied volatility. To control the total risk of stocks, equation (1) is also regressed by replacing the dependent variable with excessive implied volatility (EIV), which is used to test the hypothesis II. Hypothesis I and II can be rejected if γ_{li} is statistically significant. The rejection of these two hypotheses suggests that the option liquidity has significantly impact on the level of total and excessive implied volatility function.

Before exploring the relationship between options liquidity and implied volatility, another question is worth to considering in pricing options. That is, what increases the difference of prices among different moneyness. To answer this question, the shape of the implied volatility function/EIV function needs to be exam. Inspired by Bakshi, Kapadia and Madan(2003), equation (2) is used to capture the shape of the implied volatility function.

$$\sigma_{ik}^{imp} = a_{0i} + a_{1i}(y_{ik} - \bar{y}_i) + a_{2i}(y_{ik} - \bar{y}_i)^2 + \varepsilon_{ik}, \quad K= 1, 2 \dots J, \quad (2)$$

$$\sigma_{ik}^{imp} - \sigma_i^{GARCH} = a_{0i} + a_{1i}(y_{ik} - \bar{y}_i) + a_{2i}(y_{ik} - \bar{y}_i)^2 + \varepsilon_{ik}, \quad K=1, 2 \dots J \quad (3)$$

In the above equation, y_{ik} stands for the option moneyness and is the ratio of strike price to the spot price, $y_{ik} = K_{ik} / S_i$. \bar{y}_i Is the sample average of y_{ik} . The intercept coefficient a_{i0} in equation (2) measures the level of the implied volatility for the average moneyness in a moneyness category, whereas β_{0i} measures the EIV for the average moneyness in a moneyness

category. a_{it} And β_{it} measure the slope of the implied volatility function or EIV function. The quadratic term is used to control the curvature.

Therefore, after studying the equation (1) and adding stock characteristics to equation (1), the moneyness and quadratic moneyness terms need to be controlled in the regression.

1.3 Data Description

To test the impact of options liquidity on the implied volatility, both daily options data and stock market data need to be collected.

1.3.1 Options Data

Equity options daily data are collected for stock constitutes of S&P100 index from Ivy DB OptionMetrics. S&P 100 include 100 U.S. stocks that have exchange-traded options. The selection of these stocks guarantees that consecutive options data is available. The sample period is from January 1996 to December 2010. Furthermore, only stocks with options traded at the beginning of every year from 1996 to 2010 are selected, which leave 63 stocks in the final sample. The daily options data for S&P100 index, symbol with OEX, is also collected to compare with the behavior of equity options. The data fields include option daily trading volume, open interest, implied volatility, and best bid/ask price for each option serial. Option Serial is defined by options call/put flag, strike price and maturities. The sample is then filtered by the following criteria:

1. Observations with missing bid/ask quote, zero bid/ask quote or bid quote higher than ask quote are eliminated;

2. Observations with bid ask spread less than the minimum spread (\$0.05 for options with prices less than \$3.00; \$0.10 for options with prices greater than or equal to \$3.00).
3. Options quotes must satisfy the basic arbitrage conditions, that is, for calls, the bid prices are required to be less than the spot price and the ask prices are required to be at least as large as the spot price minus the strike. For puts, the bid prices must be less than the strike and ask prices must be at least as large as the strike price minus the spot price.
4. To eliminate the outliers, observations with implied volatility less than 0.05 or greater than 200 are eliminated.

For each option, the moneyness is calculated as strike price/ daily closing stock price. Options are then grouped into four categories according to moneyness for calls and puts separately. That is, $K/S = [0.9, 0.95], [0.95, 1.00], [1.00, 1.05]$ and $[1.05, 1.10]$. In order to test the different behavior for options with different maturity, the option data is separated into three groups according to their maturity. Options with maturities between 20 and 70 days are categorized as short-term, options with maturities between 70 and 120 days are categorized as mid-term, and options with maturities between 120 and 180 days are categorized as long-term. All observations are sorted by maturity, and then by moneyness. The variables are calculated for 24 categories separately, and regressions are run for each category.

Follow the literature, option liquidity is measured by the percentage bid-ask spread, which is calculated by using the difference between daily best offer and best bid quote, scaled by the midpoint of the bid-ask quote. For each category, the relative spread is averaged by using trading volume as the weight.

$$Pspread_{ik} = \sum_{j=1}^J Volume_{ij} \left(\frac{bestoffer - bestbid}{mid_quote} \right)_{ij}, j=1,2,\dots,J \quad (4)$$

Equation (6) is calculated for each stock, each moneyness and maturity category. Subscript i stands for i th stock and J stands for j th option serial in a particular category.

The two alternative option liquidity measures are option volume and open interest. Option volume and open interest are directly extracted from option metrics, and the total volume and total open interest are calculated for each category. Both of these two variables are then transformed into logarithm.

1.3.2 Implied volatility and excessive implied volatility

Two dependent variables are used for the analysis, the implied volatility and excessive implied volatility. The implied volatility data is collected from OptionMetrics. Implied volatilities are calculated by using Black-Schoels model for European options, and binomial-tree for American options.

The other dependent variable, excessive implied volatility (EIV), is the difference between implied volatility and bench mark volatility. The reason of using EIV is to measure the “expensiveness”, or the risk premium of options. By using EIV, I control the volatility resulting from the stock market total risk. Therefore, it is a better variable to catch the effect of option liquidity on the price of options. This approach has been used by Garleanu, Pedersen and Poteshman (2009) in their paper, among other literatures about this topic.

Follow the literature, I use GARCH (1, 1) model to estimate the bench mark volatility for individual stocks. The GARCH (1, 1) model use here is:

$$\begin{aligned}
 R_t &= \mu + \sigma_t \varepsilon_t \\
 \sigma_t^2 &= \omega + \alpha R_{t-1}^2 + \beta \sigma_{t-1}^2 \\
 \varepsilon_t &\sim NID(0,1)
 \end{aligned}
 \tag{5}$$

In equation (5), R_t is the daily stock return at day t, and σ_t^2 is the daily volatility at day t.

In particular, I estimate the GARCH (1,1) model for the trade day on a rolling basis, using 250 days return prior to the expiration day. The conditional error variance estimated from the model is then annualized. EIV is calculated by subtracting this GARCH volatility from implied volatility¹.

1.3.3 Stock variables

The firm-specific stock variables are collected from CRSP dataset. Stock trading volume is the logarithm of daily volume for each firm. Firm size is measured by logarithm of market capitalization, which is the product of daily closing stock price and number of outstanding shares. Leverage ratio is the sum of long-term debt and book value of preferred stock, divided by market capitalization.

Two variables are used to measure the systematic risk of stock, beta coefficient and the proportion of systematic risk to the total variance (Systematic). Following Duan and Wei (2009), beta coefficient is estimated by market factor model:

$$r_{it} = \alpha + \beta \times r_{mt} \quad (6)$$

Using rolling regression method, beta is estimated with the data of 250 days prior for each stock on every day. The market return is the return of S&P500 index. The systematic risk

¹ To test the robust of the study, I use an alternative benchmark, historical volatility to create EIV. Historical volatilities are the standard deviation of the stock daily return prior to the options trade day. Similar like GARCH model, I also use 250 days window on a rolling basis. The result is similar as using GARCH volatility as bench.

proportion is defined by $\frac{\beta_{it}^2 \sigma_{it}^2}{\sigma_{mt}^2}$, which is the R-squared of market factor rolling regression in equation.

1.4 Statistics Description.

Table 1.1 to 1.3 reports the summary statistics of all the variables used in the regression.

From table 1.1 one can see that the implied volatility is higher (lower) for low (high) strike options. The short term out-of-the-money (OTM thereafter) put options have an average implied volatility of 35.71%, whereas in-the-money (ITM thereafter) put options have an average implied volatility of 31.95%. For call options, average implied volatility is 34.89% for ITM and 31.53% for OTM. This pattern demonstrates a downward slope of the volatility function, and the volatility function across moneyness appears more like a smirk. The percentage spread increases from ITM to OTM. Use short term data as an example, for call options, the percentage spread increases from 4.95% for ITM to 23.12% for OTM. For put options, percentage spread increase from 5.13% for ITM to 21.08% for OTM. This result suggests that the percentage spread is related with option moneyness, and may be used to explain the implied volatility smile across moneyness. Compare with put option, call options on average has higher implied volatility and percentage spread.

Two alternative option liquidity variables, option volume and option open interest, are used to test the robustness. These two variables show the clear pattern that most of investors trade slightly OTM options.

Mid-term and long-term data appear same pattern with short-term data, but both the magnitude and variation across moneyness becomes lower. Therefore the tests mainly focus on the short-term options.

Table 1.2 presents the summary statistics for OEX index options. OEX options have lower implied volatility than equity options. The average implied volatility is 0.2132 for call options and 0.2216 for put options. The implied volatility also decreases from low strike price to high strike price, and the percentage spread increases from ITM to OTM for both of call and put options. Again, the highest trade volume appears for slightly OTM options.

Table 1.3 summarizes the statistics of underlying stock variables. On average, the beta coefficient is about 98% and the systematic proportion is about 31.6%. Duan and Wei(2009) use the largest 30 stocks in S&P 100 index, and find an average systematic risk proportion of 0.37. In this paper I use 63 stocks included in S&P100. The systematic risk proportion in this paper is lower than Duan and Wei (2009)'s, which may be due to the using of 63 stocks. With more stocks are included, there are more variation of the firms' characteristics.

1.5 Quintile sorting

The first step to see the general relationship between the percentage spread and implied volatility is to sort the data into quintiles according to their percentage spread. Table 1.4 presents the quintiles of percentage spread, average implied volatility and EIV for equity options. The results are reported for all three maturities all together, but separated for each moneyness category. I first calculate the time average for each stock, and then sort variables cross-sectionally. It is clear that for all maturities, stocks with higher percentage spread have lower implied volatility. This difference is strongest for OTM options. Use DOTM call options as example, the percentage spread in the highest quintile is 0.2331, which is 0.1345, or 136.55% higher than that of the lowest quintile. Meanwhile, the implied volatility corresponding to the highest quintile is 0.2546, which is 0.1568 or 0.3811% lower than the implied volatility

corresponding to the lowest percentage spread quintile. The association between percentage spread and EIV is mixed. The negative relationship exists for ITM options, but not for OTM.

Table 1.5 demonstrates the sorting result across all moneyness categories, but separated for the maturity. For all three maturities, the implied volatility level in the highest percentage spread quintile is lower than that in the lowest quintile. For EIV, the positive association exists for all three maturities, but the magnitude is small.

The quintile sorting results suggest that the options liquidity has negative relationship with implied volatility, but not necessarily negative for EIV. The excessive implied volatility may be determined by other variables. To test this, I control the stock variables in the regression models.

1.6 Regression analysis

The next step is to test the liquidity impact on the level of total and excessive implied volatility. In order to get valid regression result, monthly data is used to run the Fama-Macbeth regression. Every month, for each stock, option data is grouped according to the moneyness categories and maturity. There must be at least 10 observations in each group. First, the cross sectional regression is run monthly. Second, the estimates are averaged across all month and the Newey-West heteroschadestic standard errors are used to test the significance.

As mentioned before, the relationship between moneyness and implied volatility need to be considered before looking at the options liquisidity. Table 1.6 presents the regression results of equation (2) and (3). It is clear that for all moneyness/maturity categories, the average level of implied volatility and EIV decrease from low strike price options to high strike price options. The slopes are negative except the highest moneyness category. These results are consistent with the common view of the smirk/smile shape of implied volatility function. Both the level and

slope coefficients are significant. The pattern of the level and slope coefficients across moneyness categories are the same for all three maturity categories, only that for longer maturities, the level coefficients are lower, and the slopes are flatter.

Previous research has proved that Stock characteristics play an important role in determining the level and slope of implied volatility function. In order to control these characteristics, along with the options moneyness, equation (7) and (8) is used to estimate the option liquidity effect given the underlying stock properties and options moneyness.

$$\sigma^2 = \lambda_0 + \lambda_1 L + \lambda_{2i} size + \lambda_{3i} lev + \lambda_{4i} svolume + \lambda_{5i} beta + \mu_i \quad (7)$$

$$\sigma^2 = \lambda_0 + \lambda_1 L + \lambda_{2i} size + \lambda_{3i} lev + \lambda_{4i} svolume + \lambda_{5i} beta + \lambda_{6i} moneyness + \lambda_{7i} moneyness^2 + e_i \quad (8)$$

Use equation (7) and (8), cross-sectional regressions are first run on every month, and then the time series averages of the estimates are calculated. The t statistics are adjusted for serial correlation by using Newy-West heteraskadesticity. Use Fama-Macbeth regression, coefficient estimates the effect of relative spread on two dependent variables respectively, implied volatility and EIV.

The results are demonstrated by table 1.7 to table 1.12 using short-term option data², with various options liquidity variables and control variables. In summary, for all the eight option categories, percentage spread has significant negative effects on the level of implied volatility. The significant negative sign for all options rejects hypothesis I that implied volatility is not related with the level of option liquidity.

² To save space, only short-term results are reported here. The results for mid-term and long-term are similar.

In the bond and stock market, it has been documented that the illiquidity has negative effect on asset price. In these markets, investors who long the assets face the illiquidity risk when they would later sell the assets. Investors who sell the assets have no illiquidity risk. In options market, both long and short investors have exposures to the illiquidity risk. Should the illiquidity bring premium or discount depends on the net effect of buying and selling pressure. Deuskar, Gupta and Subrahmanyam (2010) argue that in the OTC market for interest rate options, the “seller effect: dominates and the more illiquidity options have higher prices. They explain it as that the market makers in such market are typical net sellers. However, in equity options market, as Garleanue et al. (2008) show in their paper, the non-market makers are typical net sellers for all moneyness and maturities. In the equity options markets, it is the “buyer-effect” that dominates, which means the illiquidity options have lower prices. The negative effects of percentage spread on the level of implied volatility proved this “illiquidity premium” in the equity options market.

In addition, without control variables, the negative impacts are stronger for OTM options than ITM options. Take short term call options as example, when using total implied volatility as dependent variable, the greatest negative impact appears in the moneyness category of [1.0, 1.05], with a -0.2371 estimated coefficient for percentage spread. The smallest impact is -0.1036 for the category of [0.9, 0.95]. The possible explanation is that the percentage spread increases from ITM options to OTM options; therefore the effect for OTM options is stronger. This is opposite with the case after controlling other variables. The coefficient is -0.1155 for [1.0, 1.05] and -0.4313 for [0.9, 0.95]. Same results can be observed for put options. In the stock options market, investors are more like to invest on OTM options because of the leverage effect of them.

The implied volatility of OTM options largely reflects investors view about the future perspective of stocks, which is reasonably more rely on the stock characteristics.

Two alternative measurements of option's liquidity, the option trade volume and open interest are also used to test hypothesis I. The results are reported in table 1.8 and table 1.9. Both of these two variables have positive impact on the implied volatility, which indicate that the higher liquidity increase the price of the options.

It is worth to considering the coefficients of the stock variables. Among the stock variables, the size of the firm, which is defined as the stock capitalization, has negative effect. The large firms tend to have lower total risk compare with small capitalization firms; leverage ratio also shows negative impact on implied volatility. Stock trading volume has positive effect on the implied volatility. Large stock trade volume, indicate large demand for using option to hedge the risks in the underlying market, therefore decrease the price of the equity options. The Two variables are used to measure the systematic risk, beta and the systematic risk portion of the total variance, which is the R^2 of the market model. As Duan, Wei (2009) have pointed out, these two variables measures different things. Beta coefficient measures the co-movement of individual stock with market return, which in this paper, has positive impact on implied volatility. It shows that given the same systematic risk proportion, the higher the stock is correlated with the market movement, the higher is the implied volatility. To save space, the results of replacing beta by systematic risk proportion are not presented. The results is very similar with the one using beta coefficients, and is consistent with Duan and Wei (2009)'s conclusion. In their paper they found that significant positive impact of systematic risk proportion on the level of the EIV. With the positive impact of beta and systematic risk proportion on the level of total implied volatility, it

demonstrate that the more the stock moves together with the market, the higher the implied volatility; and the higher proportion of systematic risk, the higher level of implied volatility.

In order to control the total risk of stock, another dependent variable, excessive implied volatility is used to test the impact of liquidity. Excessive implied volatility is defined as the difference between implied volatility and the GARCH volatility; it measures the expensiveness of stock options.

The regression results using EIV as dependent variable are presented in table 1.10 to 1.12. The effects of percentage spread on the dependent variable EIV are still significantly negative. Option trade volume and open interest influence EIV in a mixing impact.

After controlling the stock variables, percentage spread has significant negative effect on the level of EIV, and increasing from DOTM to DITM. The estimate is -0.0525 for DOTM call options and -0.1825 for DITM call options. For put options, the estimate is -0.0416 for DOTM and -0.1174 for DITM. Option volume and open interest have mixing effects on the level of EIV. The results on EIV function prove that the options liquidity has negative impact on the excessive implied volatilities. The hypothesis II has been rejected.

When use EIV as dependent variable, the sign of stock capitalization remains positive. The sign of the leverage ratio, stock trading volume and beta coefficients are all negative. This indicates that leverage ratio of the stock and stock trading volume decrease the expensiveness of the stock options. The sign of Beta and systematic risk proportion are opposite, with a negative sign for beta, but positive for systematic risk proportion. The key point is the controlling of total stock risk. EIV measures the excessive implied volatility for individual stocks. Beta measures the movement of a stock return with the market, while systematic risk proportion measures the

allocation of total risk between systematic risk and idiosyncratic risk. It is reasonable to say that higher beta increase the total risks of stock, therefore the level of total implied volatility. However, beta does not necessarily increase the excessive implied volatility. On the contrast, in this study, the co-movement of individual stock with market increases total risk but decreases the excessive implied volatility. As to the systematic risk proportion, it measures the distribution of systematic risk and idiosyncratic risk in a stock. The positive coefficients indicate that even after considering the total risk, the higher the systematic risk proportion, the higher the EIV, this is consistent with Duan and Wei (2009)'s found.

1.7 The liquidity effect of index option

After exam the liquidity impact of individual stock options, it is nature to ask the same question for the index options. I use the options of S&P100 index; symbol OEX, to compare the impact of liquidity with that of equity options.

The data of OEX are collected from 1998 to 2010. Using the same method, I create the percentage spread, options volume and open interest as the measure of options liquidity. EIV is the difference between implied volatility and GARCH implied volatility. Table 1-C shows the statistic description of the data. Use short-term as example, the implied volatility has a monotonically decrease from low strike to high strike options for call options, and the same pattern appears to put options except a small increase in DITM put options. The average implied volatility for short-term call options is 0.2132, slightly lower than the average of 0.2216 for put options. However, comparing EIV between call and put options, the EIV is 0.0195 for call and 0.0295 for put, The difference is much higher. As for the percentage spread, again it increases from ITM to OTM, same as the equity options. The percentage spread is 0.1220 for call option and 0.0860 for put option. It seems put options have higher liquidity. This is consistent with the

common view that investors mainly use index put options as hedge. And the put option has slightly higher number of trades.

I now exams the liquidity effects for the index options. Table 7-A shows the result of liquidity on the level and slope of implied volatility function. The result is very similar as the equity options. Percentage spread has negative impact on the level of implied volatility. As for the slope, the impact is mixed. The liquidity variable make the slope for DITM and DOTM options steeper, but flatten the slope for near ATM options.

When use the level and slope of EIV, the results presented in table 7-B are same as table 7-A, with a negative impact of percentage spread on the level of EIV, whereas positive impact on the slope of DITM/DOTM call and put options.

1.8 Concluding Remark

There have been numerous researches on what determine the options implied volatility since the publishing of Black-Scholes model. Among the various factors, options liquidity impact has been paid attention recently. Previous researchers have proved the importance of liquidity premium on the asset pricing in the bond and stock market. In the derivative market, BS model assume non friction of the derivative market. However, the smile/smirk shape of the implied volatility function suggests re-considering this assumption.

In this paper, I test the impact of equity and index options liquidity on the level of implied volatility function and the expensiveness of the options. The result proves the liquidity premium, like in bond and stock market, also has important influence on the price of options. The negative relationship of options liquidity on the excessive implied volatility suggests that investors pay less on the illiquidity options, expecting to earn compensation for the liquidity risk.

In addition, the study finds that the systematic risk proportion increase the stocks' total risk level and the expensiveness of the stock options. This found shed light on the risk distribution between systematic and idiosyncratic risk.

The main contribution of this paper is to document the liquidity premium in the equity and index options market, which has been proved playing different roles in different asset markets, depending on the property of the market. This paper explains the shape of implied volatility from the view point of options market microstructure. It finds that less liquid options have steeper implied volatility function, which means the difference in implied volatility across moneyness is greater for the less liquid options.

The result in this paper suggests the further research to incorporate the liquidity in derivative pricing. Options market has experienced rapid developing in the past decades, the market microstructure changes dramatically. Future research on this issue may focus on two aspects. First, what are the influences of innovation in the options market, for example, the introduction of new products, new strategies and new trading methods on the liquidity premium impact? Second, what are the changes of liquidity premium around extreme events, such as stock market turmoil, and financial crisis?

Table 1.1 Summary statistics-equity option variables

This table presents the summary statistics for equity options variables. The sample includes daily options data from Jan 1996 to Dec 2010. Data are grouped into four moneyness categories and three maturities for call and put options separately. σ^{imp} is implied volatility. EIV is the difference between implied volatility and GARCH historical volatility. Option volume is option trade volume, open interest is option open interest and Pspread is the percentage bid-ask spread. All variables are calculated at cross sectional average for each day, and then time series average across dates.

Short-term options: 20-70 days in maturity								
Moneyness.K/S	call options				Put options			
	[0.90-0.95)	[0.95-1.00)	[1.00-1.05)	[1.05-1.10]	[0.90-0.95)	[0.95-1.00)	[1.00-1.05)	[1.05-1.10]
σ^{imp}	0.3489	0.3299	0.3195	0.3172	0.3571	0.3356	0.3208	0.3195
EIV	0.0200	0.0040	-0.0090	-0.0151	0.0244	0.0076	-0.0057	-0.0102
Option Volume	292.54	707.23	1070.13	718.21	464.57	670.04	448.99	179.25
Open interest	4626.47	7234.89	8329.65	6847.06	5180.52	5598.73	4489.53	2856.41
Pspread	0.0495	0.0644	0.1079	0.2299	0.2107	0.1108	0.0678	0.0513
Mid-term options: 71-120 days in maturity								
Moneyness.K/S	call options				Put options			
	[0.90-0.95)	[0.95-1.00)	[1.00-1.05)	[1.05-1.10]	[0.90-0.95)	[0.95-1.00)	[1.00-1.05)	[1.05-1.10]
σ^{imp}	0.3331	0.3215	0.3137	0.3118	0.3406	0.3251	0.3149	0.3106
EIV	0.0114	0.0005	-0.0095	-0.0176	0.0147	0.0040	-0.0054	-0.0118
Option Volume	112.17	237.73	395.67	340.88	193.82	227.79	161.75	72.62
Open interest	4365.55	6237.05	7724.6	6763.23	5011.69	5203.39	4145.07	2856.16
Pspread	0.0444	0.0536	0.0705	0.1081	0.1072	0.0747	0.0570	0.0464
long-term options: 121-180 days in maturity								
Moneyness.K/S	call options				Put options			
	[0.90-0.95)	[0.95-1.00)	[1.00-1.05)	[1.05-1.10]	[0.90-0.95)	[0.95-1.00)	[1.00-1.05)	[1.05-1.10]
σ^{imp}	0.3301	0.3201	0.3127	0.3080	0.3349	0.3238	0.3158	0.3099
EIV	0.0080	0.0004	-0.0092	-0.0167	0.0116	0.0047	-0.0049	-0.0113
Option Volume	67.94	136.83	245.37	233.03	128.51	148.38	108.21	49.23
Open interest	2957.84	4000.27	5254.84	4934.13	3705.71	3583	2999.07	2053.15
Pspread	0.0412	0.0481	0.0588	0.0782	0.0801	0.0626	0.0513	0.0433
All maturities								
Moneyness.K/S	call options				Put options			
	[0.90-0.95)	[0.95-1.00)	[1.00-1.05)	[1.05-1.10]	[0.90-0.95)	[0.95-1.00)	[1.00-1.05)	[1.05-1.10]
σ^{imp}	0.3405	0.3262	0.3166	0.3130	0.3466	0.3302	0.3191	0.3153
EIV	0.0154	0.0025	-0.0091	-0.0160	0.0191	0.0062	-0.0055	-0.0107
Option Volume	183.614	423.523	643.954	471.472	291.475	397.005	278.19	115.134
Open interest	4321.95	6303.4	7496.23	6540.76	4920.37	5083.2	4166.04	2774.09
Pspread	0.0459	0.0570	0.0829	0.1472	0.1442	0.0879	0.0609	0.0481

Table 1.2 Summary statistics-Index option variables

This table presents the summary statistics for OEX index options variables. The sample includes daily options data from Jan 1998 to Dec 2010, and is grouped into four moneyness categories and three maturities for call and put options separately. All variables are calculated at time series average across dates.

<u>Short-term options: 20-70 days in maturity</u>								
Moneyness.K/S	call options				Put options			
	[0.90-0.95)	[0.95-1.00)	[1.00-1.05)	[1.05-1.10]	[0.90-0.95)	[0.95-1.00)	[1.00-1.05)	[1.05-1.10]
σ^{imp}	0.2628	0.2190	0.1867	0.1845	0.2522	0.2189	0.1974	0.2177
EIV	0.0733	0.0294	-0.0038	-0.0209	0.0636	0.0294	0.0066	0.0185
Option Volume	18.215	175.843	529.212	278.668	303.323	528.197	168.575	11.618
Open interest	337.42	1142.09	2154.39	1746.61	2016.47	2067.14	730.83	159.1
Pspread	0.0355	0.0528	0.1032	0.2964	0.1669	0.0811	0.0567	0.0389
<u>Mid-term options: 71-120 days in maturity</u>								
Moneyness.K/S	call options				Put options			
	[0.90-0.95)	[0.95-1.00)	[1.00-1.05)	[1.05-1.10]	[0.90-0.95)	[0.95-1.00)	[1.00-1.05)	[1.05-1.10]
σ^{imp}	0.2458	0.2194	0.1980	0.1825	0.2460	0.2223	0.2045	0.2001
EIV	0.0525	0.0270	0.0041	-0.0149	0.0528	0.0300	0.0107	0.0027
Option Volume	4.616	26.327	50.618	44.594	54.326	59.526	21.615	2.562
Open interest	188.73	560.79	696.05	641.44	726.36	813.99	323.17	90.36
Pspread	0.0342	0.0485	0.0720	0.1724	0.1016	0.0714	0.0525	0.0379
<u>long-term options: 121-180 days in maturity</u>								
Moneyness.K/S	call options				Put options			
	[0.90-0.95)	[0.95-1.00)	[1.00-1.05)	[1.05-1.10]	[0.90-0.95)	[0.95-1.00)	[1.00-1.05)	[1.05-1.10]
σ^{imp}	0.2397	0.2200	0.1995	0.1854	0.2429	0.2246	0.2062	0.1991
EIV	0.0460	0.0238	0.0077	-0.0074	0.0494	0.0285	0.0146	0.0058
Option Volume	67.94	136.83	245.37	233.03	25.27	39.781	16.592	5.357
Open interest	9.433	18.246	35.481	26.363	635.8	752.28	402.29	163.02
Pspread	286.75	558.01	764.78	693.04	0.0799	0.0616	0.0493	0.0364
<u>All maturities</u>								
Moneyness.K/S	call options				Put options			
	[0.90-0.95)	[0.95-1.00)	[1.00-1.05)	[1.05-1.10]	[0.90-0.95)	[0.95-1.00)	[1.00-1.05)	[1.05-1.10]
σ^{imp}	0.2559	0.2192	0.1911	0.1840	0.2496	0.2204	0.2003	0.2106
EIV	0.0650	0.0283	-0.0005	-0.0177	0.0593	0.0295	0.0084	0.0125
Option Volume	13.635	119.727	348.155	180.779	208.943	352.778	112.982	8.324
Open interest	291.4	926.34	1612.23	1297.72	1532.84	1597.34	584.34	138.8
Pspread	0.0348	0.0508	0.0906	0.2387	0.1409	0.0767	0.0549	0.0384

Table 1.3 Summary statistics-stock variables

This table presents summary statistics for stocks. The sample is collected from 1/1/1996 to 12/31/2010. Size is the market capitalization. Stock volume is the stock trade volume. Leverage ratio is the sum of long-term debt and book value of preferred stock, divided by market capitalization. Beta is the beta coefficient estimated by market factor model. Systematic is the systematic risk proportion, which is the R-squared of the market factor model.

	mean	median	std
Size	55960082	7179304	7650624
Stock_volume	9205045	7179304	7650624
Leverage	0.2059	0.2028	0.0259
beta	0.973	0.98	0.07
systematic	0.316	0.293	0.11

Table 1.4 Sorting of implied volatility & EIV by percentage spread

This table presents the quintile sorting result of percentage spread, and the corresponding implied volatility and EIV for each Pspread quintile. The sorting are done for four moneyness categories separately, all maturities together.

Moneyness	Quintiles	Call Options			Put Options		
		pspread	Implied volatility	EIV	pspread	Implied volatility	EIV
K/S:[0.9,0.95)	1	0.0360	0.3787	0.0171	0.1085	0.4400	0.0127
	2	0.0435	0.3394	0.0154	0.1481	0.3531	0.0220
	3	0.0476	0.3242	0.0215	0.1775	0.3365	0.0185
	4	0.0515	0.3193	0.0159	0.1985	0.3218	0.0194
	5	0.0615	0.3428	0.0081	0.2344	0.2999	0.0245
Difference(5-1)		0.0255	-0.0359	-0.0090	0.1258	-0.1401	0.0118
K/S:[0.95,1.00)	1	0.0459	0.3980	-0.0032	0.0689	0.4200	-0.0009
	2	0.0552	0.3194	0.0064	0.0876	0.3354	0.0122
	3	0.0619	0.3030	0.0075	0.1050	0.2999	0.0077
	4	0.0681	0.2966	0.0024	0.1157	0.2924	0.0067
	5	0.0802	0.3194	0.0003	0.1389	0.3179	0.0052
Difference(5-1)		0.0344	-0.0786	0.0035	0.0700	-0.1021	0.0062
K/S:[1.00,1.05)	1	0.0617	0.4009	-0.0148	0.0506	0.3640	-0.0070
	2	0.0834	0.3192	-0.0054	0.0591	0.3344	-0.0096
	3	0.0969	0.3091	-0.0082	0.0654	0.2924	0.0001
	4	0.1079	0.2892	-0.0082	0.0712	0.2909	-0.0024
	5	0.1339	0.2815	-0.0099	0.0859	0.3220	-0.0095
Difference(5-1)		0.0722	-0.1194	0.0049	0.0353	-0.0420	-0.0024
K/S:[1.05,1.10)	1	0.0985	0.4114	-0.0224	0.0376	0.3365	-0.0088
	2	0.1453	0.3379	-0.0123	0.0446	0.3245	-0.0144
	3	0.1719	0.3002	-0.0149	0.0488	0.3170	-0.0124
	4	0.1948	0.2834	-0.0180	0.0529	0.2859	-0.0061
	5	0.2331	0.2546	-0.0105	0.0632	0.3114	-0.0103
Difference(5-1)		0.1345	-0.1568	0.0119	0.0256	-0.0251	-0.0016

Table 1.5 Sorting of implied volatility & EIV by percentage spread

This table presents quintile sorting for percentage spread, and the corresponding implied volatility/EIV. The sorting are done for three maturities separately, all moneyness categories together.

term	Quintile	spread	Implied Volatility	EIV
Short_term	1	0.07355	0.41042	-0.005265
	2	0.09571	0.33513	0.005712
	3	0.11256	0.32338	0.002503
	4	0.12588	0.29927	0.00485
	5	0.15882	0.30006	0.002356
	Difference(5-1)	0.08527	-0.11036	0.007621
Mid-term	1	0.05068	0.3986	-0.012582
	2	0.06425	0.32143	0.000166
	3	0.07324	0.31885	-0.004309
	4	0.08174	0.29966	0.000227
	5	0.09926	0.2868	-0.002339
	Difference(5-1)	0.04858	-0.1118	0.010243
long-term	1	0.04438	0.38713	-0.010856
	2	0.05533	0.31927	0.000037
	3	0.06319	0.29316	-0.001582
	4	0.07025	0.29862	-0.004411
	5	0.08405	0.28636	-0.002912
	Difference(5-1)	0.03967	-0.10077	0.007944

Table 1.6 Estimate of Implied Volatility Function/EIV function

This table presents the estimates of equation (2) and equation (3). The regression is done at monthly basis. And then the estimators are averaged over time. In the table, a0 is the level of implied volatility/EIV for the average moneyness for each category, a1 is the slope of implied volatility function/EIV function, and a3 controls the curvature of the function.

		Call options							
		K/S: [0.9,0.95)		K/S: [0.95,1)		K/S: [1,1.05)		K/S: [1.05,1.1)	
term	nam	imp_vol	EIV	imp_vol	EIV	imp_vol	EIV	imp_vol	EIV
Shortterm	a0	0.350*** (24.10)	0.020*** (5.26)	0.330*** (22.48)	0.003 (0.82)	0.318*** (22.20)	-0.012*** (-3.21)	0.314*** (23.44)	-0.018*** (-4.21)
	a1	-0.302*** (-12.48)	-0.320*** (-11.51)	-0.238*** (-9.97)	-0.248*** (-8.20)	-0.086*** (-5.09)	-0.091*** (-3.50)	0.009 (0.33)	0.066 (1.05)
	a2	0.732 (0.63)	-1.867 (-0.90)	1.475 (1.40)	-0.671 (-0.37)	2.784*** (3.04)	3.090** (2.01)	3.863*** (3.23)	-0.012 (-0.00)
Midterm	a0	0.332*** (25.17)	0.011*** (2.90)	0.318*** (23.26)	-0.001 (-0.29)	0.309*** (23.51)	-0.011*** (-2.81)	0.306*** (23.16)	-0.017*** (-3.82)
	a1	-0.156*** (-8.35)	-0.154*** (-4.70)	-0.136*** (-7.05)	-0.152*** (-3.83)	-0.111*** (-7.92)	-0.101*** (-3.58)	-0.077*** (-4.46)	-0.034 (-1.33)
	a2	-0.385 (-0.45)	-3.724 (-1.52)	-0.426 (-0.49)	-0.150 (-0.06)	1.319 (1.63)	5.203** (2.12)	-0.061 (-0.05)	-2.899 (-0.94)
Long term	a0	0.325*** (26.19)	0.005 (1.19)	0.314*** (24.62)	-0.004 (-0.89)	0.308*** (24.75)	-0.012*** (-2.82)	0.302*** (24.18)	-0.020*** (-4.30)
	a1	-0.142*** (-9.26)	-0.127*** (-4.90)	-0.117*** (-9.79)	-0.136*** (-5.69)	-0.101*** (-8.49)	-0.093*** (-2.77)	-0.079*** (-5.41)	-0.095*** (-3.48)
	a2	-0.353 (-0.37)	-1.281 (-0.42)	0.873 (1.30)	2.226 (0.84)	-0.859 (-1.28)	-1.648 (-0.78)	1.108** (2.08)	-1.202 (-0.57)
		Put options							
		K/S: [0.9,0.95)		K/S: [0.95,1)		K/S: [1,1.05)		K/S: [1.05,1.1)	
term	nam	imp_vol	EIV	imp_vol	EIV	imp_vol	EIV	imp_vol	EIV
Shortterm	a0	0.355*** (24.47)	0.024*** (7.06)	0.334*** (22.58)	0.007** (2.08)	0.322*** (21.86)	-0.009** (-2.33)	0.319*** (23.43)	-0.012*** (-3.00)
	a1	-0.404*** (-23.31)	-0.424*** (-16.69)	-0.294*** (-13.15)	-0.289*** (-9.20)	-0.130*** (-6.98)	-0.125*** (-5.25)	0.024 (0.74)	0.097 (1.47)
	a2	2.507*** (2.90)	0.695 (0.38)	2.389** (2.17)	-1.490 (-0.80)	2.957*** (3.28)	3.461** (2.12)	4.457*** (4.82)	2.349 (0.51)
Midterm	a0	0.337*** (25.35)	0.016*** (4.31)	0.323*** (23.50)	0.003 (0.83)	0.313*** (23.42)	-0.007* (-1.96)	0.307*** (22.85)	-0.014*** (-3.40)
	a1	-0.207*** (-14.90)	-0.211*** (-5.86)	-0.171*** (-10.59)	-0.196*** (-4.87)	-0.134*** (-8.90)	-0.117*** (-4.67)	-0.092*** (-5.65)	-0.096*** (-3.81)
	a2	-1.298 (-1.64)	-4.001 (-1.61)	-0.279 (-0.36)	0.339 (0.15)	2.035*** (2.83)	6.658*** (2.99)	1.411 (1.57)	1.008 (0.33)
Long term	a0	0.330*** (26.65)	0.010** (2.26)	0.318*** (24.99)	0.001 (0.20)	0.311*** (24.91)	-0.009** (-2.10)	0.305*** (23.96)	-0.016*** (-3.42)
	a1	-0.173*** (-14.14)	-0.145*** (-4.54)	-0.148*** (-11.33)	-0.158*** (-5.93)	-0.111*** (-9.39)	-0.080** (-2.25)	-0.089*** (-7.20)	-0.121*** (-4.51)
	a2	-0.615 (-0.92)	-1.394 (-0.57)	0.787* (1.87)	1.311 (0.53)	-0.328 (-0.60)	-0.604 (-0.28)	0.993* (1.80)	-1.651 (-0.76)

Table 1 .7.A liquidity effects on implied volatility-percentage Spread-Short term Call options

This table presents the regression result of equation (1) and equation (8). The dependent variable is implied volatility. The daily cross-sectional regressions are run for each moneyness category and maturity category. And the estimates are averaged over time. T statistics are calculated with the Newey-West Heteroschadectis standard error. To save space, only results for short-term maturity options are reported.

	K/S: [0.9,0.95)			K/S: [0.95,1)		
Intercept	0.3608*** (25.13)	1.1199*** (13.21)	1.1194*** (13.23)	0.3497*** (23.41)	1.1407*** (12.40)	1.1377*** (12.30)
pspread	-0.1036 (-1.15)	-0.4663*** (-11.57)	-0.4313*** (-10.92)	-0.3350*** (-7.58)	-0.4122*** (-13.40)	-0.3988*** (-12.85)
size		-1.1316*** (-18.66)	-1.1260*** (-18.56)		-1.1958*** (-21.19)	-1.1933*** (-21.10)
lev		-0.0381*** (-3.35)	-0.0386*** (-3.39)		-0.0391*** (-3.47)	-0.0391*** (-3.46)
svolume		0.8790*** (16.47)	0.8725*** (16.35)		0.9336*** (19.23)	0.9314*** (19.20)
beta		0.1128*** (9.81)	0.1130*** (9.82)		0.1101*** (9.95)	0.1102*** (9.94)
moneyness			-0.3265*** (-10.67)			-0.1590*** (-5.52)
moneyness_sq			6.0906*** (5.79)			7.5670*** (7.27)
adj_rsq	0.0182*** (7.37)	0.6818*** (55.08)	0.6864*** (56.97)	(7.93)	(74.70)	(74.88)
		K/S: (1,1.05)			K/S: [1.05,1.10)	
Intercept	0.3511*** (24.03)	1.1277*** (9.57)	1.1340*** (9.67)	0.3632*** (27.35)	-0.2212 (-0.16)	-0.2273 (-0.17)
pspread	-0.3574*** (-13.18)	-0.2398*** (-12.77)	-0.2498*** (-13.42)	-0.2371*** (-11.58)	-0.1095*** (-11.11)	-0.1155*** (-11.99)
size		-1.2461*** (-19.56)	-1.2511*** (-19.62)		-0.9708*** (-3.63)	-0.9674*** (-3.59)
lev		-0.0314** (-2.35)	-0.0314** (-2.42)		0.0118 (0.21)	0.0137 (0.25)
svolume		0.9940*** (14.75)	0.9965*** (14.62)		1.1982*** (5.23)	1.1975*** (5.19)
beta		0.0842*** (4.28)	0.0845*** (4.50)		0.0891*** (8.30)	0.0876*** (8.17)
moneyness			0.1694*** (6.68)			0.3158*** (11.22)
moneyness_sq			8.7140*** (10.10)			6.0938*** (6.77)
adj_rsq	(11.25)	(76.98)	(78.76)	(15.42)	(76.67)	(79.19)

Table 1 .7.B liquidity effects on implied volatility- percentage Spread-Short term Put options

This table presents the regression result of equation (1) and equation (8). The dependent variable is implied volatility. The daily cross-sectional regressions are run for each moneyness category and maturity category. And the estimates are averaged over time. T statistics are calculated with the Newey-West Heteroschadectis standard error. To save space, only results for short-term maturity options are reported.

	K/S: [0.9,0.95)			K/S: [0.95,1)		
Intercept	0.4005*** (26.91)	1.1430*** (10.29)	1.1663*** (10.38)	0.3685*** (23.31)	0.8908*** (3.15)	0.9094*** (3.22)
pspread	-0.2411*** (-9.27)	-0.1015*** (-9.19)	-0.1211*** (-10.16)	-0.3556*** (-8.89)	-0.2136*** (-11.48)	-0.2520*** (-12.05)
size		-1.1208*** (-18.84)	-1.1269*** (-19.02)		-1.1410*** (-17.96)	-1.1550*** (-18.65)
lev		-0.0467*** (-3.29)	-0.0459*** (-3.21)		-0.0265 (-1.52)	-0.0246 (-1.41)
svolume		0.8632*** (17.95)	0.8631*** (18.18)		0.9690*** (12.36)	0.9786*** (12.38)
beta		0.1045*** (9.24)	0.1015*** (8.99)		0.1067*** (9.65)	0.1042*** (9.47)
moneyness			-0.7461*** (-33.31)			-0.6162*** (-24.39)
moneyness_sq			7.0721*** (8.49)			6.5153*** (7.62)
adj_rsqr	0.1232*** (10.64)	0.7318*** (72.78)	0.7487*** (81.71)	0.0786*** (10.18)	0.7323*** (76.44)	0.7443*** (80.94)

	K/S: (1,1.05)			K/S: [1.05,1.10)		
Intercept	0.3403*** (22.09)	1.3165*** (13.82)	1.3201*** (13.94)	0.3377*** (23.38)	1.3953*** (13.63)	1.3953*** (13.66)
pspread	-0.2529*** (-4.62)	-0.3674*** (-11.06)	-0.3963*** (-11.13)	-0.0875 (-0.93)	-0.4007*** (-8.65)	-0.4030*** (-8.71)
size		-1.2305*** (-24.42)	-1.2360*** (-24.76)		-1.2332*** (-20.29)	-1.2339*** (-20.19)
lev		-0.0435*** (-3.59)	-0.0428*** (-3.54)		-0.0488*** (-4.32)	-0.0486*** (-4.31)
svolume		0.9020*** (21.81)	0.9067*** (22.08)		0.8756*** (17.53)	0.8759*** (17.39)
beta		0.1100*** (9.90)	0.1093*** (9.86)		0.1081*** (9.14)	0.1079*** (9.14)
moneyness			-0.2972*** (-16.88)			-0.0358 (-1.31)
moneyness_sq			7.8433*** (9.21)			7.2789*** (6.83)
adj_rsqr	0.0256*** (6.38)	0.7273*** (71.42)	0.7307*** (72.78)	0.0223*** (7.01)	0.6981*** (52.78)	0.6991*** (53.33)

Table 1.8.A liquidity effects on implied volatility-Options volume short term Call options

This table presents the regression result of equation (1) and equation (8). The dependent variable is implied volatility. The daily cross-sectional regressions are run for each moneyness category and maturity category. And the estimates are averaged over time. T statistics are calculated with the Newy-West Heteroschadectis standard error. To save space, only results for short-term maturity options are reported.

	K/S: [0.9,0.95]			K/S: [0.95,1)		
Intercept	0.3176*** (24.99)	1.0378*** (12.50)	1.0716*** (13.28)	0.2997*** (22.32)	1.0162*** (9.66)	1.0503*** (10.16)
Ovolume	0.0099*** (12.28)	0.0016*** (6.37)	0.0021*** (8.11)	0.0064*** (7.44)	0.0014*** (4.37)	0.0019*** (6.33)
Size		-1.0576*** (-16.58)	-1.0596*** (-16.77)		-1.1071*** (-17.77)	-1.1117*** (-17.99)
lev		-0.0480*** (-4.06)	-0.0477*** (-4.03)		-0.0474*** (-3.91)	-0.0471*** (-3.90)
Svolume		0.8201*** (14.53)	0.8092*** (14.33)		0.8725*** (17.04)	0.8637*** (16.91)
beta		0.1168*** (10.07)	0.1162*** (10.03)		0.1170*** (10.43)	0.1166*** (10.41)
Moneyness			-0.4512*** (-15.99)			-0.3493*** (-15.71)
moneyness_sq			6.2876*** (5.71)			7.0926*** (6.36)
adj_rsq	0.0426*** (11.12)	0.6691*** (50.40)	0.6763*** (53.34)	0.0298*** (7.57)	0.6951*** (64.24)	0.6989*** (65.33)

	K/S: (1,1.05)			K/S: [1.05,1.10)		
Intercept	0.2865*** (18.99)	1.1360*** (9.34)	1.1372*** (9.33)	0.2704*** (18.70)	-0.1836 (-0.12)	-0.2516 (-0.16)
Ovolume	0.0060*** (6.40)	0.0029*** (7.86)	0.0029*** (8.01)	0.0104*** (11.97)	0.0050*** (16.32)	0.0052*** (16.11)
Size		-1.2028*** (-18.20)	-1.2039*** (-18.12)		-0.9659*** (-3.23)	-0.9511*** (-3.04)
lev		-0.0435*** (-3.19)	-0.0442*** (-3.29)		0.0089 (0.14)	0.0123 (0.19)
Svolume		0.9278*** (13.12)	0.9278*** (12.99)		1.1592*** (4.47)	1.1682*** (4.30)
beta		0.0963*** (4.85)	0.0968*** (4.99)		0.1012*** (8.63)	0.1009*** (8.58)
Moneyness			-0.1351*** (-7.50)			0.0988*** (3.16)
moneyness_sq			6.7120*** (7.32)			6.5270*** (6.86)
adj_rsq	0.0329*** (7.86)	0.7080*** (65.36)	0.7091*** (65.91)	0.0729*** (8.73)	0.7208*** (63.19)	0.7224*** (63.79)

Table 1.8.B liquidity effects on implied volatility-Options volume short term Put options

This table presents the regression result of equation (1) and equation (8). The dependent variable is implied volatility. The daily cross-sectional regressions are run for each moneyness category and maturity category. And the estimates are averaged over time. T statistics are calculated with the Newy-West Heteroschadectis standard error. To save space, only results for short-term maturity options are reported.

	K/S: [0.9,0.95]			K/S: [0.95,1)		
Intercept	0.3202*** (23.22)	1.2848*** (12.33)	1.3124*** (12.61)	0.3051*** (22.01)	0.9715*** (3.58)	0.9725*** (3.56)
Ovolume	0.0094*** (11.12)	0.0047*** (14.39)	0.0050*** (15.75)	0.0063*** (9.29)	0.0036*** (13.95)	0.0037*** (14.35)
Size		-1.1183*** (-18.52)	-1.1218*** (-18.62)		-1.1095*** (-16.88)	-1.1103*** (-16.89)
lev		-0.0528*** (-3.62)	-0.0534*** (-3.61)		-0.0357** (-2.07)	-0.0353** (-2.02)
Svolume		0.7917*** (15.73)	0.7846*** (15.61)		0.8893*** (11.65)	0.8893*** (11.60)
beta		0.1145*** (9.75)	0.1139*** (9.68)		0.1169*** (10.16)	0.1166*** (10.13)
Moneyness			-0.5580*** (-27.62)			-0.3472*** (-18.29)
moneyness_sq			7.6877*** (8.74)			6.6095*** (7.13)
adj_rsqr	0.0521*** (8.39)	0.7181*** (63.99)	0.7283*** (68.62)	0.0260*** (7.78)	0.7127*** (66.60)	0.7170*** (67.67)

	K/S: (1,1.05)			K/S: [1.05,1.10)		
Intercept	0.2905*** (22.15)	1.2922*** (13.49)	1.2832*** (13.32)	0.2946*** (24.09)	1.3806*** (13.59)	1.3870*** (13.81)
Ovolume	0.0075*** (10.04)	0.0032*** (11.04)	0.0030*** (10.70)	0.0102*** (12.19)	0.0037*** (10.92)	0.0038*** (11.52)
Size		-1.1550*** (-21.02)	-1.1531*** (-20.96)		-1.1665*** (-18.32)	-1.1661*** (-18.29)
lev		-0.0498*** (-3.90)	-0.0495*** (-3.86)		-0.0559*** (-4.70)	-0.0556*** (-4.67)
Svolume		0.8156*** (18.48)	0.8166*** (18.44)		0.7979*** (15.07)	0.7947*** (14.85)
beta		0.1175*** (10.38)	0.1175*** (10.37)		0.1124*** (9.31)	0.1121*** (9.29)
Moneyness			-0.0852*** (-4.79)			0.1078*** (3.55)
moneyness_sq			7.5960*** (8.47)			7.2032*** (6.62)
adj_rsqr	0.0275*** (8.17)	0.7122*** (64.43)	0.7134*** (64.90)	0.0445*** (9.43)	0.6912*** (49.04)	0.6931*** (50.28)

Table 1.9.A liquidity effects on implied volatility-Open Interest short term Call options

This table presents the regression result of equation (1) and equation (8). The dependent variable is implied volatility. The daily cross-sectional regressions are run for each moneyness category and maturity category. And the estimates are averaged over time. T statistics are calculated with the Newey-West Heteroschadectis standard error. To save space, only results for short-term maturity options are reported.

	K/S: [0.9,0.95)			K/S: [0.95,1)		
Intercept	0.3320*** (23.35)	0.9404*** (10.93)	0.9615*** (11.36)	0.3227*** (20.28)	0.8882*** (8.49)	0.9048*** (8.71)
OI	0.0034*** (6.10)	-0.0008** (-2.32)	-0.0005 (-1.54)	0.0010 (1.16)	-0.0016*** (-3.83)	-0.0013*** (-3.25)
Size		-1.0489*** (-16.31)	-1.0507*** (-16.46)		-1.0915*** (-17.53)	-1.0942*** (-17.64)
lev		-0.0493*** (-4.18)	-0.0493*** (-4.17)		-0.0481*** (-4.02)	-0.0479*** (-4.00)
Svolume		0.8504*** (14.97)	0.8438*** (14.88)		0.9095*** (17.28)	0.9053*** (17.23)
beta		0.1181*** (9.96)	0.1178*** (9.93)		0.1175*** (10.43)	0.1173*** (10.41)
Moneyness			-0.4088*** (-15.78)			-0.2986*** (-15.44)
Moneyness_sq			6.6124*** (6.03)			7.2023*** (6.43)
adj_rsqr	0.0133*** (7.56)	0.6688*** (49.69)	0.6751*** (52.22)	0.0150*** (6.21)	0.6954*** (63.35)	0.6985*** (64.12)

	K/S: (1,1.05)			K/S: [1.05,1.10)		
Intercept	0.3114*** (17.17)	0.9515*** (7.85)	0.9533*** (7.86)	0.2866*** (16.01)	-0.2951 (-0.20)	-0.3639 (-0.23)
OI	0.0008 (0.72)	-0.0008 (-1.32)	-0.0007 (-1.25)	0.0045*** (4.24)	0.0024*** (5.35)	0.0025*** (5.40)
Size		-1.1797*** (-18.01)	-1.1811*** (-17.93)		-0.9704*** (-3.32)	-0.9564*** (-3.13)
lev		-0.0437*** (-3.09)	-0.0444*** (-3.20)		0.0036 (0.06)	0.0068 (0.11)
Svolume		0.9790*** (13.75)	0.9790*** (13.60)		1.2063*** (4.69)	1.2164*** (4.53)
beta		0.0959*** (4.62)	0.0964*** (4.76)		0.1039*** (8.87)	0.1037*** (8.84)
Moneyness			-0.1282*** (-8.46)			0.0384 (1.41)
Moneyness_sq			6.6376*** (7.10)			7.2556*** (7.45)
adj_rsqr	0.0164*** (4.35)	0.7054*** (63.05)	0.7065*** (63.56)	0.0269*** (6.33)	0.7145*** (59.73)	0.7156*** (60.14)

Table 1.9.B liquidity effects on implied volatility-Open Interest short term Put options

This table presents the regression result of equation (1) and equation (8). The dependent variable is implied volatility. The daily cross-sectional regressions are run for each moneyness category and maturity category. And the estimates are averaged over time. T statistics are calculated with the Newy-West Heteroschadectis standard error. To save space, only results for short-term maturity options are reported.

	K/S: [0.9,0.95)			K/S: [0.95,1)		
Intercept	0.3311*** (21.52)	1.2226*** (11.51)	1.2391*** (11.65)	0.3102*** (21.43)	0.8945*** (3.06)	0.8889*** (3.02)
OI	0.0043*** (4.52)	0.0031*** (9.62)	0.0032*** (10.20)	0.0035*** (4.10)	0.0028*** (8.62)	0.0027*** (8.37)
Size		-1.1198*** (-18.56)	-1.1223*** (-18.64)		-1.1016*** (-16.16)	-1.1012*** (-16.14)
lev		-0.0546*** (-3.71)	-0.0551*** (-3.70)		-0.0358** (-2.02)	-0.0353* (-1.97)
Svolume		0.8150*** (16.03)	0.8109*** (15.95)		0.9079*** (11.41)	0.9095*** (11.39)
beta		0.1167*** (9.87)	0.1162*** (9.82)		0.1179*** (10.24)	0.1177*** (10.22)
Moneyness			-0.5162*** (-26.97)			-0.3325*** (-18.49)
Moneyness_sq			8.3719*** (8.71)			6.5986*** (7.04)
adj_rsq	0.0206*** (6.90)	0.7134*** (60.19)	0.7224*** (63.60)	0.0156*** (6.70)	0.7110*** (64.78)	0.7149*** (65.62)

	K/S: (1,1.05)			K/S: [1.05,1.10)		
Intercept	0.2848*** (21.23)	1.2769*** (12.99)	1.2694*** (12.87)	0.2824*** (22.48)	1.3828*** (13.11)	1.3881*** (13.29)
OI	0.0056*** (6.82)	0.0030*** (8.64)	0.0029*** (8.44)	0.0077*** (9.70)	0.0035*** (9.29)	0.0036*** (9.74)
Size		-1.1542*** (-20.86)	-1.1529*** (-20.82)		-1.1652*** (-18.02)	-1.1649*** (-17.99)
lev		-0.0508*** (-3.92)	-0.0506*** (-3.89)		-0.0587*** (-4.93)	-0.0585*** (-4.91)
Svolume		0.8176*** (18.71)	0.8187*** (18.71)		0.7918*** (15.19)	0.7890*** (15.00)
beta		0.1185*** (10.51)	0.1184*** (10.50)		0.1142*** (9.41)	0.1140*** (9.40)
Moneyness			-0.1100*** (-5.88)			0.0890*** (2.88)
Moneyness_sq			7.8755*** (8.87)			7.5958*** (7.00)
adj_rsq	0.0223*** (6.88)	0.7120*** (63.21)	0.7134*** (63.72)	0.0377*** (9.30)	0.6923*** (48.43)	0.6940*** (49.46)

Table 1.10.A liquidity effects on EIV-percentage Spread-Call Options

This table presents the regression result of equation (1) and equation (8). The dependent variable is EIV. The daily cross-sectional regressions are run for each moneyness category and maturity category. And the estimates are averaged over time. T statistics are calculated with the Newy-West Heteroschadectis standard error. To save space, only results for short-term maturity options are reported.

	K/S: [0.9,0.95)			K/S: [0.95,1)		
Intercept	0.0337*** (8.70)	-0.1369* (-1.74)	-0.1359* (-1.73)	0.0115*** (2.80)	0.1157* (1.89)	0.1122* (1.83)
pspread	-0.3334*** (-8.40)	-0.2239*** (-6.80)	-0.1825*** (-5.26)	-0.1551*** (-4.15)	-0.1837*** (-5.50)	-0.1593*** (-4.61)
size		0.1590*** (4.79)	0.1657*** (5.02)		0.0430 (1.59)	0.0472* (1.75)
lev		-0.0020 (-0.17)	-0.0028 (-0.25)		-0.0077 (-0.69)	-0.0079 (-0.72)
svolume		-0.0980*** (-2.99)	-0.1063*** (-3.22)		-0.0742** (-2.53)	-0.0780*** (-2.66)
beta		-0.0197*** (-3.17)	-0.0194*** (-3.09)		-0.0207*** (-3.54)	-0.0204*** (-3.49)
moneyness			-0.3635*** (-11.88)			-0.2140*** (-8.40)
moneyness_sq			3.7731** (2.29)			2.7237** (2.28)
adj_rsq	0.0178*** (4.97)	0.1079*** (10.70)	0.1163*** (11.40)	0.0187*** (3.00)	0.0978*** (8.36)	0.1021*** (8.69)

	K/S: (1,1.05)			K/S: [1.05,1.10)		
Intercept	-0.0022 (-0.50)	0.3692** (2.58)	0.3691** (2.59)	-0.0119** (-2.58)	-1.6137 (-0.90)	-1.6882 (-0.90)
pspread	-0.0786*** (-3.21)	-0.1037*** (-10.17)	-0.1028*** (-10.28)	-0.0220*** (-2.71)	-0.0514*** (-5.86)	-0.0525*** (-6.19)
size		0.1782 (1.17)	0.1749 (1.17)		0.3714 (1.03)	0.3851 (1.03)
lev		-0.0347 (-1.20)	-0.0357 (-1.20)		0.0350 (0.66)	0.0387 (0.70)
svolume		-0.3044 (-1.56)	-0.3015 (-1.57)		0.2160 (0.75)	0.2291 (0.76)
beta		-0.0299 (-1.53)	-0.0287 (-1.52)		-0.0337*** (-5.20)	-0.0342*** (-5.29)
moneyness			-0.0067 (-0.25)			0.0871*** (3.13)
moneyness_sq			2.2190 (1.52)			3.1003** (2.19)
adj_rsq	0.0200*** (2.78)	0.1243*** (6.03)	0.1263*** (6.13)	0.0153*** (3.24)	0.1361*** (7.28)	0.1389*** (7.52)

Table 1.10.B liquidity effects on EIV-percentage Spread-Put Options

This table presents the regression result of equation (1) and equation (8). The dependent variable is EIV. The daily cross-sectional regressions are run for each moneyness category and maturity category. And the estimates are averaged over time. T statistics are calculated with the Newy-West Heteroschadectis standard error. To save space, only results for short-term maturity options are reported.

	K/S: [0.9,0.95)			K/S: [0.95,1)		
Intercept	0.0274*** (6.79)	0.5544 (1.09)	0.5739 (1.12)	0.0102*** (2.61)	0.1066 (1.02)	0.1224 (1.16)
pspread	-0.0130 (-0.95)	-0.0266*** (-3.48)	-0.0416*** (-5.03)	-0.0214 (-1.14)	-0.0586*** (-5.00)	-0.0851*** (-7.47)
size		0.0659 (0.82)	0.0608 (0.75)		0.0861*** (2.70)	0.0746** (2.40)
lev		-0.0563 (-1.09)	-0.0559 (-1.07)		-0.0110 (-0.72)	-0.0103 (-0.66)
svolume		-0.2527** (-2.31)	-0.2530** (-2.31)		-0.1161*** (-3.39)	-0.1085*** (-3.11)
beta		-0.0178*** (-2.64)	-0.0200*** (-2.93)		-0.0197*** (-3.41)	-0.0212*** (-3.68)
moneyness			-0.5515*** (-24.07)			-0.4139*** (-16.96)
moneyness_sq			5.1557*** (3.32)			1.9412 (1.57)
adj_rsq	0.0132** (2.47)	0.1261*** (5.83)	0.1428*** (6.67)	0.0130** (2.45)	0.1039*** (6.79)	0.1172*** (7.27)

	K/S: (1,1.05)			K/S: [1.05,1.10)		
Intercept	0.0004 (0.09)	0.2616*** (3.81)	0.2650*** (3.84)	-0.0089* (-1.86)	0.0943 (1.08)	0.0949 (1.08)
pspread	-0.1445*** (-3.19)	-0.1792*** (-4.19)	-0.2005*** (-4.64)	-0.0955*** (-2.69)	-0.1165*** (-3.19)	-0.1174*** (-3.19)
size		0.0248 (0.80)	0.0199 (0.63)		0.0423 (1.19)	0.0411 (1.15)
lev		-0.0143 (-1.21)	-0.0137 (-1.16)		-0.0018 (-0.17)	-0.0019 (-0.18)
svolume		-0.1123*** (-3.66)	-0.1081*** (-3.52)		-0.0714** (-2.33)	-0.0703** (-2.32)
beta		-0.0198*** (-3.40)	-0.0202*** (-3.47)		-0.0256*** (-4.10)	-0.0259*** (-4.16)
moneyness			-0.2263*** (-9.11)			-0.0204 (-0.57)
moneyness_sq			3.7186*** (2.96)			2.4581 (1.57)
adj_rsq	0.0214** (2.35)	0.1114*** (7.50)	0.1156*** (7.82)	0.0105*** (4.45)	0.1162*** (10.10)	0.1187*** (10.37)

Table 1.11.A liquidity effects on EIV-Volume-Call Options

This table presents the regression result of equation (1) and equation (8). The dependent variable is EIV. The daily cross-sectional regressions are run for each moneyness category and maturity category. And the estimates are averaged over time. T statistics are calculated with the Newy-West Heteroschadectis standard error. To save space, only results for short-term maturity options are reported.

	K/S: [0.9,0.95)			K/S: [0.95,1)		
Intercept	0.0270*** (7.18)	-0.2985*** (-3.75)	-0.2669*** (-3.37)	0.0123*** (3.89)	-0.0956 (-1.42)	-0.0697 (-1.02)
Ovolume	-0.0022*** (-4.18)	-0.0020*** (-7.01)	-0.0015*** (-5.35)	-0.0021*** (-3.94)	-0.0019*** (-6.27)	-0.0016*** (-5.07)
Size		0.1995*** (6.08)	0.1981*** (6.10)		0.1047*** (3.66)	0.1009*** (3.52)
lev		-0.0071 (-0.65)	-0.0070 (-0.63)		-0.0109 (-1.03)	-0.0107 (-1.01)
Svolume		-0.0837*** (-2.75)	-0.0944*** (-3.09)		-0.0634** (-2.36)	-0.0696** (-2.60)
beta		-0.0168*** (-2.72)	-0.0171*** (-2.76)		-0.0169*** (-2.84)	-0.0171*** (-2.88)
Moneyness			-0.3755*** (-13.96)			-0.2347*** (-11.29)
moneyness_sq			4.1257** (2.51)			2.7620** (2.34)
adj_rsq	0.0109*** (7.71)	0.1012*** (10.00)	0.1100*** (10.83)	0.0123*** (8.19)	0.0895*** (8.47)	0.0944*** (8.97)

	K/S: (1,1.05)			K/S: [1.05,1.10)		
Intercept	-0.0008 (-0.22)	0.2428* (1.74)	0.2435* (1.75)	-0.0119*** (-3.06)	-1.7733 (-0.90)	-1.9103 (-0.91)
Ovolume	-0.0019*** (-3.13)	-0.0010** (-2.57)	-0.0010*** (-2.61)	-0.0009 (-1.33)	0.0007** (1.99)	0.0007** (2.02)
Size		0.2132 (1.40)	0.2104 (1.40)		0.4014 (1.03)	0.4272 (1.03)
lev		-0.0401 (-1.36)	-0.0409 (-1.36)		0.0373 (0.64)	0.0433 (0.68)
Svolume		-0.2982 (-1.54)	-0.2959 (-1.54)		0.2371 (0.75)	0.2600 (0.77)
beta		-0.0244 (-1.28)	-0.0238 (-1.27)		-0.0280*** (-4.61)	-0.0282*** (-4.65)
Moneyness			-0.1287*** (-5.86)			-0.0127 (-0.40)
moneyness_sq			1.2983 (0.86)			3.1368** (2.23)
adj_rsq	0.0131*** (6.20)	0.1130*** (5.38)	0.1151*** (5.49)	0.0148*** (6.57)	0.1280*** (7.32)	0.1301*** (7.54)

Table 1.11.B liquidity effects on EIV-Volume-Put Options

This table presents the regression result of equation (1) and equation (8). The dependent variable is EIV. The daily cross-sectional regressions are run for each moneyness category and maturity category. And the estimates are averaged over time. T statistics are calculated with the Newy-West Heteroschadectis standard error. To save space, only results for short-term maturity options are reported.

	K/S: [0.9,0.95)			K/S: [0.95,1)		
Intercept	0.0227*** (5.63)	0.5838 (1.17)	0.6092 (1.22)	0.0083*** (2.75)	0.1326 (1.29)	0.1358 (1.30)
Ovolume	0.0006 (1.22)	0.0013*** (3.58)	0.0016*** (4.60)	-0.0002 (-0.42)	0.0011*** (3.11)	0.0012*** (3.31)
Size		0.0704 (0.90)	0.0670 (0.85)		0.0963*** (2.93)	0.0942*** (2.86)
lev		-0.0565 (-1.10)	-0.0569 (-1.10)		-0.0143 (-0.91)	-0.0144 (-0.90)
Svolume		-0.2722** (-2.53)	-0.2785** (-2.58)		-0.1410*** (-4.29)	-0.1402*** (-4.24)
beta		-0.0161** (-2.43)	-0.0166** (-2.49)		-0.0174*** (-2.94)	-0.0175*** (-2.96)
Moneyness			-0.4998*** (-22.64)			-0.3207*** (-13.00)
moneyness_sq			5.2502*** (3.31)			2.1286* (1.73)
adj_rsq	0.0095*** (6.62)	0.1259*** (5.86)	0.1408*** (6.62)	0.0071*** (7.06)	0.1008*** (6.63)	0.1098*** (6.96)

	K/S: (1,1.05)			K/S: [1.05,1.10)		
Intercept	-0.0045 (-1.52)	0.2054*** (2.71)	0.1916** (2.53)	-0.0112*** (-3.18)	0.1099 (1.25)	0.1120 (1.28)
Ovolume	-0.0008* (-1.86)	0.0011*** (3.04)	0.0009** (2.43)	-0.0005 (-1.01)	0.0017*** (4.82)	0.0017*** (5.04)
Size		0.0753** (2.55)	0.0773** (2.59)		0.0608* (1.90)	0.0601* (1.87)
lev		-0.0182 (-1.48)	-0.0178 (-1.46)		-0.0043 (-0.41)	-0.0043 (-0.41)
Svolume		-0.1513*** (-5.30)	-0.1484*** (-5.20)		-0.1011*** (-3.34)	-0.1011*** (-3.38)
beta		-0.0167*** (-2.87)	-0.0167*** (-2.86)		-0.0244*** (-3.93)	-0.0247*** (-4.00)
Moneyness			-0.1467*** (-5.52)			0.0301 (0.84)
moneyness_sq			3.9501*** (3.12)			2.2912 (1.47)
adj_rsq	0.0081*** (7.80)	0.1007*** (7.99)	0.1032*** (8.22)	0.0083*** (7.00)	0.1135*** (9.68)	0.1164*** (9.97)

Table 1.12.A: liquidity effects on EIV-Open interest-call options

This table presents the regression result of equation (1) and equation (8). The dependent variable is EIV. The daily cross-sectional regressions are run for each moneyness category and maturity category. And the estimates are averaged over time. T statistics are calculated with the Newy-West Heteroschadectis standard error. To save space, only results for short-term maturity options are reported.

	K/S: [0.9,0.95)			K/S: [0.95,1)		
Intercept	0.0331*** (5.88)	-0.3110*** (-4.27)	-0.2891*** (-3.99)	0.0169*** (3.41)	-0.0751 (-1.17)	-0.0607 (-0.94)
OI	-0.0022*** (-3.01)	-0.0024*** (-4.38)	-0.0021*** (-3.91)	-0.0019*** (-2.82)	-0.0020*** (-3.36)	-0.0018*** (-3.03)
Size		0.2094*** (6.32)	0.2079*** (6.32)		0.1081*** (3.88)	0.1054*** (3.78)
lev		-0.0073 (-0.65)	-0.0073 (-0.65)		-0.0124 (-1.16)	-0.0123 (-1.15)
Svolume		-0.0864*** (-2.81)	-0.0935*** (-3.04)		-0.0723** (-2.59)	-0.0754*** (-2.70)
beta		-0.0171*** (-2.89)	-0.0173*** (-2.90)		-0.0174*** (-2.99)	-0.0175*** (-3.01)
Moneyness			-0.3755*** (-14.66)			-0.2471*** (-11.85)
Moneyness_sq			3.7716** (2.31)			2.7267** (2.36)
adj_rsq	0.0099*** (5.82)	0.1033*** (9.89)	0.1122*** (10.73)	0.0098*** (7.07)	0.0901*** (8.19)	0.0955*** (8.78)

	K/S: (1,1.05)			K/S: [1.05,1.10)		
Intercept	-0.0002 (-0.03)	0.2736** (2.01)	0.2757** (2.03)	-0.0216*** (-3.19)	-1.6711 (-0.87)	-1.8011 (-0.88)
OI	-0.0014* (-1.70)	-0.0008 (-1.42)	-0.0008 (-1.38)	0.0007 (0.84)	0.0024*** (3.94)	0.0024*** (4.04)
Size		0.2117 (1.38)	0.2085 (1.38)		0.3764 (1.00)	0.4004 (1.00)
lev		-0.0402 (-1.39)	-0.0412 (-1.39)		0.0314 (0.57)	0.0370 (0.61)
Svolume		-0.3074 (-1.58)	-0.3051 (-1.59)		0.2201 (0.70)	0.2424 (0.72)
beta		-0.0255 (-1.30)	-0.0249 (-1.30)		-0.0268*** (-4.42)	-0.0269*** (-4.45)
Moneyness			-0.1232*** (-5.77)			-0.0105 (-0.36)
Moneyness_sq			1.3158 (0.86)			3.3424** (2.34)
adj_rsq	0.0133*** (6.14)	0.1141*** (5.46)	0.1162*** (5.56)	0.0126*** (5.37)	0.1306*** (7.27)	0.1326*** (7.45)

Table 1.12.B: liquidity effects on EIV-Open interest-put options

This table presents the regression result of equation (1) and equation (8). The dependent variable is EIV. The daily cross-sectional regressions are run for each moneyness category and maturity category. And the estimates are averaged over time. T statistics are calculated with the Newy-West Heteroschadectis standard error. To save space, only results for short-term maturity options are reported.

	K/S: [0.9,0.95)			K/S: [0.95,1)		
Intercept	0.0127** (2.28)	0.6147 (1.24)	0.6310 (1.27)	-0.0048 (-0.93)	0.1896 (1.64)	0.1854 (1.58)
OI	0.0018*** (3.50)	0.0023*** (5.76)	0.0025*** (6.24)	0.0017*** (3.01)	0.0031*** (7.97)	0.0030*** (7.63)
Size		0.0631 (0.81)	0.0606 (0.77)		0.0875** (2.53)	0.0867** (2.51)
lev		-0.0580 (-1.13)	-0.0584 (-1.13)		-0.0156 (-1.02)	-0.0156 (-1.01)
Svolume		-0.2799*** (-2.62)	-0.2837*** (-2.66)		-0.1591*** (-4.77)	-0.1566*** (-4.66)
beta		-0.0155** (-2.34)	-0.0158** (-2.38)		-0.0168*** (-2.86)	-0.0168*** (-2.88)
Moneyness			-0.4893*** (-21.80)			-0.3128*** (-12.45)
Moneyness_sq			5.5963*** (3.52)			2.4172* (1.92)
adj_rsq	0.0101*** (5.52)	0.1267*** (5.92)	0.1412*** (6.66)	0.0080*** (5.10)	0.1038*** (6.82)	0.1125*** (7.13)

	K/S: (1,1.05)			K/S: [1.05,1.10)		
Intercept	-0.0142*** (-3.41)	0.2740*** (3.74)	0.2655*** (3.63)	-0.0205*** (-4.49)	0.1618* (1.79)	0.1656* (1.83)
OI	0.0009** (2.14)	0.0030*** (6.98)	0.0029*** (6.60)	0.0011*** (3.41)	0.0030*** (7.25)	0.0031*** (7.54)
Size		0.0692** (2.39)	0.0698** (2.40)		0.0595* (1.88)	0.0589* (1.85)
lev		-0.0200 (-1.65)	-0.0197 (-1.62)		-0.0073 (-0.70)	-0.0074 (-0.71)
Svolume		-0.1760*** (-6.19)	-0.1736*** (-6.12)		-0.1238*** (-3.95)	-0.1247*** (-4.02)
beta		-0.0158*** (-2.71)	-0.0159*** (-2.71)		-0.0233*** (-3.71)	-0.0236*** (-3.76)
Moneyness			-0.1295*** (-4.87)			0.0405 (1.12)
Moneyness_sq			4.0274*** (3.11)			2.5035 (1.63)
adj_rsq	0.0097*** (5.76)	0.1056*** (8.27)	0.1081*** (8.47)	0.0081*** (7.53)	0.1180*** (10.03)	0.1211*** (10.34)

Table 1.21 liquidity effects on implied volatility function-index option

This table presents the liquidity effects of index options on the shape of implied volatility function. The dependent variables are the level and absolute slope of the implied volatility functions. Independent variables are option percentage spread, option volume and option open interest. T statistics are reported in the parenthesis.

		level		level		level	
Call	K/S: [0.9,0.95)	Pspread	1.001** (2.13)	Ovolume	0.010*** (2.85)	OI	0.001 (0.15)
		ADJRSQ	0.0225	ADJRSQ	0.0442	ADJRSQ	-0.0064
	K/S: [0.95,1.0)	Pspread	-0.155 (-0.34)	Ovolume	-0.027*** (-3.04)	OI	-0.041*** (-5.68)
		ADJRSQ	-0.0058	ADJRSQ	0.0509	ADJRSQ	0.1687
	K/S: [1.0,1.05)	Pspread	-0.959*** (-8.44)	Ovolume	-0.069*** (-9.46)	OI	-0.085*** (-13.65)
		ADJRSQ	0.3131	ADJRSQ	0.3649	ADJRSQ	0.5460
Put	K/S: [1.05,1.1)	Pspread	-0.238*** (-12.82)	Ovolume	0.020** (2.58)	OI	-0.009 (-0.97)
		ADJRSQ	0.5147	ADJRSQ	0.0356	ADJRSQ	-0.0003
	K/S: [0.9,0.95)	Pspread	-0.560*** (-11.12)	Ovolume	-0.066*** (-5.90)	OI	-0.082*** (-9.49)
		ADJRSQ	0.4432	ADJRSQ	0.1802	ADJRSQ	0.3666
	K/S: [0.95,1.0)	Pspread	-1.475*** (-5.95)	Ovolume	-0.060*** (-7.71)	OI	-0.072*** (-9.49)
		ADJRSQ	0.1825	ADJRSQ	0.2750	ADJRSQ	0.3663
	K/S: [1.0,1.05)	Pspread	-0.701 (-1.58)	Ovolume	-0.023*** (-2.77)	OI	-0.002 (-0.23)
		ADJRSQ	0.0096	ADJRSQ	0.0415	ADJRSQ	-0.0062
	K/S: [1.05,1.1)	Pspread	0.494 (1.38)	Ovolume	0.017*** (7.11)	OI	0.018*** (7.66)
		ADJRSQ	0.0060	ADJRSQ	0.2471	ADJRSQ	0.2762

Table 1.22 liquidity effects on EIV function-index option

This table presents the liquidity effects of index options on the shape of implied volatility function. The dependent variables are the level and absolute slope of the EIV functions. Independent variables are option percentage spread, option volume and option open interest. T statistics are reported in the parenthesis.

		level		level		level	
Call	K/S: [0.9,0.95)	Pspread	-0.741* (-1.68)	Ovolume	0.004 (1.20)	OI	0.009** (2.42)
		ADJRSQ	0.0118	ADJRSQ	0.0029	ADJRSQ	0.0306
	K/S: [0.95,1.0)	Pspread	-1.447*** (-3.84)	Ovolume	0.012 (1.52)	OI	0.012* (1.79)
		ADJRSQ	0.0819	ADJRSQ	0.0084	ADJRSQ	0.0141
	K/S: [1.0,1.05)	Pspread	-0.323*** (-2.75)	Ovolume	-0.001 (-0.15)	OI	0.005 (0.64)
		ADJRSQ	0.0409	ADJRSQ	-0.0064	ADJRSQ	-0.0038
K/S: [1.05,1.1)	Pspread	0.003 (0.12)	Ovolume	-0.015* (-1.95)	OI	-0.007 (-0.80)	
	ADJRSQ	-0.0064	ADJRSQ	0.0179	ADJRSQ	-0.0023	
Put	K/S: [0.9,0.95)	Pspread	-0.149** (-2.50)	Ovolume	-0.001 (-0.07)	OI	-0.003 (-0.28)
		ADJRSQ	0.0331	ADJRSQ	-0.0065	ADJRSQ	-0.0060
	K/S: [0.95,1.0)	Pspread	-0.873*** (-3.87)	Ovolume	-0.003 (-0.42)	OI	-0.004 (-0.54)
		ADJRSQ	0.0830	ADJRSQ	-0.0054	ADJRSQ	-0.0046
	K/S: [1.0,1.05)	Pspread	-0.827** (-2.14)	Ovolume	-0.010 (-1.30)	OI	-0.005 (-0.76)
		ADJRSQ	0.0227	ADJRSQ	0.0044	ADJRSQ	-0.0027
	K/S: [1.05,1.1)	Pspread	-0.438 (-1.03)	Ovolume	-0.010*** (-3.16)	OI	-0.009*** (-2.67)
		ADJRSQ	0.0004	ADJRSQ	0.0560	ADJRSQ	0.0389

2. Risk-Neutral Skewness and stock earnings announcements

2.1. Introduction

The efficient-market theory argues that the information is fully incorporated into the price movement. In an incomplete market, however, the way that the information is incorporated into prices has been a long time discussion among researchers. Moreover, the development of derivatives market arouses further interest on and makes it even more intriguing to understand the way that information flows between derivative market and its underlying assets market. Among issues resulting from the introducing and development of derivative markets, the cross market relationship between stock options market and the underlying stock market become a natural place to test the direction and speed of information flow, due to the leverage effect, low transaction cost and less trading restrictions in options market.

In this paper, by using the risk-neutral skewness and kurtosis of stock return implied from options price movement, together with the model free implied volatility, I test their predictive power upon the information intensive event, quarterly earnings announcements. The result shows that stocks with less negative risk-neutral skewness, and positive change of skewness tend to have higher abnormal return in the earnings announcement event periods. On the other hand, less negative risk-neutral skewness is associated with lower total holding period return right after the earnings announcement.

This paper adds to the literature in several aspects. First, the risk-neutral skewness, which contains the information of the perspective direction of stock movements, is used to test the information role of stock options in predicting stock return during information intensive period. Second, both the abnormal return and holding period return are used to explore the price reaction

to information. Third, by controlling market risk-neutral skewness, and separating idiosyncratic and systematic risk components measured by model free implied volatility, I provide further evidence that investors price their private information about firm-specific news in options market.

The paper is organized as following parts. Literature is introduced in the first part. Data and methodology is described in the second part. The empirical results are presented next, followed by conclusion.

2.2 Literature review

Black(1975) first argued that the informed traders tend to trade in option market. His argument is based on the leverage effect and lower costs, less restrictions in the options market. Since then, there are lots of researchers focus on the linkage of transaction volume, price and information between stock and option markets during normal time or upon information intensive event, to test this argument. The early empirical results are mix. Diamone and Verrecchia(1987) models effects of short sale constraints on the spread of adjustment to private information of security prices. Suggest informed investors prefer to trade in the option market. Vijh(1990) conclude that information trading has only a small influence on the liquidity of the CBOE options and that the information content of option trades does not increase with trade size. Easley, O'Hara and Srinivas (1998) establish a pooling equilibrium in which some particular trades in option market are informative for the future stock price movement. Lee and Yi (2001) argued that the extent of information based trading in the options market decreases with trade size. Cahn Chung and Fong (2002) Suggest informed investments initiated trades in the stock market but not in the option market. Faff and Hillier (2004) argue that the leverage properties of options induce a higher level of informed trading in the aggregate market, resulting in excess listing-day price movements in

the newly optioned equity. Whalen and Collver (2004) find that although informed traders prefer to transact in both markets around earnings announcements, option market transactions contain no incremental information. Cao, Chen and Griffin (2005) examined the relative information content of stock and option volume prior to takeover announcements, the results indicate that option volume is predictive for the future stock return in the preannouncement period but not in the normal days, in which stock volume are more informative to the future return.

One hurdle of using volume, open interest or price is that without details of the transaction, these variables fail to indicate the direction of the market buying or selling pressure, especially in options market. The increase of the trading volume or open interest may result from either buyer or seller initiated. It's not clear if investors trade on their private information. Pan and Poteshman (2006) use unique dataset of trading volume of different option transaction categories, present evidence that option volume contains information about future stock prices. They also find that the predictability comes from the private information possessed by the option trader, the extent of predictability increase by the concentrations of informed traders and the leverage of the option contracts.

More recently, along with the research interests on the stochastic process and higher moments of options prices, the study on information role of options market began to focus on the risk-neutral volatility, skewness and kurtosis implied from the options price movements. Xing, Zhang and Zhao (2008) use the difference in implied volatilities between out-of-the-money put options and at-the-money options to approximate the volatility smirk, and find stocks with steeper smirks underperform stocks with less pronounced smirks. Their result proves Black (1975)'s argument in that investors with negative information tend to trade OTM put options. Cremers and Weinbaum (2010) use the difference in implied volatility between pairs of call and

put options to measure the deviations from put-call parity, find stocks with higher call options volatility outperform stocks with high put options volatility. Ang, Bali and Cakici (2010) test the joint cross-sectional relationship between options and stock market. They find increase of call (put) options predict the rising(falling) return of stocks in the following month, and the stocks with higher return tend to have increasing volatility in call options over the following month. Their result suggests the informed trading occurring in both asset markets.

The use of higher moments implied from options market appeared mainly after Bakshi, Kapadia and Mandan (2003)'s paper about the skewness laws. In the paper they derived the measurement of risk-neutral skewness and kurtosis implied from stock options. Without making specific distribution assumption, the higher moments of stock returns are replicated by integral the options price movement across all strike prices of OTM call and put options.

One advantage of using risk-neutral skewness and kurtosis is that these two measurements incorporate the direction and magnitude of jump risk. And comparing with physical stock return moments, the risk-neutral moments implied by options price reflect the investors' view about the future stock return, which makes it a better way to predict the perspective stock return. These studies provide a new stage on which researchers can test the information role of options market.

2.3 Data and summary statistics

2.3.1 Data

The sample for this paper includes quarterly earnings announcements for all equity stocks and stock options data from 1996 to 2010. Daily stock returns are collected from The Center for Research in Security Prices (CRSP). The stock abnormal return is calculated by the market factor model. CRSP also provides the stock characteristics used in this paper, including market

capitalization, trade volume and leverage ratio. Market variables are derived from S&P 500 index options and the index return.

Stocks' earnings announcements are collected from I/B/E/S, which record detailed earnings announcement history. In this paper, I collect the date, time and actual earnings value of all quarterly earnings announcement during the sample period; the date, time and value of last earnings estimates; and the standard deviation of all the earnings estimates for each announcement.

For each earnings announcement, the actual announcement day is defined as day 0, and then stock returns are collected for the window of (-91, 10) relative to the announcement day. The event period is the window of (0, 1), and the estimate period to determine the abnormal return is the window of (-91,-10). The stock abnormal return for the event period is then estimated by the market model in equation (3) with the data in the estimate period.

$$R_i = \alpha + \beta \times R_{mkt} \quad (1)$$

The abnormal return is calculated by equation (4):

$$AR_i = R_i - \hat{\alpha} - \hat{\beta} \times R_{mkt} \quad (2)$$

The accumulated abnormal return, CAR, is the sum of abnormal return AR for the event period.

Holding period return (HPR thereafter) is also used to the test. HPR is calculated by using the open price on day 0 and closing price on day 1.

Daily options data are collected from Option Metrics. Variables used in the paper are expiration date, best bid and ask quotes and strike price. Dividend distribution history and zero coupon yield curve are also collected to calculate the risk-neutral skewness and kurtosis.

Options' moneyness is defined as k/s , where k is the strike price and s is the stock spot price. Options with implied volatility less and 0.03 or greater than 2, or best bid/ask price less than 0.125, or options with best bid price greater than best ask price are deleted. The purpose of using options data is to test their predictability on the stock return during quarterly earnings announcement event, therefore I only use options with maturity between 10 days and 91 days. In addition, options that expired before the announcement day are eliminated from the analysis.

The key variables in this analysis are the risk neutral moments of stock return, the skewness, kurtosis and volatility. In Black-Scholes Model the stock payoff density functions is assumed to be logarithmic normal. After that, researchers assumed different density functions, such as stochastic process. In BKM (2003)'s paper, they assume that the stock payoffs can be fully replicated by all the OTM call and put options. And then integrated the second, third and fourth moments of the payoffs across all strike prices, therefore without assuming any kind of physical distribution, finding the model free risk-neutral volatility, skewness and kurtosis. Following BKM (2003), the risk-neutral skewness, kurtosis and model free implied volatility are calculated with the out-of-money call and put option. Let $R(t, \tau) \stackrel{\text{def}}{=} \ln \frac{S(t+\tau)}{S(t)}$ denote the τ period stock return. Let $V(t, \tau)$, $W(t, \tau)$ and $X(t, \tau)$ represent the fair value of payoffs $R(t, \tau)^2$, $R(t, \tau)^3$ and $R(t, \tau)^4$ respectively. According to Theorem 1 of BKM (2003), the τ period model free implied volatility, risk-neutral skewness and kurtosis can be expressed as:

$$MFIV(t, \tau) = \sqrt{e^{r\tau} v - \mu^2} \quad (3)$$

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

$$RNkurt(t, \tau) = \frac{e^{r\tau} X(t, \tau) - 4\mu(t, \tau) e^{r\tau} W(t, \tau) + 6e^{r\tau} \mu(t, \tau)^2 V(t, \tau) - 3\mu(t, \tau)^4}{(e^{r\tau} V(t, \tau) - \mu(t, \tau)^2)^2} \quad (5)$$

Where

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

$$V(t, \tau) \equiv \int_{S(t)}^{\infty} \frac{2(1 - \ln \frac{K}{S(t)})}{K^2} C(t, \tau, K) dK + \int_0^{S(t)} \frac{2(1 + \ln \frac{S(t)}{K})}{K^2} P(t, \tau, K) dK \quad (7)$$

$$W(t, \tau) \equiv \int_{S(t)}^{\infty} \frac{6 \ln \frac{K}{S(t)} - 3(\ln \frac{K}{S(t)})^2}{K^2} C(t, \tau, K) dK \\ - \int_0^{S(t)} \frac{6 \ln \frac{S(t)}{K} + 3 \ln \frac{S(t)}{K}^2}{K^2} P(t, \tau, K) dK \quad (8)$$

$$X(t, \tau) \equiv \int_{S(t)}^{\infty} \frac{12(\ln \frac{K}{S(t)})^2 - 4(\ln \frac{K}{S(t)})^3}{K^2} C(t, \tau, K) dK \\ + \int_0^{S(t)} \frac{12(\ln \frac{S(t)}{K})^2 + 4(\ln \frac{S(t)}{K})^3}{K^2} P(t, \tau, K) dK \quad (9)$$

In the above equations, the integrals can be approximated using trapezoidal approximation with options available on each day. The approximation requires at least two call options and two put options for each day and maturity. Option implied skewness, kurtosis and model free implied

volatility (MFIV thereafter) are calculated for each maturity on each day, and then weighted averaged by open interest on a daily basis.

2.3.2 Summary statistics

Initially, there are 213070 quarterly earnings announcements for 11204 tickers in the sample periods. Among them, 64241 announcements, with actual value below the expectation, are classified as negative surprises. While there are 145833 quarterly earnings with actual value equal or above the expectation, are classified as positive surprises. Because options are not actively traded for all stocks on every day, after being merged with options variables, the final sample includes 12873 negative announcements and 40323 positive announcements for 3999 tickers. Summary statistics of CAR and HPR are reported in table 1. On average, the CAR for negative surprise is significantly lower than that of positive surprise by 0.0405. The difference in HPR between negative and positive news is 0.0255.

To test the prediction power of options variables, I use the option variables on day -1 relative to the earnings announcement day, as well as the change of options variables from day -10 to day -1.³The average risk-neutral skewness on day-1, opp_skew1 is -0.7524. Compare with day -10, options implied skewness becomes more negative, which can be seen from the average $skew1_{-10}$ of -0.0014. Correlation coefficient matrix shows that risk-neutral skewness is related with CAR and HPR in different ways. The coefficient of opp_skew1 is positively correlated with CAR. However, the correlation is positive but not significant between opp_skew1 and HPR. While looking at $skew1_{-10}$, the change of skewness is significantly correlated with both CAR

³ I have also tried day -5, day -20 and day -30 but these days' option variables barely has information about the stock accumulated return on the event day.

and HPR. This may suggest that abnormal return and total holding period return are determined by different risk characteristics.

2.4 Preliminary analysis

The first step of analyzing the relationship between options variable and earnings announcement return is using the percentile analysis to sort the options variable into 10 groups, and then calculate the average CAR and HPR for each of the percentile group. This sorting analysis is conducted for risk-neutral skewness on day -1 as well as the change of skewness from day -10 to day -1. The result is reported in table 2. When sorting by opp_skew1, CAR increases from -0.0017 of the lowest percentile to 0.0071 of the highest percentile. The difference is significant at 1% significant level. HPR, on the other hand, does not show significant pattern across the skewness percentile. The sorting result of skew1_10 has similar pattern for CAR, with a -0.0015 CAR for the lowest percentile and 0.0038 for the highest percentile. Unlike the sorting result according to opp_skew1, when sorting by change of skewness, HPR shows increasing pattern along with the change of skewness. The sorting result is consistent with the correlation matrix analysis. Both the level and change of risk-neutral skewness is positively associated with the abnormal return right after earnings announcement. This suggests that less negative risk-neutral skewness may be used to predict higher abnormal rate of return. Why does the level of skewness fail to predict holding period return, is left to be explained using further regression analysis.

2.5 Regression analysis

Based on Fisher Black's argument that investors trade their information in options market, if investors have information about the positive or negative news of earnings announcement, they

would use options market to earn profit from betting stock price movement correctly. We expect that the risk-neutral skewness will give information about the direction of the stock price movement. The basic model in testing the hypothesis would be a regression of stock returns right after announcement on the risk-neutral skewness. Besides skewness, risk-neutral skewness is closely related with the kurtosis and implied volatility derived from options data. Therefore in the regression model I also control the activity of these two variables. The regression model is listed below:

$$CAR_{it} = \beta_0 + \beta_1 Opp_skew1_{it} + \beta_2 opp_kurt1_{it} + \beta_3 mfiv1_{it} \quad (10)$$

$$CAR_{it} = \beta_0 + \beta_1 skew1_10_{it} + \beta_2 kurt1_10_{it} + \beta_3 mfiv1_10_{it} \quad (11)$$

In equation (11), the lower subscriber i stands for the month of the actual announcement, t stands for stocks. Two dependent variables, CAR and HPR are both used for the regression. Fama-Macbeth regression is used to test the predictive power of option skewness on the abnormal return and holding period return. Earnings announcements in same month are grouped together. The regression includes two steps. First, cross-sectional regression for each month is used, in which there must be at least 10 observations in a month. The estimated coefficients are then averaged over 180 months, and the Newy-West heteroskedastic standard error is calculated.

The regression result is presented in table 3. For abnormal return CAR, the level of optionsskewness is significant positive associated with the abnormal return, even after control kurtosis and mfiv. The more negative the risk-neutral skewness is, the less is the abnormal stock return over the event period. Suppose investors have negative news about earnings announcement and predict that stock price will fall, their trading strategy in the options market

would be buying OTM put options (or selling OTM call options), and therefore one would observe more negative risk-neutral skewness in options market before negative earnings surprise.

Things are very different for the holding period return. Option skewness plays a negative role in predicting the holding period return for the event period. However, the negative impact becomes not significant after controlling kurtosis and MFIV. Risk-neutral skewness seems explain unexpected return better than total return. This result sheds light on the hypothesis that the predictive power of options skewness comes from the private information owned by investors.

Positive change of option skewness, skew1_10, increase abnormal rate of return, which confirm the result with level of the skewness. I went further to include both the level and change of options variable into the regression and receive consistent result with the results of regressing on level and change variables separately. It is worth to note that, once controlling the level of option variables, the change of skewness plays no important role on explaining abnormal return. All the explanation power is contributed by the level of variables on day-1. In addition, skew1_10 is positively associated with holding period rate of return HPR. When adding both the level and change of skewness variables into the regression, level effect again plays negative role, along with the positive role of change of skewness. Both two types of skewness variables are significant. It is no surprise that the level effect is more important for abnormal return, because level largely explain the cross-sectional difference among different announcements. The change of skewness across time, besides cross-sectional difference, may also result from market factor change overtime. Therefore it can explain the total return better.

The coefficients of kurtosis are negative for both two dependent variables, CAR and HPR, although not significant for the former. The coefficients for MFIV are significantly negative. Stocks with high implied volatility tend to have lower abnormal return during the event period.

2.6. Idiosyncratic or systematic risk

Based on the result in table 3, it is natural to think if it is the idiosyncratic or the systematic risk component indicated by the risk-neutral skewness that predicts the return in stock market. It is of particular interest in determining cross-sectional difference of return during the earnings announcement periods. One can expect that investors' private information in this informative period is more likely to be firm-specific information than market condition change.

Two approaches are used to test the hypothesis that it is the firm-specific information that has predictive power in stock returns. In the first approach, I control the same set of variables for market. Particularly, the market risk-neutral skewness, kurtosis and MFIV are derived from options on S&P 500 index. These variables are then used to approximate the information about market condition reflected by options trading. The idea is to see if these variables for individual stock options are still significant after controlling market variables.

In the second approach, MFIV, which measures the total implied risk, is decomposed into idiosyncratic risk component and systematic risk component according to market factor model.

Table 4 reports the regression after controlling market risk-neutral skewness, kurtosis and MFIV. For abnormal return, when regression on the level of variables and the change of variables separately, individual option skewness remains its significant positive impact on CAR, even after controlling market variables. Neither level nor changes of market variables show any significant impact. Once combining level and change together, options variable lose its

explanation power to market variables. However, the combined regression may suffer from multicollinearity problem.

When considering holding period return, neither level nor change of individual option skewness has significant impact separately. Once included in the regression together, change of individual option skewness and index skewness both show positive influence on the total return, along with the positive influences of market kurtosis and MFIV. Again, multicollinearity might be a problem of the combined regression.

In summary, the results indicate that it is the individual option skewness, not the market skewness, which mainly explains the cross-sectional difference in abnormal return. Change of option skewness, instead of the level, is useful to explain the total holding period rate of return, along with market variables. It makes sense that market variables only influence the total return, not abnormal return.

The second approach focus on the two separate risk components in MFIV. Dennis, Mayhew and Stivers (2006) decompose total risk of stock return according to the market factor model, and use the estimated beta coefficient to calculate the idiosyncratic risk. There formula is as below:

$$IV_{i,t}^{2,idio} = IV_{i,t}^2 - \beta^2 VIX_t^2 \quad (12)$$

In this specification, $IV_{i,t}^{2,idio}$ is the idiosyncratic risk for stock I at time t, $IV_{i,t}^2$ is the total risk of stock I at time t, and VIX_t^2 stands for the market risk. Duan and Wei (2009) derive the relationship between stock options risk-neutral skewness and market risk-neutral skewness with the following formula:

$$skew_{i,t} = \beta^{3/2} skew_m \quad (13)$$

Following their work, I generate the idiosyncratic risk by equation (12) with the β deriving from equation (13), in which $skew_m$ is the risk-neutral skewness of S&P 500 index options. The systematic risk is calculated following the same idea:

$$MFIV_{i,t}^{idio} = \sqrt{MFIV_{i,t}^2 - \beta^2 INDEX_MFIV_t^2} \quad (14)$$

$$MFIV_{i,t}^{sys} = \beta \times INDEX_MFIV_t^2 \quad (15)$$

The following regression is run to decompose the effect of idiosyncratic risk and systematic risk on the CAR/HPR.

$$CAR_{i,t} = \gamma_0 + \gamma_1 Opp_skew + \gamma_2 opp_kurt_{i,t} + \gamma_3 MFIV_{i,t}^{idio} + \gamma_4 MFIV_{i,t}^{sys} \quad (16)$$

The effect of risk-neutral skewness remains the same. Among the two risk factors, idiosyncratic risk plays more important role in determining both the abnormal and holding period return. While systematic risk does not. Dennis, Mayhew and Stivers (2006) find in their paper that stock return is largely determined by systematic risk components, instead of idiosyncratic risk components. Their result is derived with normal period without informative event. During event period, such as earnings announcements, it is reasonable to expect that firm-specific risk contains more information about stock return.

The controlling of market risk-neutral skewness variable, together with the impact of idiosyncratic risk components provides further evidence that investors price their private information in options market.

2.7 Directions of Earnings announcement

Will investors behave differently upon positive or negative information? Does risk-neutral skewness contain more information about negative news? These questions are addressed by including a dummy variable into the regression analysis. Variable Positive has a value 1 if the actual earnings announcement beats the expectations. The interactions between options variables and Positive are also included, in order to see if there is additional predictive power for positive (negative) news.

Table 6 presents the regression result. Risk-neutral skewness remains its important power in prediction abnormal returns given direction of information. The interactions, has a significant positive impact. The predictive power of options skewness is significantly higher for positive news than negative news. Interactions with other variables are not significant. In terms of change of option variables; interactions have no significant predicting power.

The results show that investors are more likely to trade their positive information in options market. There are two possible explanations for these results. First, as many research⁴ argued, call options dominate the individual stock options market. Therefore positive information is more easily to be traded in options market. Second, short selling provides another way for investors to trade their negative information with leverage advantage. Short sale strategy is often accompanied by a call option buying as a protection. This makes the options behavior before negative earnings announcement not easily to be identified, therefore is not very useful.

² For example, Bollen and Whaley (2004), Does net buying pressure affect the shape of Implied Volatility Functions? The Journal of Finance, VolLix, N0.2, April 2004

2.8 Concluding Remarks

The information flow is one of the key factors that determine the market price fluctuation. In this paper, I use risk-neutral risk variables derived in options market, test how the private information is incorporated into stock returns. The conclusion is clear that informed investors trade their private information in options market upon earnings announcements. The less negative risk-neutral skewness right before announcement day is useful to predict the higher abnormal stock returns. Further evidence of private information trading in options market are provided by the test on market options variables, as well as the decomposition of idiosyncratic risk and systematic risk. Unlike normal period, in which stock returns are more related with market risk factor, before informative event, it is the idiosyncratic risk that contains more information about abnormal stock returns. In addition, options market is more informative before positive earnings announcement.

Earnings announcement is a scheduled event. It will be more persuasive if the same results appeared before an unscheduled event. There are studies focusing on takeover event. However, both earnings announcement and takeover event have long forecasting period and the information is more likely to be known by public. Further research can be extended into unscheduled events that unlikely to release information before public noticing. Such kind of events includes the appearance of financial distress, credit default, filing bankruptcy, or unexpected dividend change.

Another potential extension is to study the index options. A lots of research study on how to forecast the Macro economy trend, such as interest rate, inflation rate, or business cycle. The characteristics of index options may contain information about the market event, such as financial crisis, market crash, and turning points of economy.

Table 2.1. Abnormal and holding period return around earnings announcement

This table summarize the statistics for stock abnormal return CAR and holding period return HPR during event day (0,1) Risk-neutral variables derived from options data are skewness, kurtosis and model free implied volatility on day -1 and the change from day -10 to day -1.

CAR	n	mean	std	Std Err	t value	pr> t
negative	12873	-0.0300	0.0925	0.0008	-37.5000	<0.0001
positive	40323	0.0106	0.0863	0.0004	26.5000	<0.0001
Difference		-0.0405	0.0878	0.0009	-43.9700	<0.0001

HPR	n	mean	std	Std Err	t value	pr> t
negative	12858	-0.0196	0.0882	0.0008	-24.5000	<0.0001
positive	40288	0.0060	0.0840	0.0004	14.9500	<0.0001
Difference		-0.0255	0.0850	0.0009	-28.9000	<0.0001

Table 2.2. Simple Statistics for main variables

variable	n	mean	Std Deviation	t value	pr> t
CAR	53196	0.0001	0.0895	1.9305	0.0535
HPR	53146	-0.0002	0.0857	-0.5298	0.5963
Opp_skew1	53215	-0.7524	0.7049	-242.7907	<0.0001
skew1_10	40443	-0.0014	0.6432	-0.4528	0.6507

Table 2.3. Correlation Coefficient			
	car	hpr	opp_skew1
hpr	0.8696		
	<.0001		
opp_skew1	0.0183	-0.0048	
	0.0002	0.3391	
skew1_10	0.0120	0.0111	0.5029
	0.0156	0.0254	<.0001

Table 2.4 percentile sorting by Opp_skew1

q	1	2	3	4	5	6
opp_skew1	-1.931	-1.386	-1.149	-0.968	-0.815	-0.673
car	-0.002	0.002	-0.002	0.001	-0.002	-0.001
HPR	0.001	0.002	-0.002	0	-0.001	-0.002
Size	22.244	22.021	21.93	21.898	21.858	21.704
BM	0.401	0.393	0.377	0.383	0.373	0.371

q	7	8	9	10	q1-q10	pr>t
opp_skew1	-0.528	-0.363	-0.144	0.433		
					-2.364	<0.0001
car	0.001	0.002	0.001	0.007	-0.009	<0.0001
HPR	-0.001	0.001	-0.001	0	0.001	0.771
Size	21.704	21.549	21.46	21.376	0.867	<0.0001
BM	0.356	0.355	0.344	0.323	0.078	<0.0001

Table 2.5 Percentile Sorting by Opp_skew1_10

q	1	2	3	4	5	6
skew1_10	-1.132	-0.577	-0.356	-0.2	-0.066	0.062
car	-0.002	0.003	-0.001	-0.001	0.002	0.002
HPR	-0.002	0.002	-0.003	-0.003	0.001	0.001
Size	21.789	21.815	21.954	21.973	22.003	21.983
BM	0.351	0.356	0.358	0.358	0.351	0.364

q	7	8	9	10	q1-q10	pr>t
skew1_10	0.197	0.355	0.572	1.131	-2.263	<0.0001
car	0.001	-0.001	0.002	0.004	-0.005	0.012
HPR	0	0	0	0.003	-0.005	0.027
Size	22.026	21.987	21.91	21.895	-0.106	0.007
BM	0.358	0.357	0.347	0.335	0.016	0.005

Table 2.6. Regression Analysis

This table presents the result of regression analysis. The regression is run by cross-sectionally for each month, and then the coefficients are averaged over 180 months. Newy-West heteroskedastic standard error is calculated.

Depvar: CAR						
intercept	0.002 (1.90)	0.013** (4.25)	0.001 (1.26)	0.001 (1.48)	0.003* (2.04)	0.018** (3.29)
opp_skew1	0.003* (2.45)	0.003* (2.38)			0.003* (2.52)	0.005* (2.32)
opp_kurt1		-0.000 (-0.78)				-0.000 (-0.58)
mfiv1		-0.051** (-4.12)				-0.070** (-3.27)
skew1_10			0.002* (2.47)	0.003* (2.43)	0.001 (0.73)	0.001 (0.58)
opp_kurt1_10				0.000 (0.19)		0.001 (1.16)
mfiv1_10				0.031 (1.80)		0.078** (2.86)
adjrsq	0.012	0.037	0.010	0.035	0.022	0.074
Depvar: HPR						
intercept	-0.003* (-2.09)	0.010** (3.75)	-0.000 (-0.57)	-0.000 (-0.09)	-0.004* (-2.56)	0.015** (2.91)
opp_skew1	-0.002* (-2.17)	-0.002 (-1.84)			-0.004** (-2.67)	-0.005* (-2.16)
opp_kurt1		-0.001* (-2.23)				-0.001* (-2.01)
mfiv1		-0.058** (-4.96)				-0.074** (-3.83)
skew1_10			0.002* (2.17)	0.002 (1.85)	0.005** (3.66)	0.006** (3.30)
opp_kurt1_10				-0.000 (-0.21)		0.001* (2.03)
mfiv1_10				0.035* (2.06)		0.089** (3.27)
adjrsq	0.012032	0.03975	0.009141	0.035936	0.021859	0.078896

Table 2.7 the impact of market variables on CAR

This table presents the result of regression analysis. The regression is run by cross-sectionally for each month, and then the coefficients are averaged over 180 months. Newy-West heteroskedastic standard error is calculated. Both individual options variable and market options variable are used. Dependent variable is abnormal return CAR.

Depvar: CAR			
intercept	0.003 (0.30)	0.002 (1.31)	-0.011 (-0.70)
opp_skew1	0.004** (2.89)		0.004 (1.50)
opp_kurt1	-0.000 (-0.70)		0.000 (0.24)
mfiv1	-0.054** (-4.12)		-0.050 (-1.81)
index_skew1	-0.004 (-1.21)		-0.024** (-3.00)
index_kurt1	-0.000 (-0.40)		-0.000 (-0.82)
index_mfiv1	0.086 (0.89)		-0.155 (-0.88)
skew1_10		0.004** (2.64)	0.003 (1.10)
opp_kurt1_10		0.000 (0.27)	0.000 (0.63)
mfiv1_10		0.021 (1.00)	0.065 (1.79)
indexskew1_10		0.002 (0.65)	0.017** (2.94)
indexkurt1_10		0.000 (1.29)	0.001* (2.59)
index_mfiv1_10		0.122 (1.54)	0.400* (2.14)
Adjrsq	0.08234	0.0746	0.16134

Table 2.8 the impact of market variables on HPR

This table presents the result of regression analysis. The regression is run by cross-sectionally for each month, and then the coefficients are averaged over 180 months. Newy-West heteroskedastic standard error is calculated. Both individual options variable and market options variable are used. Dependent variable is abnormal return HPR.

Depvar: HPR			
intercept	-0.006 (-0.48)	0.000 (0.28)	-0.016 (-0.96)
opp_skew1	-0.002 (-1.49)		-0.005 (-1.77)
opp_kurt1	-0.001 (-1.97)		-0.001 (-1.50)
mfiv1	-0.062** (-4.91)		-0.062* (-2.45)
index_skew1	-0.001 (-0.23)		-0.019 (-1.92)
index_kurt1	-0.000 (-0.03)		-0.001 (-1.16)
index_mfiv1	0.223* (2.02)		0.083 (0.48)
skew1_10		0.003 (1.93)	0.008** (2.87)
opp_kurt1_10		-0.000 (-0.04)	0.001 (1.68)
mfiv1_10		0.025 (1.31)	0.092* (2.45)
indexskew1_10		0.002 (0.73)	0.018* (1.99)
indexkurt1_10		0.000 (1.44)	0.001* (2.01)
index_mfiv1_10		0.196* (2.41)	0.397* (2.31)
Adjrsq	0.074	0.073	0.151

Table 2.9 the idiosyncratic risk and systematic risk

This table presents the result of regression analysis. The regression is run by cross-sectionally for each month, and then the coefficients are averaged over 180 months. Newy-West heteroskedastic standard error is calculated. Both individual options variable and market options variable are used.

	CAR		HPR	
intercept	0.011**	0.001	0.008**	-0.003
	(3.80)	(0.65)	(3.03)	(-1.39)
opp_skew1	0.004*	0.002	0.001	0.003
	(2.55)	(0.71)	(0.68)	(1.18)
opp_kurt1	0.000	0.001	-0.000	0.000
	(0.07)	(1.22)	(-0.34)	(1.00)
mfiv1_sys		-0.074		0.056
		(-1.02)		(0.83)
mfiv1_idio	-0.046**		-0.044**	
	(-3.99)		(-3.78)	
adjrsq	0.052	0.043	0.052	0.046

	CAR		HPR	
intercept	0.000	0.001	0.001	0.001
	(0.56)	(0.81)	(0.62)	(0.70)
skew1_10	0.004**	0.004*	0.004**	0.005*
	(3.31)	(2.25)	(3.17)	(2.38)
opp_kurt1_10	0.000	-0.000	0.000	-0.000
	(0.84)	(-0.27)	(0.70)	(-0.31)
mfiv1_10_sys		-0.000		0.037
		(-0.00)		(0.70)
mfiv1_10_idio	0.028		0.031	
	(1.45)		(1.60)	
adjrsq	0.045	0.040	0.046	0.042

Table 2.10 Directions of earnings announcement

This table presents the result of regression analysis. The regression is run by cross-sectionally for each month, and then the coefficients are averaged over 180 months. Newy-West heteroskedastic standard error is calculated. Positive is a dummy variable that equals 1 for earnings that beat the expectation. Sp1, kp1 and mp1 stands for the interaction of Positive with options variables. Ps1-10, kp1_10 and mp1_10 are the interactions of Positive with change of option variables.

Depvar: CAR								
intercept	-0.027**	-0.031**	-0.024**	-0.054**	-0.030**	-0.030**	-0.030**	-0.032**
	(-11.60)	(-9.38)	(-5.78)	(-2.64)	(-15.11)	(-14.31)	(-14.95)	(-10.08)
opp_skew1	0.004**	-0.002	0.005**	-0.006				
	(4.13)	(-0.55)	(3.61)	(-0.77)				
opp_kurt1			0.000	0.003				
			(0.69)	(1.04)				
mfiv1			-0.024	0.038				
			(-1.62)	(0.44)				
positive	0.041**	0.046**	0.041**	0.071**	0.041**	0.041**	0.041**	0.042**
	(17.25)	(13.32)	(16.85)	(3.61)	(17.40)	(16.68)	(17.21)	(12.50)
sp1		0.008*		0.013				
		(2.15)		(1.67)				
kp1				-0.003				
				(-0.87)				
mp1				-0.055				
				(-0.69)				
skew1_10					0.003**	0.001	0.004**	0.006
					(3.19)	(0.47)	(3.75)	(1.15)
opp_kurt1_10							0.000	0.003
							(1.05)	(1.68)
mfiv1_10							0.037*	0.118
							(2.06)	(1.92)
sp1_10						0.003		-0.001
						(0.93)		(-0.20)
kp1_10								-0.003
								(-1.46)
mp1_10								-0.095
								(-1.61)
adjrsq	0.041	0.040	0.042	0.045	0.040	0.038	0.039	0.044

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