The Impacts of Asymmetric Information and Short Sales on the Illiquidity Risk Premium in the Stock Option Market

Chuang-Chang Chang, **Zih-Ying Lin** and **Yaw-Huei Wang**[*]

ABSTRACT

The illiquidity risk premium hypothesis implies the existence of a positive relationship between illiquidity in the option markets and option returns. Based upon numerous studies within the extant literature examining the roles of informed traders in the option markets, we explore the ways in which asymmetric information and short sales can affect the illiquidity risk premium hypothesis. Our findings reveal that the illiquidity risk premium is higher for the options of those firms with higher information asymmetry, as well as those firms with higher short sales demand or supply. These results are found to be particularly robust for short-term and/or OTM contracts.

Keywords: Information asymmetry; Short sales; Short-sales constraints; Informed traders; Option illiquidity premium.

JEL Classification: G14.

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* Chuang-Chang Chang and Zih-Ying Lin are collocated at the Department of Finance, National Central University, Taiwan; Yaw-Huei Wang (the corresponding author) is at the Department of Finance, National Taiwan University, Taiwan. Address for correspondence: Department of Finance, National Taiwan University, No. 1 Roosevelt Road, Section 4, Taipei 106, Taiwan, ROC; Tel: 886-2-3366-1092; email: wangyh@ntu.edu.tw. The authors are extremely grateful for the helpful comments provided by Ji-Chai Lin, Hung-Neng Lai and Tzu-Hsiang Liao and also to the Ministry of Science and Technology of Taiwan for the financial support provided for this study. (Zih-Ying Lin will present the paper and email address is zylin256@gmail.com)

1. INTRODUCTION

Numerous studies have explored the relationship between illiquidity and expected returns within the financial markets, including the stock, bond and derivative markets. These studies have generally identified the existence of a positive relationship between illiquidity and expected returns in the stock and bond markets.[1] However, stocks and bonds are positive net supply assets, whereas derivatives are traded with a zero net supply; thus, in some studies, the focus is shifted to the associations between illiquidity and the expected returns on derivatives.

Bongaerts, De Jong and Driessen (2011) demonstrated that when investors with short positions in zero net supply assets are taken into consideration, the illiquidity premium could actually be zero, positive or negative; indeed, Deuskar, Gupta and Subramanyam (2011) and Bongaerts et al. (2011) respectively found negative illiquidity premiums in the credit default swap market and the interest rate derivative market, whilst Christoffersen, Goyenko, Jaconbs and Karoui (2014) found a positive relationship in the stock option market. Such inconsistencies within the extant literature motivate us to further investigate the factors potentially affecting the illiquidity risk premium in the stock option market.

1 The impact of stock illiquidity on expected stock returns was examined by Amihud and Mendelson (1986, 1989), Amihud (2002), Pastor and Stambaugh (2003) and Acharya and Pedersen (2005); Amihud and Mendelson (1991), Longstaff (2004) and Lin, Wang and Wu (2011) further noted that bond illiquidity was related to ex-post bond returns.

As compared to trading in the underlying assets, option trading involves lower transaction costs and provides higher leverage; thus, informed traders may choose to trade in options in order to take advantage of their private information. As suggested by Easley, O'Hara and Srinivas (1998), in order to earn profits, informed traders with private information are more likely to trade in the option markets when the option liquidity level is satisfactory and information asymmetry in the stock market is high. Of particular significance is the fact that options can be used as a device for circumventing the short-sale constraints in the stock market.

Many of the prior related studies, such as Manaster and Rendleman (1982) and Sheikh and Ronn (1994), indicate that information is reflected in the option markets prior to being reflected in the underlying stock markets, whilst Diamond and Verrecchia (1987) suggested that informed traders with unfavorable information on the underlying stocks will prefer to trade in the option markets. Furthermore, following the demonstration by Vayanos and Wang (2012) of the ways in which information asymmetry and imperfect competition affect liquidity and asset prices, we posit that the involvement of informed traders may well play an important role in the determination of the illiquidity risk premium in the option markets.

Whilst a number of studies have undertaken theoretical explorations of the ways in which the existence of informed trading may affect the general risk premium, such studies have reported quite mixed findings. For example, although both Leland (1992) and Wang (1993) suggested that the existence of informed traders causes information asymmetry and thus lowers the cost of capital for a firm, a number of other studies have subsequently concluded that information asymmetry actually increases such capital costs.[2]

From their examination of the differences in the composition of public and private information, Easley and O'Hara (2004) noted that uninformed traders would tend to demand a greater risk premium when trading with informed traders, since they recognize the existence of an informational disadvantage, and hence, will tend to hold fewer assets. This will ultimately drive down the prices of those securities with high levels of private information (or information asymmetry), thereby leading to an increase in the cost of capital for these firms.

These empirical findings suggest that private information induces a new form of systematic risk, and that in equilibrium investors require compensation for taking such risk. Thus, it seems natural to question whether the involvement of informed traders changes the positive association between option illiquidity and expected option returns; indeed, several related studies have documented the influence of information asymmetry on the future dynamics of asset prices, with particular focus on the links

2 See O'Hara (2003), Easley and O'Hara (2004) and Hughes, Liu and Liu (2007).

between information asymmetry and subsequent stock returns.

For example, Pan and Poteshman (2006) found that stocks with low put-call ratios outperformed stocks with high put-call ratios, with the predictability of stock returns being higher for those stocks with high concentrations of informed traders. Furthermore, using volatility spreads to predict stock returns based upon various types of informational circumstances, Atilgan (2014) found that the predictability of stock returns was stronger during major information events. Thus, our initial objective in the present study is to examine whether the level of information asymmetry plays an important role in the determination of the illiquidity risk premium across firms in the option markets.

In addition to the level of information asymmetry, both short sales demand and supply are also found to have impacts on trading by informed traders. On the demand side, it was noted by Figlewski and Webb (1993) that the level of short interest in the underlying stock can significantly affect the option prices of the stock; thus, they argued that short selling was undertaken primarily by market professionals who are also be likely to be informed traders.[3] On the supply side, several studies

[3] Since short selling is undertaken primarily by market professionals, who are also likely to be informed traders, those stocks with high (low) levels of short interest provide a signal to the market that the more informed traders expect the future prices of the stocks to fall (rise). Asquith and Meulbroek (1995) also found that stocks with high short interest in one month tended to underperform in the subsequent month, with their result suggesting that short interest is a bearish indicator conveying negative information. Desai, Ramesh, Thiagarajan and Balachandran (2002) demonstrated that after controlling for market size, book-to-market and momentum factors, firms with high levels of short interest had significantly negative abnormal returns.

have demonstrated that short-sales constraints in the stock market affect trading activities in the option market, with Hu (2014), for example, recently noting that option trading is often considered to be an effective method of mitigating short-sales constraints, and thus, conveying more information for those firms with greater short-sales constraints.[4] Our second objective is therefore to examine whether the demand and supply levels of short sales have impacts on the illiquidity risk premium across firms in the option markets.

Our empirical analysis involves the use of the 'information asymmetry index' (ASY-INDEX) and the 'probability of informed trading' (PIN) to measure information asymmetry and the levels of short interest and institutional ownership in a stock to respectively measure the demand and supply for short sales.[5] Our findings based upon US listed stocks and options are summarized as follows.

Firstly, we present evidence to show that the level of information asymmetry has significant impacts on the option illiquidity risk premium across different firms, particularly in the case of call options. The positive relationship that exists between

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4 Examples include Diamond and Verrecchia (1987), Figlewski and Webb (1993) and Johnson and So (2012). Informed traders with negative information could trade in the option market as an alternative to short selling, especially when stocks are more difficult to sell short in the stock market.

5 Following Drobetz, Grüninger and Hirschvogl (2010), we use the error in analyst forecasts, firm size, R&D expenditure, Tobin's *Q* and the number of analysts covering the firm to compile the information asymmetry index. The measure of the 'probability of informed trading' (PIN), which was developed based upon the model of Easley et al. (1998), can be used to capture informed trading in the market; this is an updated version of the data used in Brown, Hillegeist and Lo (2004). Cremers and Weinbaum (2010) and Atilgan (2014) also used this data to investigate the role of informed trading in the markets.

option illiquidity and expected option returns is found to be increased in those cases where there is a higher concentration of informed traders, a finding which is consistent with that of Easley and O'Hara (2004).

Secondly, we find that an increase in short sales strengthens the positive relationship between option illiquidity and expected option returns for call options, whilst higher short interest weakens the negative relationship for put options. Whilst uninformed traders will demand greater compensation when holding more call options (Easley and O'Hara, 2004), when there is higher short interest, the dissemination of information on prices will reduce the uncertainty in the put prices thereby reducing the illiquidity premium (Wang, 1993).

Finally, we find that higher short-sales costs (low institutional ownership) tend to strengthen the positive relationship between option illiquidity and expected option returns for put options; the reason for this is that put options contain more information when there are greater short-sales constraints on the stocks.

In summary, we provide evidence to show that information asymmetry and the demand and supply of short sales are important factors in the determination of the option illiquidity risk premium across firms; this is consistent with the argument put forward by Easley and O'Hara (2004) that uninformed traders will demand a greater risk premium when trading with informed traders. Our empirical results are also found to be particularly robust for short-term OTM options, which is consistent with the general belief that informed traders tend to prefer to use those contracts with higher leverage, better liquidity or lower transaction costs in order to take advantage of their private information.

In addition to confirming the findings of Christoffersen et al. (2014), we contribute to the extant literature by introducing the influences of informed traders on the determination of option prices. We also demonstrate that information asymmetry and the demand and supply of short sales are important factors influencing the illiquidity risk premium across different firms.

The remainder of this paper is organized as follows. Section 2 provides details of our hypothesis development, followed in Section 3 by a description of the data and empirical measures used in our study. The empirical methodology adopted for our analysis is described in Section 4, with Section 5 subsequently presenting and discussing the empirical results. Finally, the conclusions drawn from this study are presented in Section 6.

2. HYPOTHESIS DEVELOPMENT

Using the component firms of the S&P 500 index, Christoffersen et al. (2014) examined the ways in which option illiquidity affected expected option returns and identified a positive relationship between these two factors, which is consistent with the risk premium hypothesis proposed by Amihud (2002). However, in contrast to spot assets with a positive net supply, given that derivatives are zero net supply assets, certain factors may play important roles in determining the risk premium.

It has been noted in many of the prior studies, such as Manaster and Rendleman (1982) and Sheikh and Ronn (1994), that information is reflected in the option market more rapidly than in the corresponding stock market, thereby leading to the suggestion that the option market is the preferred venue for informed traders to realize their private information. Easley, O'Hara and Srinivas (1998) set up a market microstructure model to demonstrate that informed traders preferred to trade in the option markets when option liquidity was high; Easley and O'Hara (2004) subsequently noted that uninformed investors will tend to demand a higher risk premium when they are faced with informed traders in the market.

From their analysis of the ways in which information asymmetry and imperfect competition affect liquidity and asset prices, Vayanos and Wang (2012) found a positive relationship with expected returns under information asymmetry when the illiquidity was measured using Kyle's lambda. In other words, the involvement of informed traders may well vary across different firms, with uninformed traders requiring a higher risk premium when there are more informed traders in the market in order to compensate for their informational disadvantage, thereby leading to a higher level of information asymmetry.

Based upon the findings and theorems of the related studies referred to above, we argue that the level of information asymmetry may influence the relationship between option illiquidity and expected option returns. We expect to find an increasingly positive relationship between option illiquidity and expected option returns with the level of information asymmetry. Accordingly, we propose the first of our hypotheses, as follows:

Hypothesis 1: *The relationship between option illiquidity and expected option returns will be more positive for firms with higher information asymmetry.*

Figlewski and Webb (1993) demonstrated that the significantly higher average level of short interest with 'optionable' stocks (those stocks selected as the underlying asset of an option) provides support for the argument that option trading facilitates short selling. They also found that short interest in the underlying stock could significantly affect option prices and went on to suggest that short sales were primarily undertaken by market professionals.

Diamond and Verrecchia (1987) had earlier indicated that speculative short sellers were more likely to trade in the option markets (with a particular focus on trading in put options) essentially because, on the one hand, such trading could reduce their short sales costs, whilst on the other hand, it could increase their leverage. These studies therefore seem to jointly suggest that the level of short interest is positively related to the amount of informed trading, since short selling is widely regarded as being carried out primarily by market professionals.

Given that informed traders prefer to trade in the option market when they have access to private (especially negative) information, the level of short interest should be positively related to the level of information asymmetry. As suggested by Easley and O'Hara (2004), uninformed traders demand a greater risk premium when trading with informed traders because compensation is required for their losses. Thus, if uninformed traders hold more call options of those stocks with higher short interest, they naturally assume greater risk as a direct result of their informational disadvantage. Accordingly, investors holding more call options of those stocks with higher short interest may require a greater risk premium. This leads to the development of our second hypothesis, as follows:

Hypothesis 2: *The relationship between option illiquidity and expected option returns will be more positive for firms with higher short interest, particularly in the case of call options.*

In addition to the demand side of short sales explored by the studies referred to above, the stock market supply side (short-sale constraints or short-sales costs) can also affect trading activities in the option markets. Informed traders with negative information could trade in the option market as an alternative to short selling, particularly in those cases where the difficulty of engaging in short selling in the stock market is high; that is to say, if there are higher levels of short-sales constraints in the stock market, informed traders with negative information are more likely to trade in the option market.[6]

Some of the prior studies using institutional ownership as a proxy for the market supply of short interest have identified the existence of a negative relationship between the level of institutional ownership and the difficulties involved in engaging in short selling (see D'Avolio, 2002; Asquith, Pathak and Ritter, 2005). Hu (2014) also found that the informational benefit of option trading was higher for stocks with greater short-sales constraints.

Given that informed traders have incentive to buy put options to realize their private negative information for firms with higher short-sales costs, uninformed traders buying put options may assume greater levels of risk. We therefore consider shorting supply to construct out third hypothesis, as follows:

Hypothesis 3: *The relationship between option illiquidity and expected option returns will be more positive for firms with lower institutional ownership* (*higher short-sales costs*), *particularly in the case of*

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6 See Diamond and Verrecchia (1987), Figlewski and Webb (1993), Johnson and So (2012), Hu (2014).

put options.

3. DATA

The primary dataset adopted for this study includes stock option quotes and the illiquidity measures of both stocks and options, with the measures of both information asymmetry and the demand and supply of short sales also being utilized in our empirical analysis. The sample period adopted for this study runs from January 1996 to December 2007.[7]

3.1 Stock Option Quotes and Computation of Option Returns

The stock options data were collected from Option Metrics, with the dataset including daily closing bid and ask quotes, implied volatility levels and the deltas of all stock options listed in the US exchanges. As regards time to maturity, short-term options are defined as those with maturity periods ranging from 20 and 70 days, whilst long-term options are those with maturity periods ranging from 71 and 180 days.

Following Bollen and Whaley (2004) and Driessen, Maenhout and Vilkov (2009), we also adopt the option delta for our classification of moneyness in the present study. The call (put) deltas for OTM options range from 0.125 to 0.375 (−0.375 to −0.125), whilst those for ATM options range from 0.375 to 0.625(−0.625 to −0.375) and those

[7] If the short-sales ban is taken into consideration, an unexpected bias may twist the analysis in the present study; thus, the period after 2007 is not included in our sample period. This issue has been noted in many of the prior related studies, such as Battalio and Schultz (2011), Autore, Billingsley and Kovacs (2011), Grundy, Lim and Verwijmeren (2012) and Boehmer, Jones and Zhang (2013).

for ITM options range from 0.625 to 0.875 (–0.875 to –0.625).

Those option contracts which meet the following criteria are excluded from our sample in order to deal with concerns regarding liquidity or reliability: (i) prices violate the no-arbitrage conditions; (ii) ask price $\leq$ bid price; (iii) open interest is equal to 0; (iv) price details are incomplete; (v) price $<$ \$3 and bid-ask spread $<$ \$0.05 or price $\geq$ \$3 and bid-ask spread $<$ \$0.10.

Following Frazzini and Pedersen (2012) and Christoffersen et al. (2014), we compute the daily delta-hedged returns of options as:

$$\tilde{R}^{O}_{t+1,n} = R^{O}_{t+1,n} - R^{S}_{t+1} S_t \frac{\Delta_{t,n}}{O_{t,n}} \quad (1)$$

where $R^{O}_{t+1,n}$ is the daily raw return of option n and $\Delta_{t,n} = \frac{\partial O_{t,n}}{\partial S_t}$ is computed based upon the Cox, Ross and Rubinstein (1979) binomial tree model allowing for early exercise, given that all stock options are American style options. S_t is the price of the underlying stock at time t and R^{S}_{t+1} is the stock return computed from S_t and S_{t+1}. All of the details on stock prices are obtained from CRSP.

Following Coval and Shumway (2001), we use the bid-ask midpoints to compute the raw option return ($R^{O}_{t+1,n}$) as the equally-weighted average of the daily returns of all available options in each moneyness and maturity category. In other words, the return of a particular category of a firm from t to $t+1$ is defined as:

$$R^{O}_{t+1} = \frac{1}{N}\sum_{n=1}^{N} \frac{O_{t+1}(K_n,T_n-1) - O_{t}(K_n,T_n)}{O_{t}(K_n,T_n)} \qquad (2)$$

The corresponding delta-hedged return is then computed as:

$$\tilde{R}^{O}_{t+1} = \frac{1}{N}\sum_{n=1}^{N} \frac{O_{t+1}(K_n,T_n-1) - O_{t}(K_n,T_n)}{O_{t}(K_n,T_n)} - R^{S}_{t+1} S_t \frac{1}{N}\sum_{n=1}^{N} \frac{\Delta_{t}(K_n,T_n)}{O_{t}(K_n,T_n)} \qquad (3)$$

where N is the number of available contracts in each category at time t with quotes at time $t+1$; and $O_t(K_n, T_n)$ is the mid-point quote of an option with strike price K_n and maturity T_n.[8]

The summary statistics of the option returns across various maturity-moneyness categories for call and put options are reported in Table 1. We first of all compute the descriptive statistics for each firm and then take the cross-sectional averages of these statistics, as a result of which we find that the returns of put options are generally higher than those of call options. Returns on short-term options are more volatile than returns on long-term options, especially for OTM contracts.

<Table 1 is inserted about here>

3.2 Stock and Option Illiquidity Measures

Using the data obtained from the high-frequency intraday 'trade and quote' (TAQ) database, stock illiquidity is calculated in this study as the effective spread.[9] The

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[8] We use the adjustment factor provided by Option Metrics for splits and other distribution events.

[9] The same illiquidity measure has also been adopted in many of the prior related studies, including Hasbrouck and Seppi (2001), Huberman and Halka (2001), Chordia, Roll and Subrahmanyam (2000; 2001) and Chordia, Sarkar and Subrahmanyam (2005).

effective spread is defined as:

$$IL_k^S = 2\ |ln(P_k) - ln(M_k)| \tag{4}$$

where P_k is the price of the k^{th} trade; and M_k is the midpoint of the best bid and offer prices at the time of the k^{th} trade.

The dollar-volume weighted average of all IL_k^S computed over all trades during the day defines the daily effective spread of the stock, IL^S, as follows:

$$IL^S = \frac{\sum_k DolVol_k IL_k^S}{\sum_k DolVol_k} \tag{5}$$

where $DolVol_k$ refers to the dollar-volume computed as the product of the stock price and the trading volume.

Similar to Cao and Wei (2010), we adopt the relative quoted bid-ask spread as the measure of option illiquidity, which is computed from the end-of-day quoted bid and ask prices provided by Ivy DB Option Metrics.[10] For each contract, we compute the daily relative quoted spread as:

$$IL_{t,n}^O = \frac{OA_{\ t}(K_n,T_n) - OB_{\ t}(K_n,T_n)}{O_{\ t}(K_n,T_n)} \tag{6}$$

where $O_t(K_n, T_n)$, $OA_t(K_n, T_n)$ and $OB_t(K_n, T_n)$ are the respective end of day closing mid-point, ask and bid quotes for an option with strike price K_n and maturity T_n. It should be noted that $O_t(K_n, T_n) = (OA_t(K_n, T_n) + OB_t(K_n, T_n))/2$.

[10] As suggested by Cao and Wei (2010), the dollar quoted bid-ask spread is not a good alternative liquidity indicator because it is mainly driven by the maturity and moneyness of an option contract.

$$IL_t^O = \frac{1}{N}\sum_{n=1}^{N} IL_{t,n}^O \quad (7)$$

where *N* is the number of available contracts within the category at time *t*.

The summary statistics of the relative bid-ask spread illiquidity measures for all firms are presented in Table 2. According to the option illiquidity (IL^O), we find that short-term contracts are more illiquid than long-term contracts for both call and put options, with OTM contacts exhibiting the highest overall illiquidity.

<Table 2 is inserted about here>

3.3 Information Asymmetry Measures

Two measures of information asymmetry are adopted in this study. Firstly, following Drobetz et al. (2010), we create an information asymmetry index with the exclusion of those firms with a fiscal year not ending with the corresponding calendar year. Secondly, we follow several of the prior related studies on informed trading to use the 'probability of informed trading' (PIN) to measure information asymmetry.[11]

Various measures of information asymmetry have been introduced within the prior empirical studies; for example, Vermaelen (1981) identified the tendency for a reduction in information asymmetry with firm size, whilst Smith and Watts (1992) discovered an increase in information asymmetry with growth opportunities. Krishnaswami and Subramaniam (1999) indicated that information asymmetry was

[11] See Easley et al. (1998) and Easley, Kiefer and O'Hara (1997; 2002).

reduced in line with the number of analysts tracing the firm, and went on to suggest the use of analyst forecast errors as an effective measure for information asymmetry. Finally, Aboody and Lev (2000) also found an increase in information asymmetry with R&D expenditure.

For our first measure of information asymmetry in the present study, we follow the method of Drobetz et al. (2010) to construct an information asymmetry index (ASY-INDEX) based upon the various dimensions of the concepts described above. These dimensions include analyst forecast errors,[12] firm size, R&D expenditure, Tobin's Q and the number of analysts tracing the firm.[13] The accounting data, which is obtained from Compustat, includes R&D expenditure and total assets. Details on the analyst forecasts and the number of tracking analysts are collected from I/B/E/S.

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[12] We use the following measure of analyst forecast errors: $ERRORF = ln(1 + |EPS_{Forcast} - EPSActual/Median\ EPS$, where $EPS_{Forecast}$ is the earnings per share forecast, which is the average of all forecasts for a firm provided by all analysts in November and December of the previous year. The difference between actual and forecasted earnings per share is scaled by the median earnings per share forecast.

[13] Elton, Gruber and Gultekin (1984) noted that most of the forecast error in the last month of the fiscal year could be explained by erroneous estimation of firm-specific factors. Diamond and Verrecchia (1991) and Ozkan and Ozkan (2004) further indicated that large firms may be faced with less information asymmetry essentially because they are more mature and have more transparent disclosure policies; thus, they tend to receive more attention from the market. From their analysis of insider trading gains in firms with high and low R&D expenditure, Aboody and Lev (2000) found that the insider gains in R&D firms were larger than those in firms with no R&D, and provided evidence to show that R&D was related to information asymmetry. Following the indication by Smith and Watts (1992) that information asymmetry was more serious for firms with significant growth opportunities, McLaughlin, Safieddine and Vasudevan (1998) used investment opportunities as a proxy for information asymmetry. In the present study, we use Tobin's Q, defined as the book value of assets minus the book value of equity plus the market value of equity divided by the book value of assets, to measure growth opportunities. Chang, Dasgupta and Hillary (2006) suggested that the greater the analyst cover of a firm, the higher the information released to the public, and hence, the more limited the level of information asymmetry; the number of analysts can therefore also be used to proxy for information asymmetry. Brennan and Subrahmanyam (1995) argued that higher analyst coverage could reduce the adverse selection costs, as measured by the inverse of market depth.

For our compilation of the index, we first of all calculate the annual quintile ranking of a firm over all firms for each dimension of information asymmetry, with a higher score indicating a higher level of information asymmetry; for instance, a firm will be assigned a score of 5 (1) if it belongs in the smallest (largest) 20 per cent of all firms in a given year. We then sum the ranks for all five dimensions of information asymmetry, with the largest (smallest) value of the ASY-INDEX for firms with the highest (lowest) level of information asymmetry being 25 (5). The PIN is used as the second measure of information asymmetry in our analysis, with the quarterly PIN estimates for the period from January 1996 to December 2006 having been obtained from Stephen Brown.

3.4 Short Sales Measures

One stream of the extant literature on short sales suggests that high short interest ratios (shares sold short over shares outstanding) predicts low future returns,[14] whilst an alternative stream indicates that short sales are dependent upon the institutional ownership of the stock.[15]

We also follow Asquith et al. (2005) to consider both short sales demand and supply so as to define the level of stocks to short sales. We follow Figlewski and

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[14] Examples include Figlewski (1981), Figlewski and Webb (1993), Senchack and Starks (1993), Asquith and Meulbroek (1995) and Desai et al. (2002).

[15] See D'Avolio (2002), Asquith et al. (2005) and Hu (2014).

Webb (1993) to use the short interest ratio as a proxy for short sales demand and as suggested by D'Avolio (2002) and Asquith et al. (2005), we take institutional ownership as the proxy for the market supply of short interest, since it has a negative correlation with the difficulties involved in short selling.

The data on short interest are obtained from Compustat on the fifteenth day of the month (or the nearest trading day if the fifteenth day is not a trading day), whilst the institutional ownership data are obtained from 13-F filings. The descriptive statistics on the information asymmetry measures, comprising of the means, medians, standard deviations and 10%, 50% and 90% percentiles, are reported in Table 3.

<Table 3 is inserted about here>

4. METHODOLOGY

Christoffersen et al. (2014) identified a positive relationship between option illiquidity and expected option returns, attributing this result to the option illiquidity premium. However, given that derivatives are zero net supply assets, they are more complicated than assets with positive net supplies; therefore, for our examination of the ways in which information asymmetry and short sales affect the positive relationship identified by Christoffersen et al. (2014), we modify the regression model adopted in their study to consider the effect of information asymmetry in order to test Hypothesis 1, as follows:[16]

$$\tilde{R}^{O}_{i,t} = a_{0,t} + \beta_{1,t}\tilde{R}^{O}_{i,t-1} + \beta_{2,t}IL^{\mathrm{O}}_{i,t-1} + \beta_{3t}IL^{\mathrm{S}}_{i,t-1} + \beta_{4,t}IL^{\mathrm{O}}_{i,t-1} \times Dummy_{Asy.Info.} + \beta_{5,t}IL^{\mathrm{S}}_{i,t-1} \times Dummy_{Asy.Info.} + \beta_{6,t}Dummy_{Asy.Info.} + \beta_{7,t}\sigma_{i,t-1} + \beta_{8,t}ln(size_{i,t-1}) + \beta_{9,t}b_{i,t-1} + \beta_{10,t}lev_{i,t-1} + \varepsilon_{i,t} \quad (8)$$

where $\tilde{R}^{O}_{i,t}$ are the delta-hedge option returns; $IL^{O}_{i,t}$ refers to the option illiquidity and $IL^{S}_{i,t}$ denotes the stock illiquidity; $Dummy_{Asy.Info.}$ is a dummy variable which takes the value of 1 if the ASY-INDEX for stock *i* is ranked in the top 20 per cent; otherwise 0; and $\sigma_{i,t}$ denotes the historical volatility estimated using the daily stock returns from the GARCH(1,1) model.

As suggested by Duan and Wei (2009), $b_{i,t}$ is the square root of the R^2 from running the daily OLS regressions of the excess stock returns on the four factors proposed by Fama and French (1993) and Carhart (1997), with a one-year rolling window. Furthermore, we follow both Dennis and Mayhew (2002) and Duan and Wei (2009) to control for size and leverage; $size_{i,t}$ is the natural logarithm of the market capitalization of the firm; and $lev_{i,t}$ is defined as the sum of long-term debt and the par value of the preferred stock, divided by the sum of long-term debt, the par value of the preferred stock and the market value of equity.

We expect to find that if the illiquidity premium hypothesis holds, then β_2 will

[16] In order to run a reliable cross-sectional regression, there is a requirement of a minimum of 30 firm observations for each time *t*.

be positive, and if investors require a higher risk premium for the options of stocks with higher levels of information asymmetry, then β_4 will be significantly positive. Based upon the replication argument proposed by Leland (1985) and Boyle and Vorst (1992), we also expect to find that β_3 will be positive.[17]

When using the PIN as an alternative proxy for information asymmetry, the terms with $Dummy_{Asy.Info.}$ are not included in the regression model; instead, we first of all group the firms based on their quarterly PIN levels into the three categories of low (<30%), mid (30-70%) and high (>70%), and then run the cross-sectional regression model without the dummy term for the returns of options across various moneyness-maturity categories in order to examine the significance of the mean of the β_2 coefficients for each category.

As regards the short sales demand side, we follow Figlewski and Webb (1993) to use the relative short interest (that is, the number of shares sold short divided by the total outstanding shares of the firm) as the measure of the annual average short interest. For the supply side, we follow Asquith et al. (2005) and Hu (2014) to consider institutional ownership as the proxy for short-sales constraints (short-sales costs) and then rewrite the regression models, as shown below, to respectively test

[17] An option can be replicated by trading the underlying asset and a risk free bond in a frictionless and complete-market model; however, this is not the case, given the existence of liquidity risk. Market makers have net long positions in the equity option markets, and hence, need to create a synthetic short option using the underlying stock. This will lead to a reduction in the price that market makers receive from shorting the synthetic option with the illiquidity of the stock market, thereby reducing the option price.

Hypotheses 2 and 3:

$$\tilde{R}_{i,t}^{O} = a_{0,t} + \beta_{1,t}\tilde{R}_{i,t-1}^{O} + \beta_{2,t}IL_{i,t-1}^{\mathrm{O}} + \beta_{3t}IL_{i,t-1}^{\mathrm{S}} + \beta_{4,t}IL_{i,t-1}^{\mathrm{O}} \times Dummy_{RSI} + \beta_{5,t}IL_{i,t-1}^{\mathrm{S}} \times Dummy_{RSI} + \beta_{6,t}Dummy_{RSI} + \beta_{7,t}\sigma_{i,t-1} + \beta_{8,t}ln(size_{i,t-1}) + \beta_{9,t}b_{i,t-1} + \beta_{10,t}lev_{i,t-1} + \varepsilon_{i,t} \quad (9)$$

and

$$\tilde{R}_{i,t}^{O} = a_{0,t} + \beta_{1,t}\tilde{R}_{i,t-1}^{O} + \beta_{2,t}IL_{i,t-1}^{\mathrm{O}} + \beta_{3t}IL_{i,t-1}^{\mathrm{S}} + \beta_{4,t}IL_{i,t-1}^{\mathrm{O}} \times Dummy_{op} + \beta_{5,t}IL_{i,t-1}^{\mathrm{S}} \times Dummy_{op} + \beta_{6,t}Dummy_{op} + \beta_{7,t}\sigma_{i,t-1} + \beta_{8,t}ln(size_{i,t-1}) + \beta_{9,t}b_{i,t-1} + \beta_{10,t}lev_{i,t-1} + \varepsilon_{i,t} \quad (10)$$

where the $Dummy_{RSI.}$ variable takes the value of 1 if the relative short interest for stock *i* is ranked in the top 20 per cent; otherwise 0; and the $Dummy_{op.}$ variable takes the value of 1 if the institutional ownership for stock *i* is ranked in the bottom 20 per cent; otherwise 0. Similarly, if Hypothesis 2 (3) holds, then we would expect to find that β_4 will be significantly positive, particularly for call (put) options.

5. EMPIRICAL RESULTS

5.1 Preliminary Results

Prior to using our regression models to formally test for the impacts of information asymmetry and short sales on the illiquidity risk premium, we provide some preliminary evidence on the existence of the illiquidity risk premium in the option markets. We short the stocks according to their previous-day illiquidity measures and form three groups of firms in the categories of low (<30%), mid (30-70%) and high (>70%) illiquidity for each day. We then calculate the delta hedge returns of options for each group of firms across various moneyness-maturity categories. The average option returns for all categories are reported in Table 4.

<Table 4 is inserted about here>

Regardless of which moneyness or maturity is considered, the average return for the high-illiquidity group is always found to be higher than that for the low-illiquidity group, with almost all of the differences being significant at the 1% level. In other words, the average option returns are positively associated with the option illiquidity levels; this is in line with the findings of Christoffersen et al. (2014) and confirms the existence of the illiquidity risk premium in the option markets

5.2 Results on Information Asymmetry

In order to test Hypothesis 1, we first of all run the cross-sectional regression model specified in Equation (8) for each day and then take the time-series averages of the regression coefficients. We report the results based upon the information asymmetry index (ASY-INDEX) in Table 5, with Newey and West (1987) adjusted *t*-statistics. As shown in Panel A, the overall results on call options are found to be consistent across all moneyness and maturity groups.

<Table 5 is inserted about here>

The positive significance of β_2 is in line with the illiquidity risk premium hypothesis, which is again consistent with the findings of Christoffersen et al. (2014). The positive β_3 provides support for the option replication argument proposed by Leland (1985) and Boyle and Vorst (1992), although it is found to be insignificant for long-term OTM call options. The β_4 coefficient is found to positively significant at the 5% level for all groups, with the one exception of short-term ITM call options, thereby confirming Hypothesis 1. In other words, our regression results on call options strongly indicate that the higher the level of information asymmetry, the higher the illiquidity risk premium.

Furthermore, the information asymmetry effect is found to be particularly strong for short-term call options, essentially because $\beta_2 + \beta_4$ is higher for short-term contracts than long-term contracts. This finding could be attributable to the fact that informed traders are more likely to trade in short-term contracts, as opposed to long-term contracts, so that they can take advantage of certain aspects of the former, such as higher leverage and liquidity.

By contrast, as shown in Panel B, the results from put options are less convincing since the β_4 coefficient is found to be positively significant only for OTM options, which could be attributable to uninformed investors tending to view put options as insurance against existing long positions on the underlying asset, whilst also choosing not to speculate on negative news.[18] Although the effect of information asymmetry is less robust for put options, full support is still provided for the illiquidity risk premium hypothesis since all of the β_2 coefficients are found to be positively significant at the 1% level.

Our finding that the effect of the impact is particularly pronounced for OTM contracts, which are not dependent on call/put or short-/long-term contracts, is of some importance, since this finding suggests that informed traders prefer to trade in OTM options in order to take advantage of their private information, and thus, uninformed traders require a higher risk premium when trading in this group of contracts to compensate for the risk that they face due to their informational disadvantage.

The empirical results obtained from PIN, the alternative proxy for information asymmetry, are shown in Table 6. Since the PIN dataset is obtained with quarterly frequency, we run the cross-sectional regression model specified in Equation (8) without the information asymmetry dummy variable for each day on the returns of options across various moneyness-maturity categories for the three groups of firms grouped by their PIN levels. The means of the β_2 coefficients and their *t*-statistics are reported in Table 6.

[18] Several prior studies, including Bates (1996), Pan (2002) and Bakshi Kapadia and Madan (2003) have shown that hedging demand drives the pricing of put options more than the pricing of call options.

<Table 6 is inserted about here>

The results based upon the PIN levels are generally consistent with those based upon the ASY-INDEX, with strong support being provided for the illiquidity risk premium hypothesis since virtually all of the β_2 coefficients are found to be positively significant at the 1% level. Furthermore, the β_2 coefficients of the higher PIN groups are found to be larger than those of the lower PIN groups for the majority of the moneyness-maturity categories, a finding which is particularly robust for OTM (call and put) contracts.

In summary, both the ASY-INDEX and PIN results indicate that uninformed traders require a higher illiquidity risk premium for the options of firms with higher levels of information asymmetry, thereby confirming Hypothesis 1.

5.3 Results on Demand and Supply of Short Sales

Following Asquith et al. (2005), we consider the demand-side and supply-side measures of short sales in order to investigate their overall impact on the illiquidity risk premium hypothesis when informed traders are in possession of negative private information. The results from the demand-side measure for short interest are shown in Table 7.

<Table 7 is inserted about here>

For call options, with the exception of ITM contracts, we find that the illiquidity risk premium is higher when there is higher short selling of stocks, essentially because all of the β_4 coefficients are found to be positively significant at the 5% level; however, there is no clear pattern for put options. In summary, the effect of the demand of short sales on the illiquidity risk premium is particularly high for OTM call options, with these findings being largely consistent with Hypothesis 2, as well as the ASY-INDEX and PIN results.

A higher level of short interest indicates a bearish prospect for the firm. Given unfavorable information on the underlying stocks, informed traders will not only short sell the stocks, but also buy put options, since trading in the latter attracts lower transaction costs, whilst providing higher leverage. Under such circumstances, uninformed traders buying more call options will require a higher risk premium as they are more likely to lose out to informed traders who may trade more put options, an argument which is consistent with that of Easley and O'Hara (2004).

Conversely, the short interest level signals the release of negative information, which lowers the uncertainty of trading in put options. Consequently, investors trading in put options will not demand a higher illiquidity risk premium when the level of short interest in the underlying stock is higher. For most of the moneyness-maturity categories, we even find a negative β_4 coefficient, which is consistent with the argument of Wang (1993), that the illiquidity risk premium for put options will be lower when there is greater short interest in the underlying stock.

The results on the impact of the supply-side measure (short-sales constraints or short-sales costs) on the illiquidity risk premium are shown in Table 8. Although there are no significant findings for call options, for put options, almost all of the β_4 coefficients are found to be positive, with significance at the 1% level, for OTM contracts. In contrast to our earlier findings using other measures, the findings on short-sales constraints suggest that uninformed investors trading in put options will tend to demand a higher illiquidity risk premium for those stocks with higher short-sales constraints.

<Table 8 is inserted about here>

The option market can be used as a device for circumventing short-sales constraints in the stock market. For those stocks with greater short-sales constraints, informed traders will inevitably choose to trade in put options when they are in possession of private negative information. Therefore, uninformed traders buying put options on those stocks with high short-sales constraints will require a higher illiquidity risk premium since the risk arising from their informational disadvantage is higher. Although uninformed traders may realize that the put option market is a channel for informed traders to take advantage of their private negative information, they do not know when they will choose to do so; however, this is not the case for call options. These findings are generally consistent with Hypothesis 3.

In summary, we provide evidence to show that for both call and put options, information asymmetry and short sales have significant impacts on the illiquidity premium. Our findings reveal that information asymmetry and short interest (short-sale costs) are positively associated with the option illiquidity risk premium, particularly for call (put) options. Furthermore, these results are found to be especially robust for short-term or OTM option contracts, a finding which is consistent with the common belief that informed traders are more likely to trade in these contracts in order to realize their private information.

6. CONCLUSIONS

Based on the extant literature on the roles of informed traders in the option markets, we extend the work of Christoffersen et al. (2014) to examine the ways in which information asymmetry and short sales affect the option illiquidity risk premium. In addition to using the two measures of information asymmetry (ASY-INDEX and PIN), we also use the demand-side and supply-side measures of short sales (short interest and short-sales constraints) in order to examine their impacts on the relationship between option returns and option illiquidity.

Our findings reveal that both information asymmetry and short sales have significantly positive impacts on the option illiquidity risk premium, with our empirical results being found to be particularly robust for short-term contracts. These findings are also consistent with the argument put forward by Easley and O'Hara (2004) that uninformed traders will demand a greater risk premium when trading with informed traders.

In addition to confirming the findings of Christoffersen et al. (2014), we also contribute to the extant literature by introducing the influences of informed traders on the determination of option prices and documenting that information asymmetry and the demand and supply of short sales are important factors influencing the illiquidity risk premium across different firms.

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Table 1 Descriptive statistics of daily option returns

This table reports the summary statistics of the equally-weighted daily option returns, including the percentage mean, standard deviation, skewness and kurtosis. The option returns are computed using closing bid-ask price midpoints. Short-term options are defined as those with maturities ranging from 20 and 70 days, whilst long-term options are those with maturities ranging from 71 and 180 days. We adopt the option deltas to classify moneyness; the option call (put) deltas for OTM range from 0.125 to 0.375 (–0.375 to –0.125), whilst those for ATM range from 0.375 to 0.625 (–0.625 to –0.375), and those for ITM range from 0.625 to 0.875 (–0.875 to –0.625).

Variables	Mean	Std. Dev.	Skewness	Kurtosis	Avg. No. of Firms
Panel A: Calls					
a. Short-term Options					
ATM	–0.0075	0.1044	0.5729	7.5609	808
ITM	–0.0027	0.0477	0.5633	6.5945	909
OTM	–0.0210	0.3622	0.2263	9.5186	1,014
b. Long-term Options					
ATM	–0.0012	0.0829	0.7483	12.5576	1,489
ITM	–0.0006	0.0358	0.5203	11.0742	1,467
OTM	–0.0061	0.2726	0.3082	14.0850	1,389
Panel B: Puts					
a. Short-term Options					
ATM	–0.0016	0.0732	0.8400	7.5096	672
ITM	0.0000	0.0473	0.6171	4.2878	660
OTM	–0.0020	0.1757	0.9605	13.7534	937
b. Long-term Options					
ATM	0.0014	0.0507	1.0738	11.7113	1,260
ITM	0.0008	0.0337	0.6331	5.9273	970
OTM	0.0038	0.1006	1.5214	23.0853	1,484

Table 2 Illiquidity measures

This table reports the summary statistics of the equally-weighted illiquidity measure (ASY-INDEX) for a sample period running from January 1996 to December 2007. Option illiquidity (IL^O) is measured based upon the average relative bid-ask spread, where ask (bid) is the end-of-day closing ask (bid) price available from Ivy DB Option Metrics. Stock illiquidity (IL^S) is estimated from TAQ intra-day data as the dollar-volume weighted average of the effective relative spread for each day. For each firm and for each day, we compute the average relative bid-ask spreads of all the available options in a given category and then take the mean, minimum, maximum and standard deviation. All figures shown are in percentage terms.

Variables	Mean	Min.	Max.	Std. Dev.
Panel A: Calls				
a. IL^O for Short-term Options				
ATM	0.2471	0.0755	0.7696	0.1250
ITM	0.1370	0.0503	0.4475	0.0637
OTM	0.6642	0.1627	1.6375	0.3378
b. IL^O for Long-term Options				
ATM	0.1859	0.0524	0.6923	0.0957
ITM	0.1138	0.0402	0.5203	0.0742
OTM	0.4851	0.1064	1.4078	0.2640
c. IL^S for Stocks	0.0270	0.0014	0.6263	0.0352
Panel B: Puts				
a. IL^O for Short-term Options				
ATM	0.2035	0.0724	0.6309	0.1016
ITM	0.1215	0.0521	0.3617	0.0535
OTM	0.5128	0.1436	1.4295	0.2712
b. IL^O for Long-term Options				
ATM	0.1426	0.0499	0.5261	0.0706
ITM	0.0950	0.0394	0.3292	0.0444
OTM	0.3184	0.0882	1.0741	0.1727

Table 3 Asymmetric information and short-sales measures

This table reports the descriptive statistics of the information asymmetry and short-sales demand and supply measures, comprising of the means, 10%, 50% and 90% percentiles and standard deviations for a sample period running from January 1996 to December 2007; due to data availability, the quarterly probability of informed trading (*PIN*) estimates, obtained from Stephen Brown, cover the period January 1996 to December 2006 only; *PIN* is an alternative measure of information asymmetry; *ASY-INDEX* is a comprehensive index of information asymmetry based upon the quintile rankings of firm size, R&D expenditure, Tobin's *Q* and the number of analysts covering the firm. The short interest (*SI*) annual average is the average of the daily ratios of short interest over a firm's total outstanding shares in stocks with traded options. Institutional ownership (*OP*) is the firm's institutional ownership percentage.

Variables	P_{10}	P_{50}	P_{90}	Mean	Std. Dev.
ASY-Index	11.0000	15.0000	18.0000	14.7072	2.9757
PIN	0.0785	0.1391	0.2265	0.1483	0.0732
SI	0.0005	0.0117	0.0821	0.0347	0.1761
OP	0.0828	0.2636	0.6944	0.3419	0.3219

Table 4 Daily portfolios, sorted by illiquidity

This table reports the portfolio sorting results for call and put options; for each day, firms are sorted into three groups based upon their lagged option illiquidity ($IL^{O}_{i,t-1}$), comprising of low <30%, mid 30-70% and high >70%, with the time-series average of the delta-hedge option returns, $\tilde{R}^{O}_{i,t}$, being reported for each decile. The sample includes all firms with option trading from January 1996 to December 2007. ** indicates statistical significance at the 5% level; and *** indicates significance at the 1% level. The *t*-statistics include Newey-West correction for serial correlation.

Variables	Lagged Option Illiquidity ($IL^{O}_{i,t-1}$)				*t*-value
	High	Mid	Low	H – L	
Panel A: Calls					
a. Short-term Options					
High (>70%)					
ATM	0.0021	–0.0092	–0.0116	0.0137	28.77***
ITM	–0.0021	–0.0014	–0.0022	0.0001	0.54
OTM	0.0226	–0.0187	–0.0320	0.0546	41.58***
Med (30%-70%)					
ATM	–0.0126	–0.0134	–0.0145	0.0019	5.72***
ITM	–0.0025	–0.0031	–0.0033	0.0008	6.07***
OTM	–0.0372	–0.0425	–0.0478	0.0106	7.96***
Low (<30%)					
ATM	–0.0157	–0.0180	–0.0199	0.0042	11.05***
ITM	–0.0038	–0.0041	–0.0048	0.0010	9.17***
OTM	–0.0510	–0.0584	–0.0634	0.0124	7.23***
b. Long-term Options					
High (>70%)					
ATM	0.0066	–0.0010	–0.0027	0.0093	33.91***
ITM	0.0003	0.0000	–0.0007	0.0010	7.39***
OTM	0.0221	–0.0016	–0.0098	0.0319	39.05***
Med (30%-70%)					
ATM	–0.0032	–0.0047	–0.0055	0.0023	11.85***
ITM	–0.0008	–0.0010	–0.0014	0.0005	7.40***
OTM	–0.0130	–0.0173	–0.0206	0.0076	9.14***
Low (<30%)					
ATM	–0.0064	–0.0073	–0.0080	0.0015	6.94***
ITM	–0.0015	–0.0017	–0.0022	0.0006	9.56***
OTM	–0.0224	–0.0254	–0.0256	0.0032	3.12***

Table 4 (*Contd.*)

Variables	Lagged Option Illiquidity ($IL^{O}_{i,t-1}$)				*t*-stat.
	High	Mid	Low	H – L	
Panel B: Puts					
a. Short-term Options					
High (>70%)					
ATM	0.0005	–0.0033	–0.0040	0.0044	11.81***
ITM	0.0011	0.0012	0.0006	0.0005	2.60***
OTM	0.0154	–0.0081	–0.0114	0.0268	32.76***
Med (30%-70%)					
ATM	–0.0043	–0.0047	–0.0053	0.0009	3.78***
ITM	0.0004	0.0000	–0.0002	0.0006	2.97***
OTM	–0.0120	–0.0132	–0.0151	0.0031	5.76***
Low (<30%)					
ATM	–0.0058	–0.0062	–0.0060	0.0002	0.57
ITM	–0.0008	–0.0008	–0.0009	0.0001	0.37
OTM	–0.0153	–0.0159	–0.0163	0.0011	2.25**
b. Long-term Options					
High (>70%)					
ATM	0.0030	0.0016	0.0013	0.0017	9.24***
ITM	0.0012	0.0012	0.0010	0.0002	1.59
OTM	0.0119	0.0032	0.0013	0.0107	27.45***
Med (30%-70%)					
ATM	0.0006	0.0002	0.0001	0.0006	4.53***
ITM	0.0009	0.0007	0.0009	0.0000	0.30
OTM	0.0004	–0.0001	–0.0009	0.0013	5.78***
Low (<30%)					
ATM	–0.0001	–0.0003	–0.0003	0.0002	1.51
ITM	0.0007	0.0007	0.0003	0.0004	2.61***
OTM	–0.0013	–0.0020	–0.0020	0.0007	3.45***

Table 5 Information asymmetry index regression results

This table reports the results of cross-sectional regressions of the daily delta-hedge option returns ($\tilde{R}^{O}_{i,t}$) on the ASY-INDEX levels, with the regression model being specified as:

$$\tilde{R}^{O}_{i,t} = a_{0,t} + \beta_{1,t}\tilde{R}^{O}_{i,t-1} + \beta_{2,t}IL^{O}_{i,t-1} + \beta_{3t}IL^{S}_{i,t-1} + \beta_{4,t}IL^{O}_{i,t-1} \times Dummy_{Asy.Info.} + \beta_{5,t}IL^{S}_{i,t-1} \times Dummy_{Asy.Info.} + \beta_{6,t}Dummy_{Asy.Info.} + \beta_{7,t}\sigma_{i,t-1} + \beta_{8,t}ln(size_{i,t-1}) + \beta_{9,t}b_{i,t-1} + \beta_{10,t}lev_{i,t-1} + \varepsilon_{i,t}$$

where $\tilde{R}^{O}_{i,t}$ represents the delta-hedge option returns; $IL^{O}_{i,t}$ denotes the option illiquidity; $IL^{S}_{i,t}$ refers to the stock illiquidity; and $Dummy_{Asy.Info}$ is a dummy variable which takes the value of 1 in those cases where the ASY-INDEX for stock *i* is ranked in the top 20%; otherwise 0. All of the remaining variables serve as control variables: $\sigma_{i,t}$ denotes the historical volatility estimated using the daily stock returns from the GARCH(1,1) model; $b_{i,t}$ is the square root of the R^2 obtained from running the daily OLS regressions of excess stock returns on the four factors proposed by Fama-French (1993) and Carhart (1997) with a one-year rolling window; $size_{i,t}$ is the natural logarithm of the market capitalization of the firm; $lev_{i,t}$ is defined as the sum of long-term debt and the par value of the preferred stock, divided by the sum of long-term debt, the par value of the preferred stock and the market value of equity. The sample period runs from January 1996 to December 2007. * indicates statistical significance at the 10% level; ** indicates significance at the 5% level; and *** indicates significance at the 1% level. The *t*-statistics include Newey-West correction for serial correlation.

Variables	ATM		ITM		OTM	
	Coeff.	*t*-stat.	Coeff.	*t*-stat.	Coeff.	*t*-stat.
Panel A: Calls						
a. Short-term Options						
α_0	0.0108	2.80***	0.0005	0.37	0.1242	6.94***
β_1	–0.2007	–45.66***	–0.2755	–71.59***	–0.0778	–21.76***
β_2	0.0204	7.86***	0.0054	2.38**	0.0246	10.32***
β_3	0.9671	6.60***	0.2449	4.49***	2.0181	4.28***
β_4	0.0276	6.76***	0.0058	1.59	0.0274	7.86***
β_5	–0.4091	–2.49**	–0.1441	–2.22**	–1.3020	–2.62***
β_6	–0.0063	–6.65***	–0.0005	–1.33	–0.0210	–6.24***
Adj-R^2	0.1033		0.1258		0.0822	
b. Long-term Options						
α_0	0.0040	1.57	–0.0012	–1.53	0.0411	3.75***
β_1	–0.1479	–47.00***	–0.3017	–90.44***	–0.0527	–14.78***
β_2	0.0225	9.98***	0.0073	4.32**	0.0187	9.69***
β_3	0.3933	5.75***	0.1454	5.41***	0.3513	1.53
β_4	0.0219	6.32***	0.0061	2.29**	0.0204	7.02***
β_5	–0.0408	–0.50	–0.0706	–1.98**	–0.2999	–1.22
β_6	–0.0039	–5.79***	–0.0007	–3.00***	–0.0085	–4.35***
Adj-R^2	0.0832		0.1339		0.0782	

Table 5 (*Contd.*)

Variables	ATM		ITM		OTM	
	Coeff.	*t*-stat.	Coeff.	*t*-stat.	Coeff.	*t*-stat.
Panel B: Puts						
a. Short-term Options						
α_0	–0.0094	–3.42***	–0.0105	–4.64***	0.0006	0.12
β_1	–0.1842	–42.81***	–0.1214	–31.66***	–0.1412	–43.67***
β_2	0.0146	6.21***	0.0241	7.25***	0.0246	12.45***
β_3	0.4900	4.77***	–0.0761	–1.11	0.9449	3.72***
β_4	–0.0014	–0.36	–0.0070	–1.56	0.0131	4.37***
β_5	0.0207	0.17	–0.0094	–0.12	–0.6252	–2.29**
β_6	–0.0011	–1.53	0.0003	0.45	–0.0019	–1.48
Adj-R^2	0.1025		0.0981		0.0670	
b. Long-term Options						
α_0	–0.0049	–2.79***	–0.0056	–3.94***	–0.0134	–5.89***
β_1	–0.1445	–39.95***	–0.1105	–28.05***	–0.1404	–42.28***
β_2	0.0146	7.15***	0.0135	5.19***	0.0223	16.49***
β_3	0.2098	4.17***	–0.0290	–0.79	0.2521	2.47**
β_4	–0.0024	–0.80	–0.0069	–1.82*	0.0064	3.07***
β_5	0.0252	0.44	0.0055	0.14	–0.0959	–0.89
β_6	–0.0005	–1.19	0.0001	0.15	–0.0011	–1.72*
Adj-R^2	0.0900		0.0927		0.0596	

Table 6 Probability of informed trading (PIN) regression results

This table reports the results of cross-sectional regressions of daily delta-hedge option returns ($\tilde{R}^{O}_{i,t}$) on the probability of informed trading (*PIN*) levels based upon the model detailed in Table 5 for a sample period running from January 1996 to December 2006. The terms with $Dummy_{Asy.Info.}$ are not included within the regression; instead, we first of all split the firms based upon their quarterly *PIN* levels into the three groups of low (<30%), mid (30-70%) and high (>70%) *PIN*, and then run the cross-sectional regression model without the dummy term for the returns of options across various moneyness-maturity categories. Thus, we report the average β_2 coefficients and *t*-statistics (calculated using Newey-West standard errors adjusted for serial correlation). ** indicates statistical significance at the 5% level; and *** indicates significance at the 1% level.

Variables	*Low-PIN*		*Mid-PIN*		*High-PIN*	
	Coeff.	*t*-stat.	Coeff.	*t*-stat.	Coeff.	*t*-stat.
Panel A: Calls						
a. Short-term Options						
ATM	0.0163	4.44***	0.0313	13.32***	0.0412	17.71***
ITM	0.0121	4.57***	0.0109	5.48***	0.0094	4.13***
OTM	0.0046	1.08	0.0366	16.81***	0.0470	30.88***
b. Long-term Options						
ATM	0.0261	7.39***	0.0351	15.09***	0.0434	18.30***
ITM	0.0149	7.17***	0.0145	9.65***	0.0123	5.85***
OTM	0.0079	2.10**	0.0259	13.51***	0.0353	23.78***
Panel B: Puts						
a. Short-term Options						
ATM	0.0167	4.95***	0.0173	8.42***	0.0187	8.02***
ITM	0.0408	8.46***	0.0240	7.77***	0.0173	5.81***
OTM	0.0102	4.32***	0.0270	17.61***	0.0370	22.19***
b. Long-term Options						
ATM	0.0164	5.97***	0.0187	10.54***	0.0179	10.40***
ITM	0.0196	5.25***	0.0123	5.09***	0.0036	1.25
OTM	0.0210	11.37***	0.0246	20.38***	0.0278	19.39***

Table 7 Short interest regression results

This table reports the results of cross-sectional regressions of the daily delta-hedge option returns ($\tilde{R}^{O}_{i,t}$) on short interest levels, with the regression model being specified as:

$$\tilde{R}^{O}_{i,t} = \alpha_{0,t} + \beta_{1,t}\tilde{R}^{O}_{i,t-1} + \beta_{2,t}IL^{O}_{i,t-1} + \beta_{3t}IL^{S}_{i,t-1} + \beta_{4,t}IL^{O}_{i,t-1} \times Dummy_{RSI} + \beta_{5,t}IL^{S}_{i,t-1} \times Dummy_{RSI} + \beta_{6,t}Dummy_{RSI} + \beta_{7,t}\sigma_{i,t-1} + \beta_{8,t}ln(size_{i,t-1}) + \beta_{9,t}b_{i,t-1} + \beta_{10,t}lev_{i,t-1} + \varepsilon_{i,t}$$

where $\tilde{R}^{O}_{i,t}$ represents the delta-hedge option returns; $IL^{O}_{i,t}$ denotes the option illiquidity; $IL^{S}_{i,t}$ refers to the stock illiquidity; and $Dummy_{RSI.}$ is a dummy variable which takes the value of 1 if the relative short interest for stock *i* is ranked in the top 20%; otherwise 0. All of the remaining variables serve as control variables: $\sigma_{i,t}$ denotes the historical volatility estimated using the daily stock returns from the GARCH(1,1) model; $b_{i,t}$ is the square root of the R^2 obtained from running the daily OLS regressions of excess stock returns on the four factors proposed by Fama-French (1993) and Carhart (1997) with a one-year rolling window; $size_{i,t}$ is the natural logarithm of the market capitalization of the firm; $lev_{i,t}$ is defined as the sum of long-term debt and the par value of the preferred stock, divided by the sum of long-term debt, the par value of the preferred stock and the market value of equity. The sample period runs from January 1996 to December 2007. * indicates statistical significance at the 10% level; ** indicates significance at the 5% level; and *** indicates significance at the 1% level. The *t*-statistics include Newey-West correction for serial correlation.

Variables	ATM		ITM		OTM	
	Coeff.	*t*-stat.	Coeff.	*t*-stat.	Coeff.	*t*-stat.
Panel A: Calls						
a. Short-term Options						
α_0	0.0016	0.41	0.0004	0.23	0.1053	5.93***
β_1	−0.2000	−50.26***	−0.2700	−67.76***	−0.0725	−18.99***
β_2	0.0223	5.47***	0.0015	0.39	0.0264	7.71***
β_3	1.3483	7.82***	0.1684	2.39**	1.5192	3.19***
β_4	0.0127	2.57**	0.0065	1.38	0.0018	2.62***
β_5	−0.5971	−3.16***	0.0407	0.47	0.3434	0.59
β_6	−0.0031	−3.16***	−0.0009	−1.91*	−0.0141	−3.77***
Adj-R^2	0.1120		0.1284		0.0780	
b. Long-term Options						
α_0	−0.0015	−0.58	−0.0030	−3.13***	0.0329	2.87***
β_1	−0.1493	−44.29***	−0.3004	−86.73***	−0.0460	−11.94***
β_2	0.0229	8.34***	0.0073	2.62***	0.0229	9.91***
β_3	0.4051	5.57***	0.1604	4.05***	0.2538	1.30
β_4	0.0138	3.47***	0.0061	1.94*	0.0081	2.24***
β_5	−0.0192	−0.21	−0.0583	−1.35	0.0922	0.32
β_6	−0.0021	−2.93***	−0.0002	−0.84	−0.0035	−1.47***
Adj-R^2	0.0875		0.1383		0.0757	

Table 7 (*Contd.*)

Variables	ATM		ITM		OTM	
	Coeff.	*t*-stat.	Coeff.	*t*-stat.	Coeff.	*t*-stat.
Panel B: Puts						
a. Short-term Options						
α_0	–0.0143	–4.29***	–0.0155	–5.75***	0.0141	2.31**
β_1	–0.1780	–39.12***	–0.1230	–29.43***	–0.1426	–39.62***
β_2	0.0237	5.15***	0.0293	5.08***	0.0219	7.66***
β_3	0.7176	4.50***	–0.1663	–1.44	0.1687	0.52
β_4	–0.0132	–2.57**	–0.0091	–1.28	0.0069	1.93*
β_5	–0.2036	–1.14	0.0065	0.05	0.6243	1.78*
β_6	0.0008	0.97	0.0026	3.07***	–0.0050	–3.18***
Adj-R^2	0.1102		0.0984		0.0702	
b. Long-term Options						
α_0	–0.0097	–4.89***	–0.0063	–3.98***	–0.0181	–6.37***
β_1	–0.1409	–36.77***	–0.1066	–25.80***	–0.1359	–36.75***
β_2	0.0219	7.67***	0.0171	4.22***	0.0273	13.02***
β_3	0.2797	5.16***	–0.0569	–1.16	0.1161	1.04
β_4	–0.0020	–0.52	–0.0041	–0.79*	–0.0016	–0.62
β_5	–0.1368	–2.20**	–0.0035	–0.06	0.0851	0.69
β_6	0.0009	1.56	0.0011	2.12**	0.0013	1.86*
Adj-R^2	0.0953		0.0953		0.0668	

Table 8 Short-sales constraints regression results

This table reports the results of cross-sectional regressions of the daily delta-hedge option returns ($\tilde{R}^{O}_{i,t}$) on the level of institutional ownership, with the regression model being specified as:

$$\tilde{R}^{O}_{i,t} = a_{0,t} + \beta_{1,t}\tilde{R}^{O}_{i,t-1} + \beta_{2,t}IL^{\mathrm{O}}_{i,t-1} + \beta_{3t}IL^{\mathrm{S}}_{i,t-1} + \beta_{4,t}IL^{\mathrm{O}}_{i,t-1} \times Dummy_{op} + \beta_{5,t}IL^{\mathrm{S}}_{i,t-1} \times Dummy_{op} + \beta_{6,t}Dummy_{RSI} + \beta_{7,t}\sigma_{i,t-1} + \beta_{8,t}ln(size_{i,t-1}) + \beta_{9,t}b_{i,t-1} + \beta_{10,t}lev_{i,t-1} + \varepsilon_{i,t}$$

where $\tilde{R}^{O}_{i,t}$ represents the delta-hedge option returns; $IL^{O}_{i,t}$ denotes the option illiquidity; $IL^{S}_{i,t}$ refers to the stock illiquidity; and $Dummy_{RSI.}$ is a dummy variable which takes the value of 1 if institutional ownership of stock *i* is ranked in the top 20%; otherwise 0. All of the remaining variables serve as control variables: $\sigma_{i,\mathrm{t}}$ denotes the historical volatility estimated using the daily stock returns from the GARCH(1,1) model; $b_{i,\mathrm{t}}$ is the square root of the R^2 obtained from running the daily OLS regressions of excess stock returns on the four factors proposed by Fama-French (1993) and Carhart (1997) with a one-year rolling window; $size_{i,\mathrm{t}}$ is the natural logarithm of the market capitalization of the firm; $lev_{i,t}$ is defined as the sum of long-term debt and the par value of the preferred stock, divided by the sum of long-term debt, the par value of the preferred stock and the market value of equity. The sample period runs from January 1996 to December 2007. * indicates statistical significance at the 10% level; ** indicates significance at the 5% level; and *** indicates significance at the 1% level. The *t*-statistics include Newey-West correction for serial correlation.

Variables	ATM		ITM		OTM	
	Coeff.	*t*-stat.	Coeff.	*t*-stat.	Coeff.	*t*-stat.
Panel A: Calls						
a. Short-term Options						
α_0	0.0097	2.58***	0.0003	0.21	0.1097	6.78***
β_1	–0.2006	–49.81***	–0.2765	–62.07***	–0.0782	–20.18***
β_2	0.0295	10.85***	0.0116	4.07***	0.0384	18.21***
β_3	0.5841	6.32***	0.0840	1.88*	0.9700	3.40***
β_4	–0.0014	–0.35	–0.0029	–0.75	–0.0047	–1.32
β_5	0.1574	1.09	0.0284	0.41	0.3477	0.73
β_6	–0.0001	–0.06	0.0001	0.15	–0.0022	–0.82
Adj-R^2	0.1049		0.1279		0.0866	
b. Long-term Options						
α_0	–0.0001	–0.04	–0.0020	–2.61***	0.0357	3.43***
β_1	–0.1599	–46.03***	–0.3003	–68.75***	–0.0538	–15.53***
β_2	0.0353	13.83***	0.0142	5.92***	0.0297	15.43***
β_3	0.2714	5.81***	0.0514	2.24**	0.2887	2.12**
β_4	0.0022	0.66	–0.0021	–0.71	–0.0016	–0.58
β_5	0.1729	2.49**	0.0560	1.53	–0.0020	–0.01
β_6	–0.0009	–1.65*	–0.0002	–0.72	–0.0017	–1.07
Adj-R^2	0.0894		0.1399		0.0778	

Table 8 (*Contd.*)

Variables	ATM		ITM		OTM	
	Coeff.	*t*-stat.	Coeff.	*t*-stat.	Coeff.	*t*-stat.
Panel B: Puts						
a. Short-term Options						
α_0	–0.0118	–4.30***	–0.0109	–4.87***	0.0031	0.57
β_1	–0.1780	–41.02***	–0.1219	–31.80***	–0.1384	–42.08***
β_2	0.0104	3.71***	0.0239	5.96***	0.0225	8.00***
β_3	0.3283	3.64***	0.0203	0.33	0.4253	1.92*
β_4	0.0051	1.46	0.0020	0.41	0.0084	2.59***
β_5	0.2398	1.85*	–0.1194	–1.55	0.0150	0.05
β_6	0.0009	1.42	–0.0010	–1.80*	0.0075	4.97***
Adj-R^2	0.1010		0.0950		0.0681	
b. Long-term Options						
α_0	–0.0052	–3.14***	–0.0050	–3.58***	–0.0101	–4.11***
β_1	–0.1492	–41.29***	–0.1155	–30.81***	–0.1316	–32.14***
β_2	0.0112	5.29***	0.0102	3.31***	0.0189	9.22***
β_3	0.1696	4.71***	0.0022	0.07	–0.0641	–0.82
β_4	0.0060	2.11**	–0.0008	–0.24	0.0121	4.20***
β_5	–0.0153	–0.33	–0.0342	–0.97	0.0135	0.13
β_6	–0.0002	–0.42	–0.0005	–1.62	0.0010	1.10
Adj-R^2	0.0882		0.0912		0.0632	