The Effect of Option Transaction Costs on Informed Trading in the Option Market around Earnings Announcements

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Abstract

We investigate the effect of transaction costs related to trading options on the directional and volatility informed trading in the option market. We find that both forms of informed trading are significantly stronger among firms with lower option bid-ask spread. Importantly, the effect of transaction costs is significant around earnings announcements, but not significant (on average) around randomly chosen dates with no events of consequence. This suggests that transaction costs play a particularly important role during information intensive periods. Trading strategies based on directional informed trading and option transaction costs earn monthly abnormal returns of 1.39% to 1.91%.

Keywords: earnings announcement, informed trading, option trading strategy, price discovery process, transaction costs

JEL codes: D23, G11, G13, G14, M41

I. Introduction

In the last two decades, there has been an explosive growth in the volume of option contracts (specifically, stock options), traded in the United States and abroad.[1] In perfect, efficient, and frictionless financial markets, options would be redundant securities. In such ideal conditions, one would be hard pressed to explain the existence, the tremendous popularity, and growth in derivative trading. However, the reality is that financial markets are neither perfect nor frictionless. Trading in the stock market involves frictions and imperfections such as transaction costs, constraints on short sales, and asymmetric information related issues. Therefore, the options market, with its relatively less restrictions on short sales constraints higher leverage, becomes an attractive alternative to the equities market for investors, especially those with superior information (Black, 1975). This realization has spawned a number of research papers which has primarily focused on using the price discovery process in the option market to predict future stock returns and future stock volatility.

The focus of our study is the price discovery process around earnings announcements in the option market, and the role played by option transaction costs in this process. We focus on the earnings announcement because it is generally considered as an event of significance that should attract higher proportion of informed traders relative to normal times when there are no significant events. Consequently, the price discovery process in the option market is likely to be more intense during such major information events (Jin, Livnat, and Zhang, 2012; Atilgan, 2014).

[1] The global option market size is 9.42 billion worth of contract for 2013. The information is extracted from the website: http://www.futuresindustry.org/volume-.asp .The US option market size is 4.1 billion contracts, with a total of $1.2 trillion in options premium exchanging hands in 2013. This information is extracted from the website: http://online.wsj.com/articles/SB10001424052702303870704579297050280237182

It is to be expected that rational informed traders will weigh the benefits from their private information against the costs of trading, and factor the effect of transaction costs on their trading profits. It is also expected that the impact of transaction costs on informed trading in the option market is more likely to be keenly felt, and carry more significance, around earnings announcements (when superior information is really valuable) relative to normal times. It is also notable that while the fixed and variable costs involved with trades are roughly comparable across the option and stock market,[2] the relative bid-ask spread of options is much higher than that of the underlying stocks. For example, in our sample which includes about 5,000 firms during the period 1996 to 2011, the average bid-ask spread ratio of relatively liquid at-the-money options is as high as 20%; in contrast, the average bid-ask spread ratio of the underlying stocks is only 0.6%. Therefore we focus only on the transaction cost captured by the bid-ask spreads in the option market.

Specifically, we examine the impact of option transaction costs on two types of informed trading, namely, directional information trading, and volatility information trading. By directional and volatility information trading we mean using option market related measures to predict future stock returns, and future stock return volatility, respectively. We depart from prior studies that have examined transaction costs (relative bid-ask spreads) on the day of trading (an *ex post* measure), by measuring transaction costs at the close of a day prior to the actual trading day (an *ex ante* measure). Given the feedback effect between traded volume of options and the bid-ask

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[2] The commission fee (fixed cost) for every stock trade (whatever this trading size) is usually less than $10 across many brokerage firms. For some brokerage firms, there is also variable trading cost. For example, TradeStation will charge 0.6 cents per share for the amount beyond 500 shares. But most of other brokerage firms do not have this variable charge. For option trading, the commission fee includes initial trade fee (less than $10) plus variable cost (less than $1 per contract).

spread, we believe this *ex-ante* measure of transaction costs is more appropriate for the purpose of our study, rather than the realized *ex post* bid-ask spread after the trading is completed. In other words, by using the *ex ante* measure, we correct for the fact that traders could not have known what the *ex post* bid-ask spread would have been before they had traded.

We first examine the effect of transaction costs (or the relative bid-ask spread for the option) on directional informed trading in the option market. Directional informed trading option market based predictors used in this analysis are implied volatility spread, and implied volatility skew (Cremers and Weinbaum (2010); Van Buskirk (2009); Xing, Zhang and Zhao (2010); Jin, Livnat, and Zhang (2012)), in the Pre window [-7, -1], relative to the earnings announcement day (designated as day 0). We document that the predictability of implied volatility spread (skew) for abnormal stock returns over the earnings announcement window [0, +2] is stronger among firms with lower bid-ask spread. By contrast, the effect of the option bid-ask spread on the predictability of implied volatility spread (skew) is insignificant around random days when there are no known events of consequence. Then, we examine whether a hedged trading strategy incorporating the effects of transaction costs can significantly improve upon a trading strategy built solely on implied volatility spread (skew) around earnings announcements. That is, in each quarter, we assign stocks into four portfolios based on the option volatility spread (skew) quartile from the previous quarter. Our portfolio construction method ensures no look-ahead bias and is practically implementable. The baseline trading strategy that buys stocks in the highest (lowest) quartile of volatility spread (skew) and sells stocks in the lowest (highest) quartile earns monthly abnormal returns of 1.05% (1.17%). The hedge portfolio returns persist up to three months after the earnings announcement date. Particularly noteworthy is that, for our improved trading strategy conditional on the low option transaction costs, the hedge portfolio return is as high as

1.39% (1.91%) per month and statistically significant at the 5% (1%) level. By contrast, the corresponding hedge portfolio return in firms with high option transaction costs is only 0.42% (0.50%) per month and statistically insignificant. These results implies that informed trading will herd into options with lower transaction cost. Hence, the trading in these options carry economically stronger predictability for future stock return and imply a more profitable trading strategy.

Next, we investigate the effect of option transaction costs on volatility-based informed trading in the option market. Prior literature on volatility information trading suggests that both the implied volatility of at-the-money options, and the ratio of the option trading volume to stock trading volume (commonly referred to as the O/S ratio), can predict future stock return volatility (Harvey and Whaley, 1992; Canina and Figlewski, 1993; Jorion (1995); Christensen and Prabhala (1998); Roll, Schwartz, and Subrahmanyam (2010); Govindaraj et al. (2015)).[3] Our first predictor is the average implied volatility of short-term ATM call options in the Pre window [-7, -1]. We find that the predictability of ATM implied volatility for absolute abnormal stock returns over the earnings announcement window [0, +2] is stronger when the relative bid-ask spread of the ATM call option is lower. However, this effect is not significant around randomly chosen (non-event) dates. Our second predictor is the option O/S ratio. For consistency, we also use the underlying stock relative bid-ask spread to scale the option relative bid-ask spread when measuring option transaction cost. The finding is interesting: the predictability of O/S ratio about absolute abnormal returns over the earnings announcement window [0, +2] is significantly stronger when the option bid-ask spread ratio is higher, instead lower, relative to the underlying stock bid-ask spread ratio. Because O/S ratio is an *ex post* measurement of realized option

[3] The option trading volume is the total trading volume of all traded options for an underlying stock.

trading activity, the option trading volume is the result of a tradeoff between expected gains from private information and expected losses from transaction costs for informed traders. Then if an investor is willing to trade options in spite of the higher transaction costs, he is more likely to have more accurate and important private information that can help him gain more profit than the transaction costs. Higher transaction cost plays a role of hurdle to differentiate noise trading and informed trading, and highlights the informed trading *ex post*. Therefore, we find that, for a given level of realized O/S ratio, the higher the *ex ante* transaction costs of options relative to that of the underlying stock, the stronger the informed trading hidden in these options. Similar to our results for the ATM implied volatility, the effect of transaction costs on the predictability of O/S ratio is not significant around randomly chosen dates.

A large body of recent research in the area of market microstructure of option market traces its roots to an influential paper by Easley, O'Hara, and Srinivas (1998), who proposed that the amount of informed trading in the options market should be related to the relative liquidity of the options market *vis à vis* the stock market, and the amount of leverage achievable with options. Since then, there have been a number of papers validating the propositions of the Easley, O'Hara, and Srinivas (1998). To cite a few, Chakravarty, Gulen and Mayhew (2004) find that option market price discovery tends to be greater when the option volume is higher relative to stock volume (the O/S ratio), and when the effective bid-ask spread in the option market is narrow relative to the spread in the stock market. With particular focus on predicting future stock returns, Cremers and Weinbaum (2010) document that the predictability of volatility spread for future stock returns is larger when option liquidity is high and stock liquidity is low. Xing, Zhang and Zhao (2010) find that the volatility skew predicts future stock returns better when stock market liquidity (stock turnover) deteriorates. Similar findings about the predictive power of option volatility skew and option volatility spread in predicting future stock returns have been recorded by Van Bursirk (2009), and more recently by Jin, Livnat, and Zhang (2012), and other authors (for example, Bali and Hovakimian, 2009; Chan, Chang and Lung, 2009). Some of the papers that have focused on predicting future stock volatility using the implied volatility of at-the-money options and the O/S ratio include Jorion (1995); Christensen and Prabhala (1998); Roll, Schwartz, and Subrahmanyam (2010); Govindaraj et al. (2015).

Our work differs from the prior studies in a number of ways. First, we focus on the effects of transaction costs on informed trading in the option market around a significant event, namely, the earnings announcement. There is little prior research on the effects of transaction costs with respect to any specific information event, and none with respect to earnings announcement. This is particularly important because the connection between private information and informed trading is most relevant around important information events; and it is our conjecture that transaction costs during these events can help shed light on informed and uninformed trading.

Second, in addition to informed trading on directional information, we also investigate how transaction costs affect the informed trading about the future volatility around earnings announcements. To the best of our knowledge, our study is the first one to examine the impact of transaction costs on volatility-related informed trading in the option market.

Third, as pointed out earlier, prior studies measure transaction costs and liquidity concurrently or after the trading volume is revealed, and show that options with higher trading volume or lower *ex post* bid-ask spread are more informative about future stock returns. Unlike these studies, we examine how the *ex ante* transaction costs of options affect the trading decisions of informed traders.

The remainder of this article is organized as follows: In Section II, we present our research design. Data and sample is presented in the Section III. Section IV presents empirical results on the effect of option transaction costs on the directional informed trading in the option market. The trading strategy based on volatility spread (skew) and transaction costs is described in Section V. In section VI, we investigate the effect of option transaction costs on the volatility-related informed trading. Section VII summarizes our results and presents suggestions for future research.

II. Research Design and Sample

A. Base and Pre Windows

It seems intuitive that option traders would have stronger incentives to acquire private information before information events, particularly before anticipated information events such as earnings announcements. Therefore, an informed trader's information advantage is presumably larger immediately before significant information events (Kim and Verrecchia, 1994, Skinner, 1997). Following this reasoning, we use the incremental predictive ability of the option market measures in a window close to and just prior to the announcement date (we refer to this window as the Pre window), relative to that of the same measures during a window before the Pre window (we refer to this as the Base window), to capture informed trading in option market. We first identify the event date (day 0). We then measure volatility spread/skew, implied volatility of ATM call options and O/S ratio over two windows: trading days [–30, –8] (Base window) and trading days [–7, –1] (Pre window)[4]. We attempt to predict abnormal returns and absolute abnormal return in [0, +2] (event window). Figure 1 below illustrates this graphically on a time line.

[4] Our results were unaffected when using other windows such as [-30, -11] for the Base window and [-10, -1] for the Pre window.

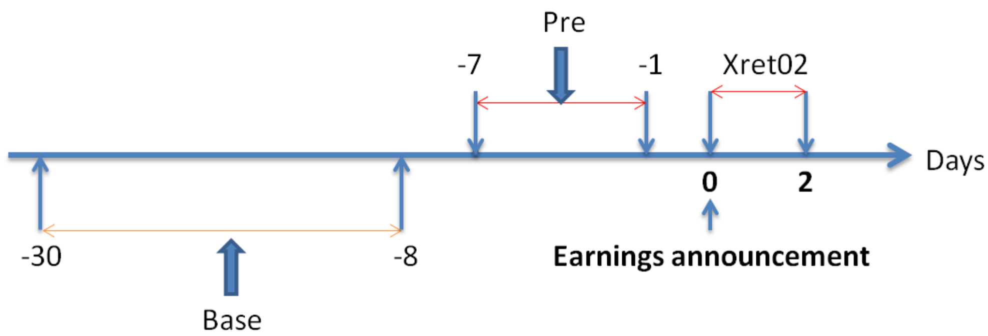

Figure 1

B. Measures of Informed Trading

We construct four measures of informed trading in the option market. Two of these measure directional informed trading, namely, implied volatility (IV) spread, and implied volatility (IV) skew. These are used for predicting future stock abnormal returns. The other two measures, namely, the implied volatility of ATM call options and option trading volume to stock trading volume (O/S) ratio, are the volatility-related informed trading measures that we use to predict the absolute value of future stock abnormal returns.

IV spread is the implied volatility difference between call and put options with the same strike price and maturity (call-put parity deviation). We calculate volatility spread as the equal-weighted average of the difference in implied volatilities between all matched call and put option pairs over the Base and Pre window.[5] While the original Black-Scholes model predicts this spread should be zero, later work has shown this is not true in reality. As an example, it has been recorded that when option traders obtain information about a positive (negative) event, the demand for call (put) options increases relative to the demand for put options, and this results in deviations from zero for the IV spread. Ofek, Richardson, and Whitelaw (2004) and Cremers and Weinbaum (2010) show that this volatility spread can predict future stock returns, and Jin, Livnat

[5] We also consider volume-weighted and open-interest weighted measures.

and Zhang (2012) show that the volatility spread can predict abnormal stock returns around earnings announcement.

IV skew is the difference between the implied volatilities of out-of the money (OTM) put options and at-the-money (ATM) call options. To understand why there should be a difference, consider the case where option traders obtain information about a negative event. To protect themselves, they would trigger an excess demand for OTM put options relative to the demand for ATM call options, thereby increasing volatility skew. Consistent with volatility skews reflecting negative information, Xing, Zhang, and Zhao (2010) document that stocks with the largest volatility skews in their traded options underperform stocks with the smallest skews by 10.9% per year. Jin, Livnat and Zhang (2012) also find that volatility skew can (negatively) predict abnormal returns around earnings announcement dates. Following Jin, Livnat and Zhang (2012), for the Base and Pre windows, we select call options that have a delta in the range of [+0.4, +0.7], and choose the one closest to 0.5. Its implied volatility is the ATM implied volatility; and we then select all put options that have a delta in the range of [–0.45, –0.15][6]. We impose the conditions that the option expiration date should be between 10 and 60 days away and open interest should be positive. The volatility skew is the equal-weighted implied volatility of the OTM put options minus the implied volatility of the ATM call option over the Base and Pre window.[7]

The first measure of volatility informed trading in the option market is the implied volatility of ATM call options. Prior research shows that the implied volatility of an option can predict the ex-post realized stock return volatility over the remaining life of the option. For example,

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[6] We do not follow Jin, Livnat and Zhang (2012) by only choosing the put options with delta closest to -0.3. This is because the informed trader with negative information can also trade other options. Furthermore, when we apply the volume-weighted measure of IV skew, we need to consider the trading volume, and so we include all the options in the delta range [-0.45, -0.15]. We also try the method in Jin, Livnat and Zhang (2012) as a robustness check, and our results remain qualitatively similar.

[7] Once again, we also consider volume-weighted and open-interest weighted measures.

Christensen and Prabhala (1998) document that volatility implied by S&P 100 index option price outperforms past volatility in forecasting future volatility. Ederington and Guan (2002) show that the implied volatility from S&P500 futures options has strong predictive power and generally subsumes the information in historical volatility. To measure the ATM implied volatility, we identify for each day all call options of a firm with time-to-maturity between 10 and 90 days, and expiring after the earnings announcements (or random event days as the case may be). Then, from this set, we select call options that have a delta in the range of [+0.4, +0.7], and choose the one closest to 0.5. Its implied volatility is the ATM implied volatility.

O/S ratio is defined as the natural logarithm of the total daily option trading volume divided by the daily stock trading volume. Roll, Schwartz, Subrahmanyam (2010) show that the O/S ratio in pre-earnings announcement window can predict absolute abnormal returns in the earnings announcement window [0, +2]. This is consistent with the notion that at least a part of the increases in the O/S ratio occur just before earnings announcements is attributable to increased trading by the informed traders attempting to exploit their private knowledge of the upcoming unanticipated earnings surprise. In addition, since earnings surprises can be either negative or positive, and given that both long side and short side strategies can be conducted in the options market, the O/S ratio can reflect the private information about the magnitude of future earnings announcement abnormal return.

C. The measurement of transaction costs for options

We measure option transaction costs using the option relative bid-ask spread, which is defined as the ask price minus the bid price and then divided by the average of the bid and ask price. In the absence of real time intra-day data on bid-ask spreads for the option market, we use the closing bid-ask spread from the previous trading day for call and put options to measure their transaction costs. Since we are interested in the volume of informed trading conditional on the transaction costs, it seems natural to document the next day traded volume, given the bid-ask spread before they trade (an *ex ante* measure). As mentioned earlier, this is distinct from prior studies that measure traded volume and the bid-ask spread concurrently at the closing time of the same trading day. Since the bid-ask spread and volume are jointly determined, the closing time bid-ask spread incorporates the volume traded; and in this sense it is an *ex-post* measure of transaction costs.

III. Data and descriptive statistics

A. Data

The sample period for our study is from 1996 to 2011. We obtain earnings announcement dates from Compustat, and data on stock returns as well as trading volume information from the Center for Research on Security Prices (CRSP) database. Our option data is obtained from OptionMetrics, which provides daily close bid and ask quotes, open interest, volume, implied volatilities, and option "greeks" for all put and call options listed and traded in the U.S. options market. OptionMetrics calculates the underlying implied volatilities of individual options using the binomial trees methodology that takes into account early exercise of individual stock options, and the dividends expected to be paid over the lives of the options.

B. Descriptive statistics

Table 1 presents the summary statistics. Panel A presents the descriptive statistics for the IV spread sample. The sample consists of 92,504 earnings announcements for 4,927 unique firms. The mean and standard deviation of the abnormal return over the earnings announcement window [0, +2] are 0.1% and 9.1%, respectively. The means of the IV spreads in the Base window [-30, -8] and the Pre window [-7, -1] are both about -0.01, suggesting that put options are on average more expensive than call options.[8] The standard deviation of IV spread in the Pre window is 3.6%, which is about 20% larger than that in the Base window. The mean of option relative bid-ask spread in the Pre window [-7, -1] is as high as 31.7%. The firm size (i.e. market value of equity) is on average 1.5 billion dollars (similar to Johnson and So (2012)), the book to market ratio is on average 0.38, and the momentum (month t-12 to month t-1) is on average 18.1%. The annualized historical volatility of stock returns on the window [-70, -10] is 45% on average. This is similar to the findings in Xing, Zhang and Zhao (2010).

<INSERT TABLE 1 HERE>

Panel B presents the descriptive statistics in the IV skew regressions. The sample consists of 66,872 earnings announcements for 4,510 unique firms. The average IV skew in the Base window [-30, -8] is 0.030 and it increases to 0.035 in the Pre window [-7, -1]. Compared to call options, put options become more expensive in the period closer to earnings announcement. The average option relative bid-ask spread is 34.1%, with standard deviation of 29.3%. The firm size, book to market ratio and historical volatility are similar to those in the IV spread sample.

Panel C presents the descriptive statistics in the IV_ATM regressions. The sample consists of 92,474 earnings announcements for 5,293 unique firms from the year 1996 to 2011. The average implied volatility of ATM call options in the Pre window [-7, -1] is 0.515, which is slightly higher than that in the Base window [-30, -8] which is (0.50). This is consistent with the fact that option market incorporates more information about the uncertainty of the upcoming earnings

[8] This is consistent with the notion that more jump risk premium is embedded in put options (e.g. Cummins, 1988; Pan, 2002).

release closer to the earnings event date (Roll, Schwartz and Subrahmanyam, 2010). The average relative bid-ask spread of ATM call options is 20.1%, which is much lower compared to those in the IV spread and IV skew sample. This suggests that the relative bid-ask spread of ATM call options is lower than the average of all options or that of OTM put options. The annualized historical stock returns volatility is on average 0.467. It is lower than the option implied volatility. This is consistent with Bakshi and Kapadia (2003a, 2003b), who attribute the difference between option implied volatility and stock historical volatility to the negative volatility risk premium.

Panel D displays the summary statistics for O/S ratio sample. The sample consists of 81,237 earnings announcements of 4,752 unique firms from the year 1996 to 2011. The absolute value of abnormal returns in the 3-day earnings announcement window [0, +2] is on average 6.3% This is larger than the average absolute abnormal returns of 5.1% in the one-week Pre window [-7, -1] immediately before the earnings window). The O/S ratio in the Pre window [-7, -1] is smaller than zero, indicating that the total dollar trading volume across all options is less than the dollar trading volume of the underlying stock. More specifically, the option trading volume is on average only 3.4% of the stock trading volume in the Pre window. In the meantime, the relative bid-ask spread in the option market is about 550 times as high as that in the stock market, suggesting that the stock market is much more liquid than the option market.

Table 2 presents the Pearson and Spearman correlation coefficients. Panels A, B, C, and D show the correlation for the variables in the IV spread regressions, IV skew regressions, IV_ATM regressions and the O/S ratio regressions, respectively.

<INSERT TABLE 2 HERE>

In Panel A, the IV spread in the Pre window [-7, -1] is positively and significantly correlated with the abnormal stock returns in window [0, +2] (XRET02), with Pearson and Spearman correlation coefficients at 0.022 and 0.018 respectively. Although IV spread in the Base window is highly correlated with IV spread in the Pre window (Spearman 0.463 and Pearson 0.595), it is not significantly correlated with XRET02. This suggests that informed trading in the option market is stronger in the Pre window than in the Base window. The relative bid-ask spread in the Pre window is negatively correlated with firm size and positively correlated with book-to-market ratio, suggesting lower option transaction costs in larger firms, and firms with lower book-to-market ratios. Additionally, as expected, firm size is negatively correlated with historical volatility (Spearman -0.478 and Pearson -0.390). Panel B shows that IV skew in the Pre window is significantly and negatively correlated with the abnormal stock returns in window [0, +2] (XRET02), with Pearson and Spearman correlation coefficients at -0.015 and -0.019 respectively. However, the correlation between IV skew in the Base window and XRET02 is insignificant. Panel C shows that the implied volatility of ATM call options in both the Pre window and the Base window are positively correlated with AXRET02. The Pearson and Spearman correlation coefficients are 0.359 and 0.357 and both are significant at 1% level. The implied volatility is negatively correlated with firm size and book-to-market ratio, and positively correlated with historical stock return volatility. In Panel D, the O/S ratio in the Pre window [-7, -1] is positively correlated with absolute abnormal returns in the window [0, +2] (AXRET02). The Pearson and Spearman correlation coefficients are 0.038 and 0.044 and both are significant at 1% level. The O/S ratio in the Base window, while somewhat smaller in magnitude, is also positively and significantly correlated with AXRET02 (Pearson 0.025 and Spearman 0.031). In addition, both the historical stock returns volatility and implied volatility of ATM call options are positively correlated with AXRET02 at the 1% significance level.

C. Options trading volume and implied volatility around earnings announcements

Figure 2 illustrates the option trading volume and implied volatility in the 60 trading days ([-30, +30]) around earnings announcements. Call options and put options show similar patterns. The implied volatility starts to increase from about 18 trading days before earnings announcements, peaks on 1 trading day before earnings announcements and then plunges to the previous level in about 7 trading days after earnings announcements. The option trading volume starts to increase from about 7 trading days before earnings announcement, peaks on the earnings announcement date and then plunges to the previous level in about 7 trading days after earnings announcements. Based on the change of options trading volume, we choose [-7, -1] as our prediction window and [-30, -8] as the Base window.[9]

<INSERT FIGURE 2 HERE>

Another interesting fact from Figure 2 is that the call option trading volume is larger than the put option trading volume. In the Base window period, the average daily trading volume is about 60 contracts for call options and 50 contracts for put options. In the earnings announcement period, the average daily trading volume is about 140 contracts for call options and 110 contracts for put options. Consistent with Lakonishok et al. (2007), Figure 2 suggests that call options trading is more active than put options trading.

IV. The effect of transaction costs on the directional informed trading

[9] We also choose [-10,-1] as prediction window as a robustness test. The results remain qualitatively similar.

Table 3 reports the Fama–MacBeth statistics based on 64 quarterly regressions. The heteroscedasticity and autocorrelation in the time-series t-statistics are corrected according to the Newey and West (1987) procedure using four lags[10]. The sample includes all earnings announcements with data available from 1996 to 2011. The dependent variable is the stock excess return in the window [0, +2], with earnings announcement date designated as the trading day 0. Following Daniel and Titman (1997), we measure excess returns as the buy-and-hold return over the designated window minus the buy-and-hold return from a portfolio of stocks of similar size (market value of equity, two groups), book-to-market ratio (three groups), and 12-month momentum (three groups). Panel A presents the regression results for earnings announcement sample and Panel B presents the results for a randomly chosen date sample. We winsorize each of these variables at 1st and 99th percentile to control for outliers.[11]

<INSERT TABLE 3 HERE>

We first discuss the results in Panel A. Equal-weighed IV spread is the predictor in Models 1to 3; equal-weighted IV skew is the predictor in Models 46. Model 1 is the base model and only includes IV spreads in the Base and Pre window (Jin, Livnat and Zhang, 2012). The coefficient of IV spread in the Pre window is 0.074, and is positively significant at the 1% level. From an economic point of view, our results show that one standard deviation increase of IV spread leads to 2.7% increase in abnormal stock returns in earnings announcement window. These results are consistent with previous literature (Cremers and Weinbaum, 2010, Jin, Livnat and Zhang, 2012). Model 2 presents the effect of transaction costs on the predictability of IV spread. The interaction term between transaction costs and IV spread is significant at 1% level and the coefficient is -

[10] We choose four lags because the seasonality of quarterly earnings. The earnings at quarter t is likely to be autocorrelated with earnings at quarter t-4, so is the abnormal return around earnings announcement.
[11] We also carried out regressions without winsorizing the variables, and the results remains qualitatively similar.

0.117, with opposite sign to the coefficient of IV spread. This indicates that, transaction costs impose a significant offsetting effect on informed trading in the option market. Additionally, after controlling for the effect of transaction costs, the predictability of IV spread increases. The coefficient of IV spread increases by 70%, from 0.074 to 0.126, and the t-value remains similar. This implies that the predictability of IV spread is largely influenced by option related transaction costs. In Model 3, to rule out the possibility that the result is sensitive to other determinants of abnormal stock returns, we control for size and book-to-market factors as in Fama and French (1993), a momentum factor as in Carhart (1997) and the historical volatility of stock return over [-70, -10] as in Xing, Zhang, and Zhao (2010). Additionally, we also control for the abnormal stock return in Pre window [-7, -1], due to the reversal pattern of stock returns (Jegadeesh, 1990). The predictability of IV spread is still highly significant. The effect of transaction costs still remains significant at the 5% level and also economically important.

Models 4-6 presents the results for IV skew. Model 4 is the base model (Jin, Livnat and Zhang, 2012) and only includes IV skew in the Base window [-30, -8] and in the Pre window [-7, -1]. The coefficient of IV skew in the Pre window is -0.036, and is significant at the 1% level. Our results show that one standard deviation increase in IV skew induces 2.6% lower stock excess returns in the earnings announcement window. We consider the effect of option related transaction costs in Model 5. The interaction term between transaction costs and IV skew is significant at 5% level and the coefficient is 0.068, with opposite sign to the coefficient of IV skew. Similar to IV spread, after controlling for the effect of transaction costs, the predictability of IV skew also increases: the magnitude of coefficient increases by 97%, from -0.036 to -0.071, and the t-value increases from 3.53 to 4.74. Therefore, the predictability of IV skew is also affected by option related transaction costs. In model 6, after controlling for size, book-to-market ratio, momentum and abnormal stock returns in the Pre window and historical volatility, the effect of transaction costs still remains significant at 5% level.

To compare the effect of transaction costs in different information environment, we replicate our analysis in a random day sample. The results are presented in Panel B. This day is a randomly selected trading day in the calendar day window of [+30, +60][12] relative to the earnings announcement date. Earnings announcement is a significant and anticipated information event, which triggers strong market reaction. More informed trading happens during this period (Kim and Verrecchia, 1994; Skinner, 1997). Because rational informed traders are expected to weigh the benefits from their private information against the costs of trading, they are likely to care more about option transaction costs than liquidity and noise traders. However, there is less informed trading on a randomly selected date, when no significant information is released. Therefore, we expect option transaction costs to have a much weaker effect on informed trading in the option market in this Pseudo event. In Models 1-3, we find the predictability of IV spread decreases but still remains significant, which is consistent with Cremers and Weinbaum (2010) and Jin, Livnat and Zhang (2012). However, the effect of option transaction costs becomes insignificant in Models 2 and 3 for the Pseudo event. We find similar results in the regressions of IV skew, in Models 4-6.

As a robustness test, we also consider volume-weighted and open interest-weighted measures of IV spread (skew) and transactions costs, and find similar results. For brevity, the results are not tabulated. The above empirical findings are consistent with Easley, O'Hara, and Srinivas (1998): transaction costs play an important role in the informed trading in the option market.

[12] We also try other windows: [+0, +30], and [+60, +90] relative to the earnings announcement date. The results remain qualitatively similar.

Additionally, these results also confirm the our predication about the effect of transaction costs: option trading costs play a more important role during major information events due to the more intense informed trading during these periods.

Chakravarty, Gulen and Mayhew (2004) have argued that the effect of option transaction costs is of secondary importance, compared with the effects of option leverage. However, this does not apply to the volatility spread in our study. We construct the volatility spread by a pair of call and put options, with the same strike price and maturity. The sum of the absolute values of their deltas will always be theoretically equal to 1. There is no cross-sectional and time series variation of leverage (delta) for different volatility spreads.[13] So the effect of leverage cannot substitute the effect of transaction costs for volatility spread. On the other hand, the leverage of volatility skew (the leverage of put option) is positively correlated with its relative bid-ask spread (transaction cost).[14] Therefore the options with higher transaction costs will attract less informed trading, but their higher leverage should attract more informed trading (Easley, O'Hara, and Srinivas; 1998). This offsetting effect of transaction costs and leverage should make the statistical significance of option transaction costs weaker, and make it less likely that we will obtain significant results. Despite this offsetting effect of leverage, we still find significant effect of option transaction costs on informed trading, and adds to the strength of our findings.

We also note the differences between our study and the prior work by Amin and Lee(1997), Cremers and Weinbaum (2010) and Atilgan (2014). They also use option relative bid-ask spread

[13] Empirical data show very small variation in the interval [+0.49, +0.51].
[14] We only consider the leverage of put option here, because call option is only used as a benchmark in the construction of IV skew. The OTM put's leverage is larger than the ITM put's leverage, because its delta-to-premium ratio is larger.

to examine the relationship between option liquidity on the predictability of IV spread. In contrast to our study, they use the contemporaneous closing bid-ask spread ratio to measure liquidity and compare predictability of IV spreads with different liquidity. However, given that option trading affects liquidity and predictability simultaneously, it is difficult to make a causality argument between liquidity and predictability of IV spread. Another difference between our study and theirs is the intra-firm comparisons versus the inter-firm comparisons in our study. In their research, option volatility spreads are assigned to three groups according to their liquidity within every stock. The comparison of the predictability of volatility spread is within firm. In other words, their methodology captures the intra-firm variation of the predictability of option volatility spread. However, our methodology captures the inter-firm variation of the predictability of volatility spread. For every firm every quarter, we have one measure of option transaction costs. The Fama-Macbeth regression in our study compares the predictability of volatility spread across all firms in each quarter. Our methodology of inter-firm comparison can help construct an implementable trading strategy in the stock market.

V. Trading Strategy

The above results show that IV spread and IV skew can predict future abnormal stock returns. Our next goal is to construct a stock trading strategy based on these option informed trading measures, and investigate the effect of option transaction costs on the trading profit.

A. Base strategy

The base trading strategy is constructed as follows. In every quarter, all firms are assigned to four groups based on the average volatility spread or volatility skew in the pre-earnings announcement window [-7, -1]. Then we have three cutoff points determined by the quartile

(25th, 50th, and the 75th percentile) of volatility spread or volatility skew. In quarter t+1, we buy (short) the stocks with volatility spread (skew) larger than the 75th percentile cutoff point of quarter t, and short (buy) the stocks with volatility spread (skew) smaller than the 25th percentile cutoff point in quarter t. From 1996 to 2011, we construct trading portfolios in 63 quarters (from 1996Q2 to 2011Q4). The reason that we only have 63 quarterly portfolios is that we use the first quarter of the sample period, 1996Q1, to construct the stock selection benchmark for the next quarter, and we continue with the same construction process for the following quarters. Therefore, our last stock selection benchmark is the 3rd quarter of 2011. This portfolio formation method is practically implementable and involves no look-ahead bias. Equally-weighted buy-and-hold abnormal returns for this long-short strategy are shown for three periods, [0, +2], [0, +7], and [0, +30].[15] As in Daniel and Titman (1997), the abnormal return is calculated as the return of a particular stock minus the return from a portfolio of stocks of similar size (market value of equity, two groups), book-to-market ratio (three groups), and 12-month momentum (three groups. The reported t-statistics of the long-short strategy abnormal return are calculated over the time-series of 63 calendar quarters.

<INSERT TABLE 4 HERE>

Table 4 presents the abnormal returns for the implementable trading strategies. Panel A presents the results for volatility spread. As the rank of volatility spread becomes higher, the abnormal return becomes larger. This pattern is close to monotonic. For 3-day holding period, the long-short strategy produces 0.51% abnormal returns. For 1-week holding period, the abnormal return is 0.65%. For 1-month, 2-month and 3-month holding periods, the abnormal returns are 1.05%, 1.15% and 1.76%, respectively. The number of stocks in our portfolio ranges from 216 to 827

[15] Value-weighted buy-and-hold return shows qualitative similar results.

over the 63 calendar quarters. The portfolio returns are significant at 1% or 5% level. The magnitude of abnormal return increases as the holding period becomes longer. These results imply that the implied volatility spread can predict abnormal stock returns for up to 3 months after the earnings announcement. .

Panel B presents the results for volatility skew. As volatility skew becomes larger, the abnormal return becomes smaller monotonically. The abnormal returns for holding period [0, +2], [0, +7] and [0, +30] are 0.61%, 0.83%, and 1.17%, respectively. All of them are significant at 1% level over the 63 calendar quarters. And for 2-month and 3-month holding period, the abnormal returns are 1.50% and 1.75%, respectively. Both of them are significant at 5% level. The number of stocks in the portfolio ranges from 158 to 510 over the 63 calendar quarters. Similar to the findings for volatility spread, the abnormal return becomes larger as the holding period becomes longer. These results imply that the implied volatility skew can predict abnormal stock returns for up to 3 months after the earnings announcement.

It is important to note that our trading strategy and stock portfolio is constructed before the anticipated earnings announcement based on information solely from option market. This makes our trading strategy practically implementable. Our result is also in line with previous literature documenting that option market leads stock market in the price discovery process (Pan and Poteshman (2006), Ni, Pan and Poteshman (2008), Bali and Hovakimian (2009), Cremers and Weinbaum (2010), Xing, Zhang and Zhao (2010), Jin, Livnat and Zhang (2012), Johnson and So (2012), An et al. (2014)).

B. Improved strategy incorporating transaction costs

As shown in Table 3, informed trading in the option market is stronger among firms with lower option relative bid-ask spread. Therefore, we next show that by incorporating transaction costs when constructing the trading portfolio, we can improve substantially the abnormal returns obtained from our Base strategy in subsection A.

Similar to the benchmark selection of volatility spread (skew), in quarter t, the average option transaction costs in the pre-earnings announcement window [-7, -1] is assigned to 4 groups. So we have 3 quartiles (25th, 50th, and 75th percentile) for quarter t. Then, in quarter t+1, we select stocks whose option transaction costs in the pre-earnings announcement window [-7, -1] fall into the highest and lowest quartile from quarter t. Within these two groups of stocks, we repeat the portfolio formation step in the above subsection A to construct the long-short trading portfolios. Our results are presented in table 5.

<INSERT TABLE 5 HERE>

Panel A of Table 5 presents the portfolio abnormal returns based on volatility spread and transaction costs. For low transaction costs group, abnormal returns increase monotonically with the rank of volatility spread. The abnormal portfolio returns of the low transaction costs group increase from 0.91% to 3.03% as the holding period increases from [0, +2] to [0, +90], and are statistically significant (except for the 2-month holding period). More importantly, for all holding periods, the abnormal portfolio returns are larger than the corresponding abnormal returns from the base strategy. The number of stocks in the portfolio ranges from 54 to 359 over the 63 calendar quarters, which provides a large enough stock pool for the trading strategy. It may be worth noting that while the new strategy incorporating transaction costs outperforms the base strategy across all 5 holding periods, the statistical significance (t-statistics) decreases. One possible reason is that, the standard error of abnormal returns now come from two sources, namely volatility spread and transaction costs, instead of just one source (only volatility spread) as in the base strategy. It is possible that introducing this extra dimension increases standard error and decreases the significance level of abnormal returns.

In the high transaction costs group, we do not find a monotonic relationship between the rank of volatility spread and abnormal stock returns. The abnormal portfolio returns are smaller than the abnormal returns from the base strategy and insignificant. This suggests that the predictability of volatility spread deteriorates when option transaction costs are high.

Panel B of Table 5 presents the portfolio abnormal return based on volatility skew and transaction costs. For low transaction costs group, abnormal returns decreases monotonically with the rank of volatility skew. The abnormal portfolio returns of the low transaction costs group increase from 0.65% to 2.46% as the holding period increases from [0, +2] to [0, +90], and are statistically significant. More importantly, for all holding periods, the abnormal portfolio returns are larger than the corresponding abnormal returns from the base strategy. The number of stocks in the portfolio ranges from 58 to 241 over the 63 calendar quarters. In the high transaction costs group, we do not find a monotonic relationship between the rank of volatility skew and abnormal stock returns. The abnormal portfolio returns are smaller than those from the base strategy and insignificant.

For the high transaction costs group, the abnormal returns for the 5 different holding periods are insignificant, and smaller than the corresponding abnormal returns from Base strategy. In a nutshell, the above results from panel A and Panel B show that incorporating option transaction costs effect can largely improve the performance of the implementable trading strategies based on volatility spread and volatility skew. More importantly, option transaction costs can still maintain its information-filtering function in this out-of-sample trading strategy analysis, in addition to the in-sample regression analysis in Section IV.

Figure 3 presents the quarterly time-series abnormal return of implementable trading strategies in Table 4 and 5. Abnormal portfolio returns for the 1-month ([0, +30]) holding period are displayed over 63 quarters (from 1996Q2 to 2011Q4). Figure 3a presents the quarterly abnormal return series for the base strategy of volatility spread. Figure 3b presents the abnormal return series for the improved strategy based on volatility spread and transaction costs. The green bar represents the abnormal return of low transaction costs group and the red bar represents the abnormal return of high transaction costs group. In 38 of the total 63 quarters (60%), the low transaction costs group produces higher abnormal returns than the high transaction costs group. Compared to abnormal return series in figure 3a, the two groups of abnormal return series in figure 3b become more volatile. This is consistent with the above result that adding one more dimension (transaction costs) into the trading strategy induces higher volatility of portfolio returns. Figure 3c presents the quarterly abnormal return series for the base strategy of volatility skew. Figure 3d presents the abnormal return series for the improved strategy based on volatility skew and transaction costs. Similarly, the green bar represents the low transaction costs group and the red bar represents high transaction costs group. In 39 of the total 63 quarters (62%), low transaction group produces higher abnormal returns than high transaction costs group.

<INSERT FIGURE 3 HERE>

VI. The impact of transaction costs on volatility-related informed trading

In this section, we investigate whether ex ante transaction costs affect volatility-related informed trading (second moment informed trading, namely, informed trading based on private information about the future volatility of the underlying stock return) in the option market. Specifically, we study the effect of option transaction costs on the predictability of implied volatility for the future absolute abnormal returns. It is worth noting that since we are predicting the future absolute returns, we cannot easily exploit the results to construct trading strategies that earn abnormal returns in the stock market.

A. The impact of transaction costs on the predictability of implied volatility

Table 6 shows the impact of transaction costs on the predictability of implied volatility for future absolute abnormal returns. The dependent variables are the absolute abnormal returns in the window [0, +2]. Following previous literature(e.g., Harvey and Whaley, 1992; Canina and Figlewski, 1993; Jorion,1995; and Christensen and Prabhala, 1998), the predictor we use is the implied volatility of ATM call options. The models are estimated using the Fama–MacBeth regressions over 64 calendar quarters. Results for earnings announcement sample and Pseudo event sample are reported in Models 1 to 3, and Models 4 to 6, respectively.

<INSERT TABLE 6 HERE>

For the earnings announcement sample, we find that the implied volatility in the Base window and Pre window are both positively and significantly associated with absolute abnormal returns in the window [0, +2] (Model 1). However, the coefficient and statistical significance for the Pre window implied volatility are much larger than those for the Base window implied volatility, suggesting stronger informed trading in the Pre window. In Model 2, we add the proxy for *ex ante* transaction costs and its interaction with the implied volatility in the Pre window. The coefficient for the interaction is -0.065, significant at 1% level. This implies that investors with volatility information are more likely to trade options with lower transaction costs. In model 3, we add more control variables to check the robustness of our results. The control variables include firm size, book-to-market ratio, historical stock returns volatility, and absolute abnormal returns in the Pre Window. After controlling for these variables, we still find a negative and significant coefficient for the interaction between the option bid-ask spread and implied volatility.

We perform similar analysis for the sample of randomly chosen dates. We find that the implied volatility in Pre window also has predictability for future abnormal stock returns (Model 4). However, the coefficient for implied volatility in the Pre window is only half as large compared to the earnings announcement sample, suggesting a weaker predictability around random dates. The effect of *ex ante* transaction costs on the predictability of implied volatility is marginally significant in Model 5. After controlling for other variables, the effect becomes insignificant (Model 6). These results show consistent patterns with those in the directional informed trading from Section IV: option transaction costs play an important role in the informed trading, and its effect is only significant around information-intensive events.

B. The impact of transaction costs on the predictability of O/S ratio

<INSERT TABLE 7 HERE>

Table 7 shows the impact of transaction costs on the predictability of O/S ratio for future absolute abnormal returns. The dependent variables are the absolute abnormal returns in the window [0, +2]. The models are estimated using the Fama–MacBeth regressions over 64 calendar quarters. Results for earnings announcement sample and random date sample are reported in Models 1 to 3 and Models 4 to 6, respectively.

We first discuss results for the earnings announcement sample. Consistent with Roll, Schwartz, and Subrahmanyam (2010), we find that O/S ratio in the Pre window can predict absolute abnormal returns in the earnings announcement window [0, +2] (Model 1). This indicates that the larger ratio of options trading volume to stock trading volume prior to an earnings announcement is, ceteris paribus, associated with a larger absolute price movement during the earnings announcement window. In Model 2, we add the proxy for transaction costs (relative bid-ask spread) and its interaction with the O/S ratio in the Pre window. We find that the predictability of O/S ratio is significantly stronger when the relative bid-ask spread of options market is higher relative to that of stock market. That is, for a given level of O/S ratio, the higher the transaction costs of options relative to that of the underlying stock, the stronger the information revealed from O/S ratio about future absolute abnormal returns. That means, if an investor is willing to trade in spite of the higher transaction costs, then he is more likely to have more accurate and important private information that can help him gain more profit than the transaction costs. As the trading volume is the result of a tradeoff between gains from private information and losses from transaction costs, for each unit of trading volume that has been realized, a larger transaction costs implies stronger information associated with the transaction, and stronger informed trading. In Model 3, we add more control variables to check the robustness of our results. The control variables include firm size, book-to-market ratio, historical stock returns volatility, implied volatility of ATM options and absolute abnormal returns in the Pre window. After controlling for these variables, we still find a positive coefficient for the interaction between relative bid-ask spread and the statistical significance level increases from 10% to 5%.

For the Random date sample, we find O/S ratio in Pre window also has predictability for future abnormal stock returns (Model 4). However, the coefficient and statistical significance for O/S ratio in the Pre window are much smaller than those in the earnings announcement sample, suggesting a weaker predictability around Random date. More importantly, the effect of transaction costs on the predictability of O/S ratio becomes insignificant, as shown in Model 5 and Model 6.

Taken together, we find significant impact of ex ante transaction costs on the volatility informed trading in the option market around earnings announcements. Specifically, the implied volatility of ATM options is more informative about future abnormal returns when the relative bid-ask spread at the end of the previous trading day is lower. For a given level of O/S ratio, the higher the transaction costs of options relative to that of the underlying stock, the stronger the information revealed from O/S ratio about future abnormal returns. However, we find no significant role of transaction costs in the Random dates sample.

VII. Conclusions

In this study, we investigate the effect of ex ante option transaction costs on the informed trading in the option market. We examine two forms of informed trading: directional-based and volatility-based informed trading. We find that both forms of informed trading in the option market are significantly stronger among firms with lower option relative bid-ask spread. We also document that option transaction costs have different effects in different information environments. It has significant effect around earnings announcements, but not around random days with no events of consequence. This suggests that transaction costs play a particularly important role during information intensive periods. We also build a trading strategy, which produces abnormal monthly return of 1.05% (1.17%) based on volatility spread (skew). After considering transaction costs, the performance increases to 1.39% (1.91%) per month at significance level of 5% (1%).

One limitation of our study is the data. As we do not have the transaction level data, we can only use the methodology of lead-lag relationship between option market and stock market to investigate the effect of transaction costs. It might also be interesting to use the transaction level data and apply methodology such as Hasbrouck's information share (Hasbrouck, 1991) to explore the effects of option transaction costs in the future.

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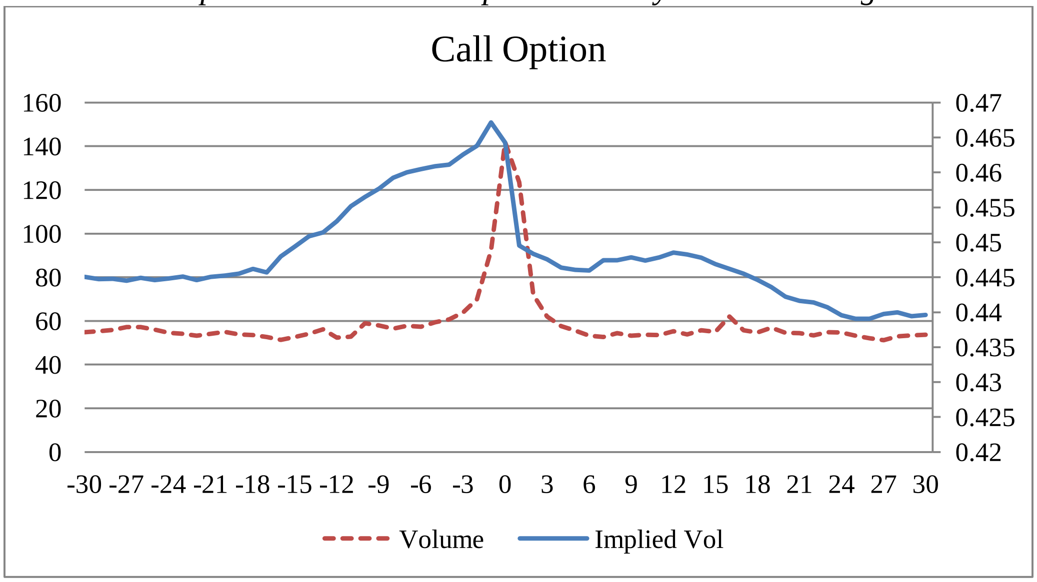
Appendix: Variable Definitions

XRET02	Abnormal stock returns over the earnings announcement window [0, +2]. The abnormal stock return is calculated as the buy-and-hold return of a particular stock minus the buy-and-hold return from a portfolio of stocks of similar size (market value of equity, two groups), book-to-market ratio (three groups), and 12-month momentum (three groups), similar to Daniel and Titman (1997).
XRET71	Abnormal stock returns over the Pre-earnings-announcement window [-7, -1].
AXRET02	Absolute value of XRET02.
AXRET71	Absolute value of XRET71.
IV Spread	Each day, implied volatility spread is calculated as the weighted average difference between implied volatilities of call and put options matched on strike price and maturity date, where the weight is the combined open interest of the pair, scaled by the combined open interest of all available pairs.
IV Skew	Each day, volatility skew is calculated as Implied volatility of the out-of-the-money (OTM) put option minus the implied volatility of the at-the-money (ATM) call option. We select all call options that have a delta in the range [+0.4,+0.7], and choose the one closest to 0.5. Its implied volatility is the ATM implied volatility. We then select all put options that have a delta in the range [–0.15,–0.45], and choose the one closest to –0.3. Its implied volatility is the OTM implied volatility.
IV_ATM	The implied volatility of ATM call options. We identify for each day all call options of a firm with time-to-maturity between 10 and 90 days and expire after the earnings announcements or Pseudo events. Among those we select call options that have a delta in the range of [+0.4,+ 0.7], and choose the one closest to 0.5. Its implied volatility is the ATM implied volatility.
O/S Ratio	Ln(O/S) is the natural logarithm of the total daily option trading volume divided by the daily stock trading volume. Total daily option trading volume for each firm is calculated across all options listed on the stock (we account for the fact that each contract is for 100 shares of stock).
_Base	The average of IV Spread, IV Skew, IV_ATM or O/S Ratio over the Base window [-30,-8].
_Pre	The average of IV Spread, IV Skew, IV_ATM or O/S Ratio over the Pre window [-7,-1].
BAspd	The average of relative bid-ask spread of options in the window [-7,-1]. The relative bid-ask spread is the end-of-day ask price minus bid price then divided by the average of the bid and ask price.

OS_BAspd	The average of the ratios of option relative bid-ask spread to the underlying stock relative bid-ask spread in the Pre window [-7,-1]. It is shown in hundreds.
Size	The natural logarithm of market value of equity.
BM	The natural logarithm of book to market ratio.
Momentum	The buy and hold return of during the previous 12 months (t-12 through t-1).
Hvol	Annualized historical stock returns volatility. It is calculated the standard deviation of stock returns in the previous two months. It is then annualized by multiplying by square root of 252.

Figure 1: Options Trading Volume and Implied Volatility around earnings announcements
This figure shows the movement of option implied volatility and option trading volume around earning announcement in the trading day window [-30,+30], where earnings announcement is day 0. The solid blue line is the option implied volatility and the red dashed line is the option trading volume. Panel A presents the implied volatility and trading volume of call option, and Panel B presents put option. The sample period is from 1996 to 2011.

Panel A: Call option—volume and implied volatility around earnings announcements



Panel B: Put option—volume and implied volatility around earnings announcements

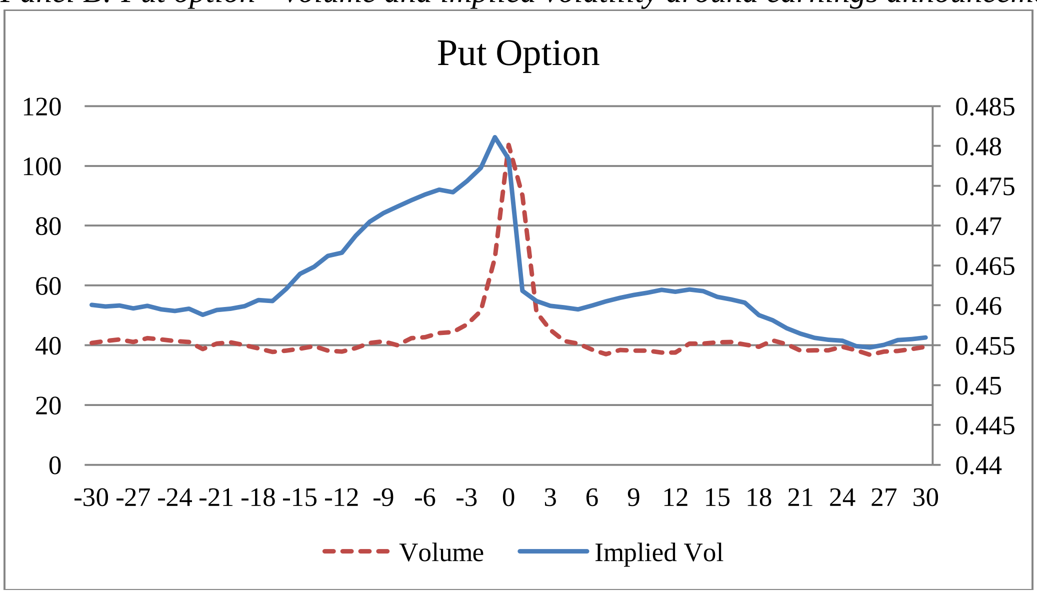


Figure 3: Trading Strategies and Abnormal Returns

This figure presents the quarterly time-series abnormal return of implementable trading strategy in Tables 4 and 5. Abnormal portfolio returns for the 1-month ([0,+30]) holding period are displayed over 63 quarters (from 1996Q2 to 2011Q4). Figure 3a presents the quarterly abnormal return series for the base strategy of volatility spread. Figure 3b presents the abnormal return series for the improved strategy based on volatility spread and transaction costs. The green (red) bar represents the abnormal return of low (high) transaction costs group. Figure 3c presents the quarterly abnormal return series for the base strategy of volatility skew. Figure 3d presents the abnormal return series for the improved strategy based on volatility skew and transaction costs. The green (red) bar represents the low (high) transaction costs group.

Figure a: IV Spread

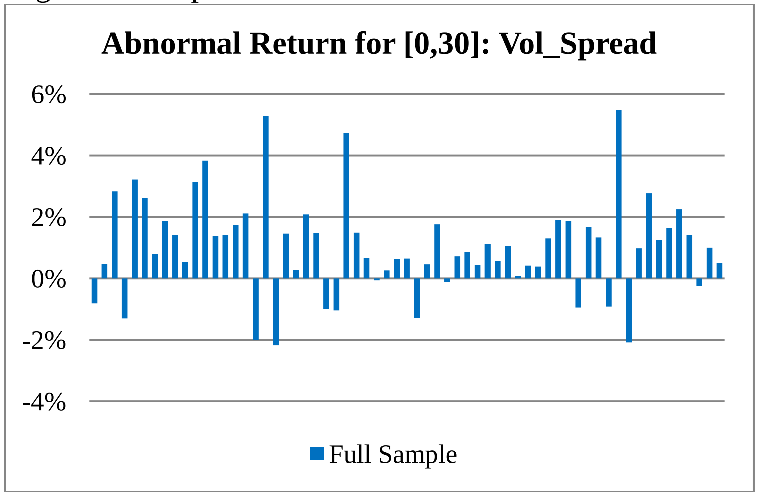


Figure b: IV Spread and Option Transaction Costs

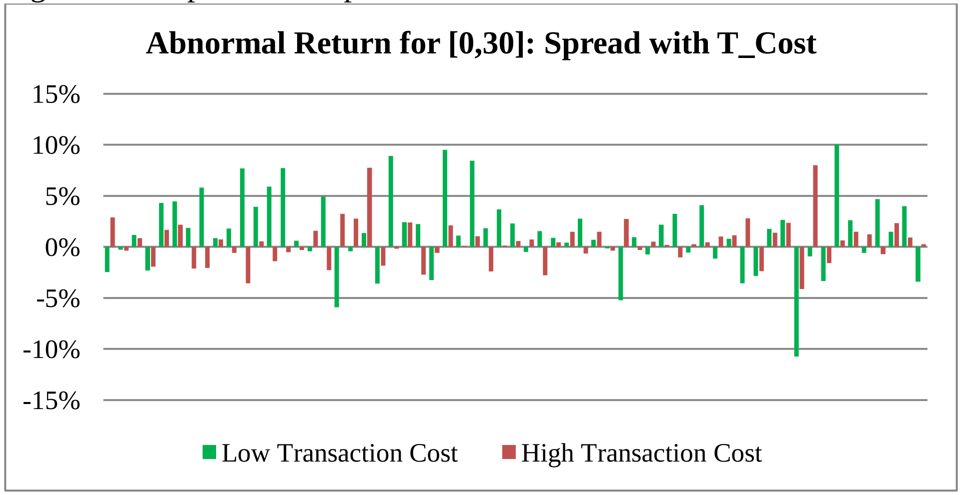


Figure c: IV Skew

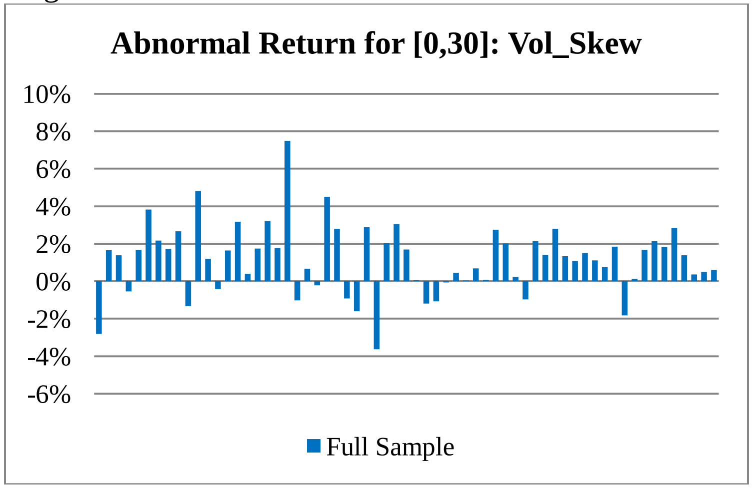


Figure d: IV Skew and Option Transaction Costs

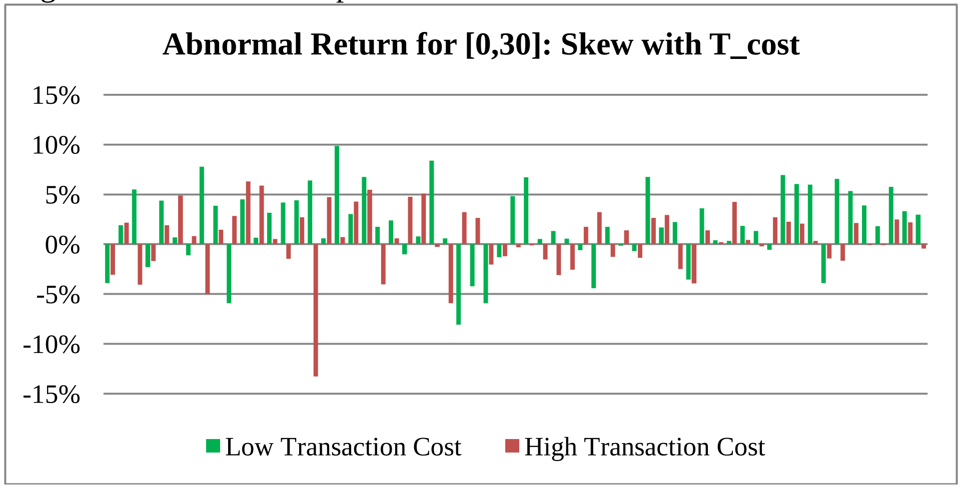


Table 1: Summary Statistics

This table presents the summary statistics of regression variables. Panel A presents the variables used in the implied volatility spread regression. Panel B presents the variables used in the implied volatility skew regression. Panel C presents the variables used in the O/S ratio regression. Size is the log of market capitalization and BM is the log of book to market ratio. The sample period is from the year 1996 to 2011. The 5^{th} (P5), 25^{th} (P25), 75^{th} (P75) and 95^{th} (P95) percentile are presented. See the appendix for definitions of the variables.

	N	Mean	SD	P5	P25	Median	P75	P95
Panel A: IV Spread Sample								
XRET02	92,504	0.001	0.091	-0.140	-0.040	0.000	0.043	0.144
XRET71	92,504	0.003	0.062	-0.096	-0.029	0.001	0.031	0.108
_Base	92,504	-0.010	0.030	-0.059	-0.017	-0.007	0.000	0.028
_Pre	92,504	-0.010	0.036	-0.068	-0.020	-0.007	0.003	0.039
BAspd	92,504	0.317	0.199	0.103	0.180	0.265	0.392	0.718
Size	92,504	7.323	1.512	5.046	6.222	7.198	8.264	10.073
BM	92,504	-0.962	0.797	-2.420	-1.409	-0.885	-0.434	0.223
Momentum	92,504	0.181	0.626	-0.583	-0.186	0.087	0.382	1.261
Hvol	92,504	0.448	0.283	0.158	0.258	0.375	0.554	0.989
Panel B: IV Skew Sample								
XRET02	66,872	0.001	0.091	-0.142	-0.042	0.001	0.045	0.145
XRET71	66,872	0.004	0.070	-0.096	-0.029	0.002	0.034	0.110
_Base	66,872	0.030	0.059	-0.023	0.007	0.023	0.044	0.106
_Pre	66,872	0.035	0.073	-0.033	0.008	0.027	0.053	0.128
BAspd	66,872	0.341	0.293	0.077	0.155	0.254	0.421	0.902
Size	66,872	7.611	1.502	5.445	6.501	7.434	8.554	10.335
BM	66,872	-1.071	0.840	-2.503	-1.511	-0.990	-0.529	0.106
Momentum	66,872	0.265	1.169	-0.539	-0.158	0.117	0.436	1.408
Hvol	66,872	0.453	0.272	0.169	0.270	0.383	0.556	0.976
Panel C: IV_ATM Sample								
AXRET02	92,474	0.064	0.068	0.003	0.019	0.043	0.086	0.194
AXRET71	92,474	0.053	0.061	0.003	0.015	0.035	0.068	0.161
_Base	92,474	0.500	0.240	0.213	0.329	0.446	0.618	0.962
_Pre	92,474	0.515	0.254	0.216	0.335	0.458	0.637	1.000
BAspd	92,474	0.201	0.198	0.050	0.095	0.147	0.234	0.515
Size	92,474	7.414	1.529	5.196	6.305	7.244	8.348	10.191
BM	92,474	-1.041	0.860	-2.525	-1.489	-0.953	-0.488	0.162
Hvol	92,474	0.467	0.291	0.168	0.271	0.390	0.576	1.032

Panel D: O/S ratio Sample

AXRET02	81,237	0.063	0.067	0.004	0.019	0.043	0.085	0.191
AXRET71	81,237	0.051	0.060	0.003	0.015	0.034	0.066	0.156
_Base	81,237	-3.604	1.231	-5.596	-4.474	-3.618	-2.741	-1.580
_Pre	81,237	-3.386	1.310	-5.611	-4.275	-3.333	-2.447	-1.339
OS_BAspd	81,237	5.512	5.955	0.196	0.820	3.975	7.861	16.733
Size	81,237	7.410	1.510	5.221	6.321	7.248	8.321	10.157
BM	81,237	-1.029	0.850	-2.489	-1.469	-0.942	-0.484	0.154
Hvol	81,237	0.455	0.282	0.164	0.265	0.380	0.559	1.001
IV_ATM	81,237	0.503	0.246	0.211	0.330	0.449	0.621	0.972

Table 2: Correlation Analysis

This table shows the correlation matrix of variables in the IV Spread sample, IV Skew sample and O/S Ratio sample, respectively. Spearman correlations are reported above the main diagonal and Pearson correlations are reported below the main diagonal. * denotes significance at 1% level. See appendix for variable definitions.

Panel A: IV Spread Sample

	XRET02	*XRET71*	*_Base*	*_Pre*	*BAspd*	*Size*	*BM*	*Momentum*	*Hvol*
XRET02	1	-0.060*	0.003	0.0217*	0.004	0.033*	0.004	0.001	-0.029*
XRET71	-0.060*	1	0.010*	-0.0807*	-0.039*	0.008	-0.015*	0.020*	0.002
_Base	0.005	0.012*	1	0.4628*	-0.001	-0.016*	0.043*	-0.024*	-0.057*
_Pre	0.018*	-0.059*	0.595*	1	-0.011*	-0.010*	0.025*	0.007	-0.053*
BAspd	0.005	-0.037*	-0.038*	-0.042*	1	-0.396*	0.297*	-0.120*	-0.085*
Size	0.017*	-0.017*	0.023*	0.015*	-0.358*	1	-0.243*	0.229*	-0.478*
BM	0.011*	-0.009*	0.045*	0.029*	0.252*	-0.238*	1	-0.382*	0.034*
Momentum	-0.019*	0.014*	-0.010*	0.008	-0.114*	0.114*	-0.385*	1	-0.250*
Hvol	-0.020*	0.044*	-0.082*	-0.077*	-0.054*	-0.390*	0.043*	-0.093*	1

Panel B: IV Skew Sample

	XRET02	*XRET71*	*_Base*	*_Pre*	*BAspd*	*Size*	*BM*	*Momentum*	*Hvol*
XRET02	1	-0.062*	-0.007	-0.019*	-0.003	0.024*	0.009	-0.012*	-0.022*
XRET71	-0.061*	1	-0.013*	0.036*	-0.002	-0.009	-0.006	0.015*	0.010*
_Base	-0.005	-0.013*	1	0.390*	-0.057*	-0.053*	0.037*	-0.100*	0.240*
_Pre	-0.015*	0.011*	0.383*	1	-0.014*	-0.036*	0.041*	-0.109*	0.190*
BAspd	-0.001	0.001	0.051*	0.089*	1	-0.487*	0.262*	-0.107*	-0.034*
Size	0.014*	-0.028*	-0.067*	-0.049*	-0.372*	1	-0.180*	0.135*	-0.456*
BM	0.015*	-0.001	0.034*	0.034*	0.201*	-0.172*	1	-0.374*	-0.008
Momentum	-0.018*	0.010	-0.034*	-0.035*	-0.059*	0.011*	-0.255*	1	-0.197*
Hvol	-0.014*	0.050*	0.187*	0.147*	-0.066*	-0.366*	0.002	0.027*	1

Panel C: IV_ATM Sample

	AXRET02	*AXRET71*	*_Base*	*_Pre*	*BAspd*	*Size*	*BM*	*Hvol*
AXRET02	1	0.164*	0.345*	0.357*	0.017*	-0.211*	-0.032*	0.302*
AXRET71	0.192*	1	0.394	0.404	0.049*	-0.227*	-0.023*	0.384*
_Base	0.340*	0.429*	1	0.963*	0.097*	-0.553*	-0.012*	0.885*
_Pre	0.359*	0.444*	0.944*	1	0.089*	-0.541*	-0.026*	0.868*
BAspd	0.011*	0.021*	0.068*	0.079*	1	-0.567*	0.296*	0.078*
Size	-0.206*	-0.216*	-0.481*	-0.463*	-0.379*	1	-0.194*	-0.458*
BM	-0.023*	-0.030*	-0.037*	-0.049*	0.209*	-0.184*	1	-0.016*
Hvol	0.298*	0.410*	0.843*	0.813*	0.027*	-0.362*	-0.029*	1

Panel D: O/S Ratio Sample

	AXRET02	*AXRET71*	*_Base*	*_Pre*	*Os_BAspd*	*Size*	*BM*	*Hvol*	*IV_ATM*
AXRET02	1	0.159*	0.031*	0.044*	-0.092*	-0.217*	-0.023*	0.302*	0.359*
AXRET71	0.185*	1	0.048*	0.038*	-0.246*	-0.234*	-0.012*	0.384*	0.405*
_Base	0.025*	0.042*	1	0.834*	-0.059*	0.193*	-0.236*	0.091*	0.124*
_Pre	0.038*	0.035*	0.834*	1	-0.021*	0.197*	-0.230*	0.058*	0.101*
OS_BAspd	-0.140*	-0.215*	-0.054*	-0.039*	1	0.336*	0.055*	-0.442*	-0.433*
Size	-0.213*	-0.227*	0.242*	0.231*	0.332*	1	-0.209*	-0.461*	-0.542*
BM	-0.011*	-0.013*	-0.233*	-0.220*	0.036*	-0.199*	1	0.005	-0.007
Hvol	0.298*	0.412*	0.067*	0.042*	-0.362*	-0.369*	0.001	1	0.866*
IV_ATM	0.359*	0.445*	0.109*	0.089*	-0.395*	-0.465*	-0.024*	0.812*	1

Table 3: The Effect of Option Transaction Cost on the Predictability of IV Spread and IV Skew

This table shows the impact of option bid-ask spread on the predictability of IV Spread and IV Skew for future abnormal returns around earnings announcements and randomly selected days. The dependent variables in Panels A and B are 3-day ([0,+2]) abnormal returns around quarterly earnings announcements and Pseudo event day, respectively. The Random day is a randomly selected trading day in the calendar window of [+30,+60] relative to the earnings announcement date. Models 1-3 show the effect of transaction costs on the predictability of IV Spread and Models 4-6 show the effect of transaction cost on the predictability of IV Skew. The coefficients are estimated with Fama-MacBeth regressions. The t-statistics are adjusted using Newey and West (1987) procedures with four lags. ***, **, and * denotes significance at the 1%, 5%, and 10% level respectively, based on two-tailed t-tests. See appendix for variable definitions.

Panel A: Earnings Announcement

	Dependent Variable: XRET02					
	IV Spread			**IV Skew**		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
_Base	-0.033**	-0.037***	-0.029**	-0.007	-0.006	-0.003
	(-2.40)	(-2.73)	(-2.12)	(-0.65)	(-0.58)	(-0.30)
_Pre	**0.074*** **	0.126***	0.103***	**-0.036*** **	-0.071***	-0.060***
	(5.60)	(5.24)	(4.43)	(-3.53)	(-4.74)	(-4.25)
BAspd		0.003	-0.001		0.000	-0.003
		(1.53)	(-0.60)		(0.01)	(-1.44)
*BAspd*_Pre*		**-0.117*** **	**-0.091** **		**0.068** **	**0.053** **
		(-2.69)	(-2.13)		(2.37)	(2.08)
Size			0.000			-0.000
			(0.49)			(-0.16)
BM			0.000			0.001
			(0.62)			(1.51)
Momentum			-0.001			-0.001
			(-1.27)			(-1.50)
XRET71			-0.079***			-0.074***
			(-9.18)			(-7.94)
Hvol			-0.014***			-0.012***
			(-5.15)			(-4.74)
Constant	0.002***	0.001	0.008**	0.002***	0.002**	0.011***
	(2.79)	(1.38)	(2.09)	(2.74)	(2.23)	(2.88)
N	92,504	92,504	92,504	66872	66872	66872
Adj.R-Squared	0.002	0.004	0.015	0.004	0.007	0.019

Panel B: Random Days

	Dependent Variable: XRET02					
	IV Spread			**IV Skew**		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
_Base	-0.019*	-0.020*	-0.018	0.004	0.005	0.003
	(-1.79)	(-1.75)	(-1.55)	(0.54)	(0.59)	(0.45)
_Pre	**0.023*** **	0.033**	0.031**	**-0.014** **	-0.008	-0.006
	(2.71)	(2.40)	(2.25)	(-2.39)	(-0.91)	(-0.68)
BAspd		0.001	0.001		0.001	0.001
		(0.24)	(0.33)		(0.87)	(0.88)
*BAspd*_Pre*		**-0.014**	**-0.013**		**-0.008**	**-0.010**
		(-0.79)	(-0.74)		(-0.69)	(-0.82)
Size			-0.001			0.002
			(-0.07)			(0.05)
BM			-0.002			0.001
			(-0.34)			(0.28)
Momentum			0.001			0.001
			(0.73)			(1.01)
XRET71			-0.024***			-0.020***
			(-5.37)			(-3.66)
Hvol			-0.008***			-0.007***
			(3.35)			(3.22)
Constant	0.001	-0.002	-0.002	-0.000	-0.001	-0.001
	(0.00)	(-0.02)	(-0.03)	(-0.54)	(-0.83)	(-0.38)
N	94,557	94,557	94,557	67,333	67,333	67,333
Adj.R-Squared	0.003	0.006	0.014	0.005	0.009	0.019

Table 4: Trading Strategies based on IV Spread or IV Skew

This table shows the equal-weighted buy-and-hold abnormal returns for each volatility spread portfolio (Panel A) or volatility skew portfolio (Panel B). All returns are shown in percentage. Every quarter, firms are assigned to four groups based on the average volatility spread or volatility skew in the pre-earnings announcement window [-7,-1]. The cutoff point is determined by the quartile (25th, 50th and 75th percentile) of volatility spread or volatility skew from the previous quarter, which ensures that there is no look-ahead bias in the portfolio construction. Buy-and-hold abnormal returns are shown for five periods: [0,+2], [0,+7], [0,+30], [0,+60] and [0,+90]. Following Daniel and Titman (1997), the abnormal return is calculated as the return on a particular stock minus the return from a portfolio of stocks of similar size (market value of equity, two groups), book-to-market ratio (three groups), and 12-month momentum (three groups). Reported t-statistics are based on the difference in high and low portfolios over the time-series of calendar quarters.

Panel A: Portfolios based on IV Spread

IV Spread	Holding Period				
	[0,+2]	[0,+7]	[0,+30]	[0,+60]	[0,+90]
Low	-0.31	-0.44	-0.31	-0.69	-1.11
2	0.14	0.10	0.35	0.12	0.11
3	0.24	0.26	0.56	0.41	0.44
High	0.20	0.21	0.74	0.45	0.65
High-Low	0.51***	0.65***	1.05***	1.15**	1.76***
t-stat	(3.98)	(3.77)	(2.88)	(2.23)	(2.82)

Panel B: Portfolios based on IV Skew

IV Skew	Holding Period				
	[0,+2]	[0,+7]	[0,+30]	[0,+60]	[0,+90]
Low	0.33	0.33	0.77	0.42	0.45
2	0.29	0.28	0.56	0.38	0.60
3	-0.05	-0.17	0.01	0.18	0.22
High	-0.28	-0.50	-0.40	-1.08	-1.30
Low-High	0.61***	0.83***	1.17***	1.50**	1.75**
t-stat	(3.82)	(4.06)	(2.77)	(2.60)	(2.37)

Table 5: Improved Trading Strategies

This table shows the impact of transaction cost and leverage on volatility spread or volatility skew portfolio returns. All returns are shown in percentage. Firms are sorted into four groups each quarter based on the average option bid-ask spread in the Pre window [-7,-1]. Firms in the first (fourth) group have the lowest (highest) bid-ask spread or low (high) transaction costs. The cutoff point is determined by the quartile (25th, 50th and 75th percentile) of bid-ask spread from the previous quarter, which ensures that there is no look-ahead bias in the portfolio construction. Similarly, firms are sorted into four groups each quarter based on the absolute value of option delta in the Pre window [-7,-1] and those in the first (fourth) group with lowest (highest) absolute value of delta have high (low) leverage. Then we show the volatility spread or volatility skew portfolio returns for firms with high and low transaction costs (or leverage) separately. The volatility spread or volatility skew portfolio returns are calculated in the same way as described in Table 5.

Panel A: Portfolios based on IV Spread and Transaction Costs

Holding Period	[0,+2]		[0,+7]		[0, +30]		[0, +60]		[0, +90]	
	Transaction Costs		Transaction Cost		Transaction Costs		Transaction Costs		Transaction Costs	
IV Spread	Low	High	Low	High	Low	High	Low	High	Low	High
Low	-0.66	-0.03	-1.05	-0.01	-1.01	0.19	-1.72	-0.03	-2.39	-0.32
2	-0.05	0.27	-0.26	0.40	-0.02	0.92	-0.31	0.48	-0.10	0.21
3	0.04	0.15	-0.04	0.15	0.19	0.46	-0.27	0.67	-0.08	0.88
High	0.25	0.21	0.09	0.23	0.38	0.61	-0.00	0.48	0.64	0.65
High-Low	0.91***	0.24	1.13***	0.24	1.39**	0.42	1.72	0.51	3.03**	0.97
t-stat	(3.06)	(1.44)	(3.36)	(1.06)	(2.01)	(1.19)	(1.58)	(1.00)	(2.11)	(1.61)

Panel B: Portfolios based on IV Skew and Transaction Costs

Holding Period	[0, +2]		[0, +7]		[0, +30]		[0, +60]		[0, +90]	
	Transaction Cost		Transaction Cost		Transaction Cost		Transaction Cost		Transaction Cost	
IV Skew	Low	High	Low	High	Low	High	Low	High	Low	High
Low	0.18	0.24	0.14	0.28	0.87	0.77	0.24	0.41	0.18	0.54
2	0.13	0.41	-0.01	0.59	0.24	0.67	-0.14	0.96	0.36	1.24
3	-0.23	0.10	-0.44	0.02	-0.36	0.22	-0.67	0.10	-0.49	0.08
High	-0.47	-0.14	-0.86	-0.28	-1.03	0.25	-2.00	0.18	-2.28	-0.65
Low-High	0.65**	0.38	1.00***	0.55**	1.91***	0.50	2.24**	0.59	2.46**	1.19
t-stat	(2.32)	(1.62)	(3.01)	(2.06)	(2.81)	(0.96)	(2.33)	(0.90)	(2.02)	(1.50)

Table 6:The Impact of Transaction Costs on the Predictability of IV_ATM for Future Absolute Abnormal Returns

This tables shows the impact of transaction costs (option relative bid-ask spread) on the predictability of implied volatility of ATM call options for absolute abnormal returns over the 3-day window [0,+2] around earnings announcements and Random dates. The Random date is a randomly selected trading day in the calendar window of [+30,+60] relative to the earnings announcement date. AXRET02 and AXRET71 used in the following regressions are in percentage. The coefficients are estimated using Fama–MacBeth regressions over 64 calendar quarters. T-statistics reported in parentheses are based on Newey and West (1987) adjusted standard errors using four lags. ***, **, and * denotes significance at the 1%, 5%, and 10% level respectively, based on two-tailed t-tests. See appendix for variable definitions.

	Earnings Announcement Sample			**Pseudo Event Sample**		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
_Base	0.012**	0.005	-0.004	0.015***	0.012**	0.005
	(2.16)	(1.35)	(-0.89)	(2.73)	(2.36)	(1.01)
_Pre	**0.092*** **	0.115***	0.100***	**0.047*** **	0.054***	0.045***
	(13.84)	(21.21)	(15.94)	(7.08)	(9.12)	(7.82)
OS_BAspd		0.026***	0.008		0.007***	0.002
		(5.41)	(1.59)		(2.78)	(0.77)
*OS_BAspd*_Pre*		**-0.065*** **	**-0.049*** **		**-0.011***	**-0.002**
		(-5.83)	(-4.41)		(-1.70)	(-0.35)
Size			-0.004***			-0.001***
			(-7.32)			(-4.81)
BM			-0.001***			-0.001***
			(-3.78)			(-4.88)
Hvol			0.000			0.007***
			(0.05)			(6.82)
AXRET71			0.035***			0.042***
			(4.43)			(9.90)
Constant			0.040***	0.002***	0.000	0.006***
			(7.08)	(4.72)	(0.20)	(3.71)
N	92,474	92.474	92,474	88,616	88,616	88,616
Adj.-R squared	0.112	0.118	0.129	0.122	0.130	0.142

Table 7:The Impact of Transaction Costs on the Predictability of O/S Ratio for Future Absolute Abnormal Returns

This tables shows the impact of transaction costs (option bid-ask spread relative to stock bid-ask spread) on the predictability of O/S ratio for absolute abnormal returns over the 3-day window [0,+2] around earnings announcements and Random dates s. The Random date is a randomly selected trading day in the calendar window of [+30,+60] relative to the earnings announcement date. AXRET02 and AXRET71 used in the following regressions are in percentage. The coefficients are estimated using Fama–MacBeth regressions over 64 calendar quarters. T-statistics reported in parentheses are based on Newey and West (1987) adjusted standard errors using four lags. ***, **, and * denotes significance at the 1%, 5%, and 10% level respectively, based on two-tailed t-tests. See appendix for variable definitions.

	Earnings Announcement Sample			**Pseudo Event Sample**		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
_Base	-0.049	-0.084	-0.218***	0.118**	0.112**	0.034
	(-0.68)	(-1.22)	(-6.13)	(2.54)	(2.49)	(1.47)
_Pre	**0.363***	0.334***	0.205***	**0.096***	0.104***	0.009
	(9.43)	(5.26)	(4.35)	(4.66)	(2.88)	(0.37)
OS_BAspd		-0.246	0.167**		-0.246	-0.026
		(-1.20)	(2.02)		(-1.63)	(-0.59)
*OS_BAspd*_Pre*		**0.072***	**0.045****		**-0.001**	**-0.009**
		(1.84)	(2.02)		(-0.02)	(-0.68)
Size			-0.332***			-0.107***
			(-6.16)			(-8.61)
BM			-0.194***			-0.105***
			(-3.95)			(-3.88)
Hvol			0.211			0.950***
			(0.66)			(7.16)
IV_ATM			7.955***			4.222***
			(16.36)			(13.34)
AXRET71			0.029***			0.040***
			(3.49)			(10.88)
Constant	7.366***	8.322***	4.216***	4.013***	4.589***	1.370***
	(20.55)	(27.10)	(5.67)	(11.90)	(17.78)	(6.78)
N	81,237	81,237	81,237	77,050	77,050	77,050
Adj.-R squared	0.007	0.035	0.127	0.007	0.033	0.139