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Abstract

This paper documents a robust new finding that delta-hedged equity option return decreases monotonically with an increase in the idiosyncratic volatility of the underlying stock. Buying calls on low idiosyncratic volatility stocks and selling calls on high idiosyncratic volatility stocks (both delta-hedged) on average earns about 1.4% over the next month. Our results can not be explained by standard stock market risk factors or volatility risk premium. They are distinct from existing anomalies in the stock market or volatility-related option mispricing. Our results are consistent with theory of option pricing under market imperfections. Option dealers charge a higher premium for options on high idiosyncratic volatility stocks because these options have higher arbitrage costs. Controlling for several limits to arbitrage proxies reduces the strength of the negative relation between delta-hedged option return and idiosyncratic volatility by about 40%.

1 Introduction

Despite the tremendous growth in equity options in recent decades, we know very little about the determinants of expected return in this market. Partly responsible for this may be the view that options are merely leveraged positions in the underlying stocks. Correspondingly, academic research on options has traditionally focused on no-arbitrage valuation of options relative to the underlying stocks. However, recent studies show that options are not redundant,[1] and there are limits to arbitrage between options and stocks.[2]

The main test hypothesis of this paper is a negative relation between option returns and the idiosyncratic volatility of the underlying stock. The hypothesis is motivated by theory of option pricing in the presence of limits to arbitrage between stocks and options (e.g., Garleanu, Pedersen, and Poteshman (2009)). No-arbitrage approach can only establish very wide bounds on equilibrium option prices. Option prices are importantly affected by demand for options by the end-users and the costs of option dealers to supply options when they can not perfectly hedge the options. We focus on the relation between option returns and idiosyncratic volatility, because idiosyncratic volatility is the most important proxy of arbitrage costs, as it is correlated with transaction costs and imposes a significant holding cost for arbitrageurs (e.g., Pontiff (2006)).

Under limited arbitrage between the options and the underlying stocks, both supply and demand considerations suggest that option return is expected to be negatively related to stock's idiosyncratic volatility. On the one hand, stocks with high idiosyncratic volatility attract speculators (e.g., Kumar (2009), Han and Kumar (2010)). On the other hand, options on high idiosyncratic volatility stocks are more costly to supply because they are more difficult to hedge. Thus, option dealers charge a higher premium for options on high idiosyncratic volatility stocks, leading to lower future returns.

To test the hypothesis, we examine a cross-section of options on individual stocks each month. We pick one call (or put) option on each optionable stock that has a common time-to-maturity (about one and a half months) and is closest to being at-the-money. At-the-money

[1] See, e.g., Buraschi and Jackwerth (2001), Coval and Shumway (2001), Jones (2006). Options are traded because they are useful and, therefore, options cannot be redundant for all investors (Hakansson (1979)).

[2] See, e.g., Figlewski (1989), Figlewski and Green (1999), Bollen and Whaley (2004), Garleanu, Pedersen, and Poteshman (2009).

options are most sensitive to changes in stock volatility. For each optionable stock and in each month we evaluate the return over the following month of a portfolio that buys one call (or put), delta-hedged with the underlying stock. The delta-hedge is rebalanced daily so that the portfolio is not sensitive to stock price movement. We study option returns after hedging out the exposure to the underlying stocks so that our results are not driven by determinants of the expected stock returns. Our results are obtained from about 210,000 delta-hedged option returns for 6,000 underlying stocks.

Empirically, we find that on average, delta-hedged options have negative returns, especially when the underlying stock has high idiosyncratic volatility. The delta-hedged options on stocks with high idiosyncratic volatility on average earn significantly lower returns than those on low idiosyncratic volatility stocks. This is the key new finding of our paper. The same pattern holds for both call options and put options. For example, a portfolio strategy that buys delta-hedged call options on stocks ranked in the bottom quintile by idiosyncratic volatility and sells delta-hedged call options on stocks from the top idiosyncratic volatility quintile earns about 1.4% per month.

We also find that the delta-hedged option return is on average significantly more negative when the underlying stocks or the options are less liquid, and when the option open interests are higher. These results are consistent with option dealers charging a higher option premium when there are more limits to arbitrage between stocks and options, such as when the options are more difficult to hedge and demands for them are higher.

Limits to arbitrage also play an important role explaining the negative relation between delta-hedged option return and idiosyncratic volatility. This relation is stronger when it is more costly to arbitrage between options and stocks. Controlling for several limits to arbitrage proxies reduces the strength of the negative relation between delta-hedged option return and idiosyncratic volatility by about 40%.

Further supporting the limits to arbitrage explanation, we find that the profitability of our volatility-based option strategy crucially depends on option trading costs. Buying delta-hedged call options on stocks ranked in the bottom idiosyncratic volatility quintile and selling delta-hedged call options on stocks from the top idiosyncratic volatility quintile earns about 1.4% per month, when we assume options are traded at the mid point of the bid and the ask quotes. If we assume the effective option spread is equal to 25% of the quoted spread, the average return of our option strategy is reduced to 0.79%. If the effective option spread is equal to 50% of the quoted spread, then the profit of our option strategy is only 0.17%, which is no longer statistically or economically significant. Thus, only arbitrageurs facing sufficient low costs can profit from our option trading strategy.

We explore a number of potential alternative explanations for our results. The first is that the profitability of our option strategy reflects compensation for bearing volatility risk. It is well known that stock return volatility is time-varying. Delta-hedged options are positively exposed to changes in the volatility, and their average returns could embed a volatility risk premium.

After we control for the volatility risk premium in Fama-MacBeth regressions with the delta-hedged option return as the dependent variable, the coefficient on idiosyncratic volatility remains negative and significant. Further, we run time-series regressions of the returns to our option strategy on several proxies of market volatility risk and common idiosyncratic volatility risk. Our portfolio strategy still has a significant positive alpha of about 1.32% per month, after controlling for these volatility-related risk factors in addition to the Fama-French three factors and the momentum factor. Thus, our results can not be explained by the volatility risk premium.

Another potential explanation of our results is volatility-related option mispricing. Stocks with high current volatility may have experienced recent increase in volatility. If investors overreacted to recent change in volatility (see, e.g., Stein (1989), Poteshman(2001)), and paid too much for options on stocks with high current volatility, then it could explain our result. However, after we control for recent changes in volatility, we still find a significant negative relation between delta-hedged option returns and the idiosyncratic volatility of the underlying stock. Our results are not simply manifestation of investor overreaction to changes in volatility.

Further, we control for the difference between the realized volatility and the at-the-money option implied volatility. Goyal and Saretto (2009) argue that large deviations of implied volatility from historical volatility are indicative of mis-estimation of volatility dynamics. Consistent with their paper, we find that delta-hedged options on stocks with large positive differences between historical volatility and implied volatility have higher returns.[3] However,

[3] Unlike our study, Goyal and Saretto (2009) hold delta-hedged option positions for a month without daily

after controlling for the difference between historical and option-implied volatility, we find a more negative relation between delta-hedged option return and idiosyncratic volatility. Thus, controlling for volatility-related option mispricing exacerbates rather than explains our results.

A voluminous literature has studied the cross-section of stock returns, but papers that examine the cross-section of option returns are sparse. Previous studies on option returns have focused on index options (e.g., Coval and Shumway (2001)). Duarte and Jones (2007) use delta-hedged options to study properties of individual stock volatility risk premium. They find that the individual stock volatility risk premium is related to stock's exposure to the market volatility risk and depends on the market volatility level. They do not examine how delta-hedged stock option return is related to the idiosyncratic volatility of the underlying stock, which is the focus of our study.[4] Goyal and Saretto (2009) link delta-hedged options to the difference between historical realized volatility and at-the-money option implied volatility. They are motivated by investors' mis-estimation of volatility dynamics and volatility-related option mispricing. We examine additional theory-motivated variables (not examined in previous studies) that are expected to be related to delta-hedged stock option returns, including proxies of option demand pressures and costs of arbitrage between stocks and options.

The rest of the paper is organized as follows. Section 2 describes the data and delta-hedged option returns. Section 3 presents Fama-MacBeth regression results and tests several potential explanations of our results. Section 4 presents portfolio-sorting results and studies an option trading strategy taking into account realistic transaction costs. Section 5 concludes the paper.

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rebalancing. We thank an anonymous referee for pointing that rebalancing could have important impact on the performance of delta-hedged option positions, as there is a big difference in performance between an unrebalanced delta hedge and one that is rebalanced as a function of the stock's realized price path.

[4]Bali and Murray (2010) study the return of skewness asset constructed from a pair of option positions (one long and one short) and a position in the underlying stock. By design, their skewness asset is not exposed to changes in stock volatility. Thus, their study has a different focus from our paper.

2 Data and Delta-hedged Option Returns

2.1 Data

We use data from both the equity option and stock markets. For the January 1996 to October 2009 sample period, we obtain data on U.S. individual stock options from the Ivy DB database provided by Optionmetrics. The data fields we use include daily closing bid and ask quotes, trading volume and open interest of each option, implied volatility as well as the option's delta and vega computed by OptionMetrics based on standard market conventions. We obtain daily and monthly split-adjusted stock returns, stock prices, and trading volume from the Center for Research on Security Prices (CRSP). For each stock, we also compute the book-to-market ratio using the book value from COMPUSTAT. Further, we obtain the daily and monthly Fama-French factor returns and risk-free rates from Kenneth French's data library.[5]

At the end of each month and for each optionable stock, we collect a pair of options (one call and one put) that are closest to being at-the-money and have the shortest maturity among those with more than 1 month to expiration. We apply several filters to the extracted option data. First, our main analyses use call options whose stocks do not have ex-dividend dates prior to option expiration (i.e., we exclude an option if the underlying stock paid a dividend during the remaining life of the option).[6] Second, we exclude all option observations that violate obvious no-arbitrage conditions such as $S \geq C \geq max(0, S - Ke^{-rT})$ for a call option C where S is the underlying stock price, and K is the option strike price, T is time to maturity of the option, and r is the riskfree rate. Third, to avoid microstructure related bias, we only retain options that have positive trading volume, positive bid quotes and where the bid price is strictly smaller than the ask price, and the mid-point of bid and ask quotes is at least \$1/8. We keep only the options whose last trade dates match the record dates and whose option price dates match the underlying security price dates. Fourth, the majority of the options we pick each month have the same maturity. We drop the options whose maturity is longer than that of the majority of options.

[5] The data library is available at `http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/`.

[6] For the short-maturity options used in our study, the early exercise premium is small. We verify that our results do not change materially when we include options for which the underlying stock paid a dividend before option expire.

Thus, we obtain, in each month, reliable data on a cross-section of options that are approximately at-the-money with a common short-term maturity. Our final sample in each month contains, on average, options on 1514 stocks. The pooled data has 213,640 observations for delta-hedged call returns and 199,198 observations for delta-hedged put returns. Table 1 shows that the average moneyness of the chosen options is 1, with a standard deviation of only 0.05. The time to maturity of the chosen options ranges from 47 to 52 calendar days across different months, with an average of 50 days. These short-term options are the most actively traded. We utilize this option data to study the cross-sectional determinants of expected option returns.

Compared to the whole CRSP stock universe, our sample of stocks with traded options have larger market cap, more institutional ownership and analyst coverage. For stocks in our sample, the average market cap of is 3.81 billion dollars, the average institutional ownership is 66.68%, and the average number of analyst coverage is 8.72. Our results are not driven by small or neglected stocks.

2.2 Delta-hedged Option Returns

To measure delta-hedged call option return, we first define delta-hedged option gain, which is change in the value of a self-financing portfolio consisting of a long call position, hedged by a short position in the underlying stock so that the portfolio is not sensitive to stock price movement, with the net investment earning risk-free rate. Our definition of delta-hedged option gain follows Bakshi and Kapadia (2003). Specifically, consider a portfolio of a call option that is hedged discretely N times over a period $[t, t+\tau]$, where the hedge is rebalanced at each of the dates t_n, $n = 0, 1, \cdots, N-1$ (where we define $t_0 = t$, $t_N = t+\tau$). The discrete delta-hedged call option gain over the period $[t, t+\tau]$ is

$$\Pi(t, t+\tau) = C_{t+\tau} - C_t - \sum_{n=0}^{N-1} \Delta_{C,t_n}[S(t_{n+1}) - S(t_n)] - \sum_{n=0}^{N-1} \frac{a_n r_{t_n}}{365}[C(t_n) - \Delta_{C,t_n} S(t_n)], \quad (1)$$

where Δ_{C,t_n} is the delta of the call option on date t_n, r_{t_n} is annualized riskfree rate on date t_n, a_n is the number of calendar days between t_n and t_{n+1}.[7] Delta-hedged call option return

[7]Following Carr and Wu (2009) as well as Goyal and Saretto (2009), our delta hedges rely on implied volatilities and "Greeks" from the Black-Scholes model. We also compute option delta based on the GARCH

is $\Pi(t, t+\tau)/(\Delta_t S_t - C_t)$. Definition for the delta-hedged put option gain is the same as (1), except with put option price and delta replacing call option price and delta.

3 Empirical results

3.1 Average Delta-hedged Option Returns

First, we examine the time-series average of delta-hedged option returns for individual stocks. Table 1 Panel A and B show that for both call options and put options, the mean and median of the pooled delta-hedged option returns are negative. For example, the average delta-hedged at-the-money call option return is -0.81% over the next month and -1.13% if held till maturity (which is on average 50 calendar days). The median delta-hedged call option return is -0.92% (respectively -1.29%) for the next month (respectively till maturity). For put options, the median delta-hedged option return is -0.73% (respectively -1.17%) for the next month (respectively till maturity).

Table 1 Panel D reports the results of t-test for the time-series mean of individual stock delta-hedged option returns. We have time series observations of call options on 6141 stocks. About 78% of them have negative average delta-hedged call option returns and 32% of them have significantly negative average delta-hedged call option returns. In contrast, the average delta-hedged call option return is significantly positive for about only 1% of the cases. The pattern for the put options is similar.

3.2 Delta-hedged Option Returns and Idiosyncratic Volatility

Table 1 shows there are large variations in the delta-hedged option returns. We study the cross-sectional determinants of delta-hedged option returns using monthly Fama-MacBeth regressions. For Tables 2 to 6, the dependent variable in month t's regression is delta-hedged call option return till maturity, i.e., $\Pi(t, t+\tau)/(\Delta_t S_t - C_t)$, where the common time to maturity τ is about one and a half months. The independent variables are all pre-determined at time t. The key variable of interest is the idiosyncratic volatility of the underlying stock.

volatility estimate and obtain similar results.

Table 7 reports robustness checks for different holding periods (e.g., one week or one month) and for put options.

Table 2 Panel A shows that delta-hedged option return is negatively related to the total volatility of the underlying stock. Model 1 is the univariate regression of delta-hedged option returns on stock return volatility VOL, measured as the standard deviation of daily stock returns over the previous month. The VOL coefficient estimate is -0.0299, with a significant t-stat of -8.72. In Model (2), we add option vega as a regressor to control for cross-sectional difference in option moneyness. The point estimate and t-stat of the VOL coefficient in Model 2 barely change from those in Model 1.

The significant negative relation between delta-hedged option returns and stock volatility is robust to alternative measures of stock volatility. In Model 3, we measure stock volatility as the square root of average of daily returns squared over the previous month. In Model 4, volatility is estimated as the standard deviation of monthly stock returns over the past 60 months. In Model 5, we use at-the-money Black-Scholes option implied volatility IV at the beginning of the option holding period. The coefficients for all of these volatility measures are significantly negative.

Table 2 Panel B shows that the negative relation between delta-hedged option returns and the volatility of the underlying stock is entirely driven by the idiosyncratic volatility. In Model 1 of Table 2 Panel B, we decompose individual stock volatility into two components: idiosyncratic volatility $IVOL$ and systematic volatility $SysVol$. We measure idiosyncratic volatility as the standard deviation of the residuals of the Fama-French 3-factor model estimated using the daily stock returns over the previous month, and systematic volatility is $\sqrt{VOL^2 - IVOL^2}$.[8] When both idiosyncratic volatility and systematic volatility are included as regressors, the estimated $IVOL$ coefficient is -0.0405 with a t-stat of -15.38. In contrast, the estimated coefficient of systematic volatility is 0.0165 with a t-stat of 3.93.

We confirm that the significant negative relation between delta-hedged option returns and idiosyncratic volatility is not sensitive to how idiosyncratic volatility is measured. In Model 2, we measure idiosyncratic volatility as the standard deviation of the residuals of the

[8] Our definition of idiosyncratic volatility follows Ang, Hodrick, Xing, and Zhang (2006). Our definition of systematic volatility follows Duan and Wei (2009). They report a positive relation between the level or the slope of the option implied volatility curve and the amount of systematic volatility in the underlying stock.

CAPM model estimated using monthly stock returns over the past 60 months. In Model 3, we estimate an EGARCH (1,1) model using all historical monthly returns, and use the fitted volatility of residuals.[9] In Model 4, we estimate idiosyncratic volatility as the one-period ahead expected volatility of residuals of the EGARCH(1,1) model. The coefficients for all of these idiosyncratic volatility measures are significantly negative.

The impact of idiosyncratic volatility on delta-hedged option return is not only statistically significant, but also economically significant. Based on the -0.0405 coefficient estimate for $IVOL$ and its summary statistics reported in Table 1 Panel C, a one-standard deviation increase in the idiosyncratic volatility would reduce the delta-hedged option return on average by 0.93%. Moving from the 10 (resp. 25) percentile of stocks ranked by idiosyncratic volatility to the 90 (resp. 75) percentile, the delta-hedged option return can be expected to decrease by 2.14% (resp. 1.09%).

3.3 Controlling for Volatility Risk and Jump Risk

Under the Black-Scholes model, the call option can be replicated by trading the underlying stock and riskfree bond. In this case, the discrete delta-hedged gain in Equation (1) has a symmetric distribution centered around zero (e.g., Bertsimas, Kogan, and Lo (2000)). When volatility is stochastic and volatility risk is priced, the mean of delta-hedged option gain would be different from zero, reflecting the volatility risk premium. For example, Bakshi and Kapadia (2003) show that under stochastic volatility model, the expected delta-hedged option gain depends positively on the volatility risk premium. Existing option pricing models with stochastic volatility specify volatility risk premium as a function of the volatility level. For example, in Heston (1993), the volatility risk premium is linear in volatility. The negative relation between delta-hedged option return and stock volatility is consistent with a negative volatility risk premium whose magnitude increases with the volatility level.[10]

[9] Each month and for each stock in our sample, we estimate the EGARCH(1,1) model using all available historical monthly stock returns since 1963, if at least 5 years of historical data are available.

[10] Only a few papers have examined the volatility risk premium for individual stocks. Carr and Wu (2009) report that out of the 35 individual stocks they study, only seven generate volatility risk premiums that are significantly negative. For stocks belonging to the S&P 100 index, Driessen, Maenhout and Vilkov (2009) report "We find no evidence for the presence of a significant negative volatility risk premium in individual stock options. If anything, there is weak evidence of a positive risk premium for variance risk in individual options."

In Table 3, we control for the volatility risk premium to examine whether it can explain the negative relation between delta-hedged option return and idiosyncratic volatility. The volatility risk premium of stock i in month t is

$$VRP_{i,t} = \sqrt{RV_{i,t}} - \sqrt{IV_{i,t}}$$

where $RV_{i,t}$ is realized return variance over month t computed from high frequency return data, and $IV_{i,t}$ is the risk-neutral expected variance extracted from equity options on the last trading day of each month t (see Appendix 1 for details). Our estimates of implied variance IV and realized variance RV are identical to those in Bollerslev, Tauchen and Zhou (2009) and Drechsler and Yaron (2010).[11] Due to data limitation and to ensure the reliability of the variance risk premium estimates, we obtain the the volatility risk premium only for a subset (about one-third) of our sample in Table 2.[12]

Table 3 Model 1 is identical to Table 2 Panel A Model 2, and Table 3 Model 4 is identical to Table 2 Panel B Model 1, except the sample size smaller in Table 3. Just like in Table 2, delta-hedged option return decreases with an increase in the total volatility of the underlying stock (Table 3 Model 1), and this result is entirely driven by the idiosyncratic volatility (Table 3 Model 4).

Table 3 Model 2 show a significantly positive relation between the delta-hedged option return and the volatility risk premium. However, after controlling for the volatility risk premium, we still find significant negative coefficients for both total stock volatility and idiosyncratic volatility, but significant positive coefficient for stock's systematic volatility exposure (just like in Table 2). The coefficient estimates and their t-statistics barely change in the presence of the volatility risk premium. The negative relation between delta-hedged option return and idiosyncratic volatility can not simply be explained by the volatility risk premium.[13]

[11] Buraschi, Trojani and Vedolin (2009) measure the volatility risk premium as $\sqrt{IV_{i,t}} - \sqrt{RV_{i,t}}$, which is our measure multiply by -1, except that they estimate realized variance from daily stock returns while our measure is based on intra-daily stock returns.

[12] The set of stocks for which we estimate the variance risk premium is a subsample of all optionable stocks that have larger market cap, higher institutional ownership, and higher analyst coverage.

[13] In unreported empirical work, we find that the regression coefficient of delta-hedged option return on idiosyncratic volatility does not change much and remains significant when we control for stocks' beta with respect to several proxies of systematic volatility risk factors. The first factor is the monthly change of the

Table 3 Model 3 and 6 examine whether our result can be explained by a state-dependent jump risk premium. For example, in Pan (2002), the jump-arrival intensity is linear in the volatility level, and the jump-risk premium is linear in stock volatility VOL. Following Bakshi and Kapadia (2003), we control for the jump risk by including the option implied risk-neutral skewness and kurtosis of the underlying stock return. Appendix 2 provides details of these measures. The coefficients of risk-neutral skewness and kurtosis are negative and statistically significant. However, after controlling for the jump risk proxies, there is still a significant negative relation between delta-hedged option return and idiosyncratic volatility. Thus, our result can not be explained by jump risk premium.

3.4 Controlling for Volatility-related Option Mispricing

Another potential explanation of our result is volatility-related option mispricing. First, Goyal and Saretto (2009) provide evidence of volatility mispricing due to investors' failure to incorporate the information contained in the cross-sectional distribution of implied volatilities when forecasting individual stock's volatility. They argue that large deviations of implied volatility from historical volatility are indicative of mis-estimation of volatility dynamics. They find that options with high implied volatility (relative to the historical volatility) earn low returns.

Table 4 Model 2 controls for the log difference between historical and at-the-money option implied volatility, the same variable used by Goyal and Saretto (2009).[14] This variable has a significant positive coefficient, which is consistent with Goyal and Saretto (2009). More importantly, after controlling for this proxy of volatility-related option mispricing, the coefficient for idiosyncratic volatility not only remains statistically significant, but its magnitude more than doubles. The $IVOL$ coefficient estimate is now -0.0741 (Model 2), compared to -0.0325 (Model 1) without controlling for the Goyal and Saretto variable. Thus, volatility-related mispricing documented by Goyal and Saretto (2009) exacerbates rather than explains our result.

VIX index from the Chicago Board Options Exchange. The second factor is the zero-beta straddle return on the S&P 500 index. The third is the market variance risk premium. The fourth factor is the monthly change of the equal-weighted average idiosyncratic volatility of individual stocks.

[14] Our results do not change when we use the difference (rather than log difference) between historical and at-the-money option implied volatility.

Second, stocks with high idiosyncratic volatility may have experienced increase in volatility recently. If investors overreact to recent changes in volatility (see, e.g., Stein (1989), Poteshman(2001)), and pay too much for options on high volatility stocks, then the subsequent returns of delta-hedged option positions would be low. In Table 4 Model 3, we control for the average change in stock volatility over the past six months. Delta-hedged option return tends to be lower after recent increase in volatility. This is consistent with the overreaction to volatility story. However, after controlling for recent change in volatility, we still find a significant negative relation between delta-hedged option return and the idiosyncratic volatility of the underlying stock. Thus, our result can not be explained simply by investors' overreaction to recent change in volatility.

Table 4 Model 4 further controls for the change in the implied volatility of the same option over the same time period as the dependent variable, the delta-hedged option return. If the negative relation between delta-hedged option return and the stock volatility at the beginning of the period just reflects the correction of some kind of volatility-related option mispricing, then it should become insignificant once we control for the contemporaneous change in the option implied volatility. We find a strong and significantly positive coefficient for the contemporaneous change in the option implied volatility.[15] However, we find that the $IVOL$ coefficient continues to be highly significant, both statistically and economically.

3.5 Controlling for Stock Characteristics

The dependent variable in all of our regressions is the returns of delta-hedged option positions. We rebalance the delta-hedges daily to minimize the influence of underlying stock price for delta-hedged option position. Still, it may be possible that due to the imperfections in the delta-hedges, the strong link between delta-hedged option return and stock idiosyncratic volatility we document is related to some known pattern in the cross-section of expected stock return. To test this possibility, the regressions reported in Table 5 control for several stock characteristics that are significant predictors of the cross-section of stock returns, including size (ME), book-to-market ratio (BE/ME) of the underlying stock and past stock returns. Following Fama and French (1992), we measure ME as the product

[15]Note that by definition, delta-hedged option return is positively related to contemporaneous change in the option implied volatility, even in the absence of volatility mispricing.

of monthly closing stock price and the number of outstanding common shares in previous June. BE/ME is the previous fiscal-yearend book value of common equity divided by the calendar-yearend market value of equity.

The $IVOL$ coefficient remains negative and highly significant in all regressions reported in Table 5. In particular, the strong negative relation between delta-hedged option return and idiosyncratic volatility is insensitive to controlling for past stock returns over various horizons, including past one month, between 12 months and 1 month ago, and between three years and one year ago. The $IVOL$ coefficient is about -0.038 to -0.039 in the presence of the past stock returns. By comparison, the $IVOL$ coefficient is -0.0325 without the past stock returns as additional regressors (see Table 4 Model 1). Thus, controlling for past stock returns actually strengthens the negative relation between delta-hedged option return and idiosyncratic volatility. This is in stark contrast to the return-idiosyncratic volatility relation in the stock market. Huang, Liu, Ghee, and Zhang (2009) report that the volatility-return relation in the cross-section of stocks becomes insignificant when past one-month return is used as a control variable. Controlling for size and book-to-market ratio does not materially affect the magnitude and statistical significance of the $IVOL$ coefficient either.

Interestingly, Table 5 shows that delta-hedged call option return is significantly and positively related to the underlying stock return over past one year as well as between three years and one year ago. The same pattern holds for delta-hedged put option returns (see Table 7 Panel B). These findings can not be explained by stock return predictability by past returns. First, we examine delta-hedged options that are not sensitive to stock price movement by construction. Second, it is hard to explain why past return between three years and one year ago is positively related to delta-hedged call option return but negatively related to stock return if our result just reflects stock return predictability by past returns.

To summarize, we have shown that the negative relation between delta-hedged option return and idiosyncratic volatility can not be explained by volatility risk premium or volatility related option mispricing. Our finding is robust and distinct from known results on the determinants expected stock return.

3.6 Limits to Arbitrage

In this section, we provide evidence that our result can be better understood under models of option valuation in imperfect market (e.g., limits to arbitrage between options and stocks). Traditionally, options are priced relative to the underlying stock by the no arbitrage principle. Recent studies document that options are non-redundant and there are limits to arbitrage in the options market. No-arbitrage approach can only establish very wide bounds on equilibrium option prices (e.g., Figlewski (1989)).

In the presence of limited arbitrage between options and the underlying stocks, delta-hedged option return is expected to be negatively related to stock's idiosyncratic volatility. First, investors' demand for equity options is higher when the underlying stock is more volatile. In particular, stocks with high idiosyncratic volatility attract speculation (e.g., Kumar (2009)) and thus demand for options on these stocks is also higher. Several recent studies have shown that due to limits to arbitrage in the options market, investors' demand pressures for options importantly affect option prices (e.g., Bollen and Whaley (2004), Garleanu, Pedersen, and Poteshman (2009)). Thus, high demand for options on stocks with high idiosyncratic volatility leads to high prices paid for these options and low future returns.

Second, among the hindrances to arbitrage activity, idiosyncratic risk has been found to be one of the more robust and strong factors associated with mispricing (e.g., Pontiff (2006)). Idiosyncratic volatility prevents arbitrageurs from engaging in arbitrage trades. In particular, it is difficult to hedge options on high idiosyncratic volatility stocks. Thus, option supply considerations combined with idiosyncratic volatility acting as a proxy for limits to arbitrage would also suggest a negative relation between delta-hedged option return and the underlying stock's idiosyncratic volatility.

Table 6 examines the impact of limits to arbitrage proxies on delta-hedged option returns and how it affects the relation between delta-hedged option returns and stock's idiosyncratic volatility. We control for the effect of option demand pressure using individual option's open interest as a proxy. We use option open interest at the end of the month scaled by monthly stock trading volume.[16] We also control for various liquidity measures for options and underlying stocks, such as option's bid-ask spread, stock price and the Amihud (2002)

[16] Our results are qualitatively the same if we use option trading volume instead of open interest, or if we scale by stock's total shares outstanding.

measure of the price impact for stocks. The Amihud illiquidity measure for stock i at month t is defined as

$$IL_{i,t} = \frac{1}{D_t}\sum_{d=1}^{D_t} |R_{i,d}|/VOLUME_{i,d},$$

where D_t is the number of trading days in month t, $R_{i,d}$ and $VOLUME_{i,d}$ are, respectively, stock i's daily return and trading volume in day d of month t. The motivation is that arbitrage between stock and option is more difficult to implement when transaction costs in options are high, and when the stocks are illiquid. These cases tend to be associated with high stock volatility as well.

Table 6 Model 2 shows that delta-hedged option returns decrease with option open interest, which has a significantly negative coefficient of -0.0704 (t-stat -7.91). This is consistent with the idea that option market makers charging higher premium for options with large end-users demand. Further, Table 6 Model 3 to 5 show that the delta-hedged option returns are more negative when the option bid-ask spread is higher, when the underlying stock is less liquid and when the underlying stock has low price. These results confirm that delta-hedged option returns importantly depend on the difficulty to arbitrage between stocks and options.

After controlling for the limits of arbitrage proxies above, the magnitude of the $IVOL$ coefficient is reduced by about 41% from -0.0366 (Table 6 Model 1) to -0.0214 (Model 6). Thus, limits to arbitrage play a key role in explaining the negative relation between delta-hedged option return and stock idiosyncratic volatility. In Section 4.4, we provide further evidence on the importance of limits to arbitrage for our results.

3.7 Robustness Checks

Table 7 reports several robustness checks on our results. In previous regression tables, the dependent variable, delta-hedged option returns, are measured as changes in daily rebalanced delta-hedged option portfolio till maturity scaled by the initial value of the delta-hedged portfolio. In Table 7 Panel A, we use delta-hedged option return over alternative holding periods, such as one week or one month. Previous tables report the results for call options. In Table 7 Panel B, we re-run the regressions for put options. In all regressions, we still find a significant negative $IVOL$ coefficient.

We have conducted additional robustness checks. First, our results are qualitatively the same when we scale the delta-hedged gains by the initial stock price or option price. Second, we also control for option theta. In univariate regression, option theta is negatively correlated with delta-hedged option return. In the presence of other control variables, theta loses its significance. In all regressions, the coefficient for idiosyncratic volatility is still significantly negative. Third, we re-estimate our models using panel regressions (both OLS and with firm-time clustered standard errors). We find again a significantly negative relation between delta-hedged option returns and stock idiosyncratic volatility, consistent with the results from Fama-MacBeth cross-sectional regressions.

4 Volatility-based Option Trading Strategy

This section studies the relation between delta-hedged option returns and stock idiosyncratic volatility using the portfolio sorting approach. We confirm the previous results obtained by the Fama-MacBeth regressions, propose a volatility-based option trading strategy, and examine the impact of liquidity and transaction costs on the profitability of our option strategy.

At the end of each month, we rank stocks with traded options into five quintiles based on their idiosyncratic volatility (we also repeat the exercise sorting on total volatility or systematic volatility). Our option strategy buys the delta-hedged call options on stocks ranked in the bottom volatility quintile and sells the delta-hedged call options on stocks ranked in the top volatility quintile.[17] We rebalance daily the delta-hedged option positions and track their performances over the next month.

A long delta-hedged option position involves buying one contract of call option and selling Δ shares of the underlying stock, where Δ is the Black-Scholes call option delta. A short delta-hedged option position involves selling one contract of call option against a long position of Δ shares of the underlying stock. In both cases, we adjust the delta hedge each trading day by buying or selling proper amount of stock, keeping the option position to be one contract until the end of next month when it is closed out. The return to selling a delta-hedged call over one trading day $[t, t+1]$ is $H_{t+1}/H_t - 1$ where $H_t = \Delta S_t - C_t$, with

[17]As in Section 3, for each optionable stock, we choose a call option that is closest to being at-the-money and has a time-to-maturity of about 50 days.

C and S denoting call option price and the underlying stock price. We compound the daily returns to compute the monthly return.

4.1 Average Returns

Table 8 reports the average returns of five portfolios, each of which consists of short positions in daily-rebalanced delta-hedged calls on stocks ranked in a given quintile by the underlying stock's total volatility (Panel A) or by its idiosyncratic volatility (Panel B). Table 1 shows that the returns of delta-hedged options are negative on average. We use short positions in delta-hedged call options in Table 8 so that the average portfolio returns are positive. Table 8 also reports in the "5-1" column the difference in the average returns of the top and the bottom (idiosyncratic) volatility quintile portfolios, which is by definition exactly the return of our volatility-based option trading strategy.

We try three weighting schemes in computing the average portfolio return: equal weight, weighted by the market capitalization of the underlying stock or by the market value of total option open interests on each stock (at the initial formation of option portfolio). Our results are consistent across different weighting schemes.

Table 8 shows that the average return of selling delta-hedged calls is positive. Corresponding to the significant negative relation between delta-hedged option return and stock (idiosyncratic) volatility in the regressions, we find that the average return to selling delta-hedged calls on high (idiosyncratic) volatility stocks is significantly higher than that on low (idiosyncratic) volatility stocks. For example, the average difference in returns between the equal-weighted portfolio of short positions in delta-hedged calls for stocks ranked in the top volatility quintile and that for stocks ranked in the bottom volatility quintile is 1.2%. The same result is stronger (1.4%) when we sort stocks by their idiosyncratic volatility. All of these return differences are significant both statistically and economically.

In both Panel A and B, the value-weighted portfolio return differences between the top and the bottom (idiosyncratic) volatility quintiles are only about half the magnitude as the corresponding equal-weighted results. This suggests that our results are stronger among smaller stocks. Table 8 Panel C confirms this. Each month, we first sort stocks into five quintiles by their market capitalization, and then within each size quintile, we sort further by stock's idiosyncratic volatility. We document the average returns of five portfolios and the "5-1" difference (i.e., the profitability of our option strategy) separately for each size quintile.

The average return of our option strategy ranges from 1.63% for the bottom size quintile to 0.32% among the top size quintile. Our option strategy is profitable both in January and in the rest of the year. The average equal-weighted return to our strategy is over 1% per month in all subperiods (1996 to 1999, 2000 to 2003, 2004 to 2006 and 2007 to 2009).

4.2 Double Sorts on Idiosyncratic Volatility and Systematic Volatility

Previously, we use Fama-MacBeth regressions to show that the negative relation between delta-hedged option return and stock volatility is entirely driven by the idiosyncratic volatility. Table 8 Panel D and E use conditional double sorts to highlight the differential impact of idiosyncratic volatility and systematic volatility on the delta-hedged option returns. In Panel D, we first sort stocks at the end of each month into five portfolios by their systematic volatility exposures, and then within each systematic volatility quintile, we further sort stocks by their idiosyncratic volatility. In Panel E, we switch the order of double sorts, first sorting on idiosyncratic volatility, and then on systematic volatility.

Table 8 Panel D shows that in all five systematic volatility quintiles, selling delta-hedged calls on high idiosyncratic volatility stocks significantly outperforms selling delta-hedged calls on low idiosyncratic volatility stocks. The average outperformance ranges from 2.07% in the highest systematic volatility quintile to 0.82% in the lowest systematic volatility quintile. These findings are consistent with the negative relation between delta-hedged option return and idiosyncratic volatility. Further, this negative relation is significant after controlling for stock's systematic volatility exposure.

On the other hand, when we sort stocks by their systematic volatility exposures, the average portfolio returns to selling delta-hedged options show a pattern that is opposite to those when we sort stocks by their idiosyncratic volatility. Table 8 Panel E shows that selling delta-hedged options on stocks with high systematic volatility tends to underperform, not outperform, selling delta-hedged options on stocks with low systematic volatility. This is consistent with the positive regression coefficients on stock's systematic volatility in Table 2 Panel B and Table 3.

4.3 Controlling for Common Risk Factors

Table 9 examines whether return of our option strategy can be explained by the systematic volatility risk factors. We regress the time-series of equal-weighted monthly returns of our option strategy on several systematic volatility risk factors. The first is the zero-beta straddle return on the S&P 500 index, which proxies for the market volatility risk (e.g., Coval and Shumway (2001) and Carr and Wu (2009)). For robustness, we also measure the market volatility risk by change in the VIX index from the Chicago Board Options Exchange following Ang et al (2006). The third volatility risk factor is the common individual stock variance risk used in Driessen, Maenhout and Vilkov (2009). It is measured as value-weighted zero-beta straddle returns on the individual stocks that are components of the S&P 500 index. In addition, we include the Fama-French three factors and the momentum factor as additional regressors.

Table 9 shows that the estimated coefficients for the volatility risk factors are negative, but only the coefficient for the common individual stock variance risk is significantly negative in all specifications. In addition, our option strategy loads positively on the SMB factor and the momentum factor. More importantly, after controlling for the volatility risk factors and common risk factors from the stock markets, our option strategy still has a significant positive alpha of 1.318% per month, compared to the raw equal-weighted average return of 1.4% (Table 8 Panel B). Therefore, common risk factors only explain a tiny fraction of the profitability of our option strategy.

4.4 Transaction Costs

For all of the previous results, we assume the options can be bought or sold at the mid-point of the bid and ask price quotes. Table 10 examines the impact of transaction cost on the profitability of our volatility-based option strategy. To take into account the costs associated with buying or selling options, we assume the effective option spread is equal to 10%, 25%, or 50% of the quoted spread. Effective spread is defined as twice the difference between the actual execution price and the market quote at the time of order entry. The column "MidP" in Table 10 Panel A corresponds to zero effective spread, i.e., transaction price equals the mid-point of the bid and ask quotes, like in all previous tables.

Table 10 Panel A shows that the average return to the equal-weighed portfolio strategy of selling delta-hedged calls on stocks ranked in the top idiosyncratic volatility quintile and buying delta-hedged calls on the bottom idiosyncratic volatility quintile stocks decreases monotonically with the transaction cost. It is 1.40% per month when evaluated at the mid-point of bid and ask quotes. When the effective option spread is 10% or 25% of the quoted spread, the average return of our option strategy is reduced to 1.16% or 0.79% respectively, although still statistically significant. When we buy an option at the average of the ask price and the mid-point of the quoted spread, and sell an option at the average of the bid price and the mid-point of the quoted spread (i.e., the effective spread is 50% of the quoted spread), the average return of our option strategy is only 0.17%, which is no longer significant statistically or economically. The results are similar when we consider the Fama-French three-factor alphas rather the raw returns, or when we modify the trading strategy from "5 minus 1" to "10 minus 1" using the extreme deciles sorted by idiosyncratic volatility.[18] Hence, only market participants who face relatively low transaction costs can take advantage of our option strategy profitably.

Table 10 Panel B documents how the profitability of our option strategy varies with liquidity. Each month, we first sort the optionable stock sample into five quintiles by the stock price or its Amihud (2002) illiquidity measure. Then within each quintile, we further sort by stock's idiosyncratic volatility. Panel B shows that the average return of our idiosyncratic volatility based option strategy is significantly higher for illiquid and low priced stocks.[19] For example, the average return of our option strategy is 2.04% among stocks ranked in the top quintile by the Amihud illiquidity measure, and 1.99% among lowest priced stocks. In contrast, for stocks ranked in the bottom quintile by the Amihud illiquidity measure and for highest priced stocks, the average return of our option strategy is insignificant,

[18] The average return of the "10 minus 1" strategy is still significantly positive when the effective spread is 50% of the quoted spread. But it becomes insignificant when the effective spread is 75% of the quoted spread.

[19] We also verify these results in unreported Fama-MacBeth regressions that include $IVOL$, stock price, Amihud illiquidity measure, as well as $IVOL\times$ stock price and $IVOL\times$ Amihud measure as regressors.

both statistically and economically. These results highlight again that limits to arbitrage play a key role explaining the negative relation between delta-hedged option return and idiosyncratic volatility documented in this paper.

4.5 Discussions

A rapidly growing literature documents that low-volatile stock portfolios earn high risk-adjusted returns (e.g., Ang, Hodrick, Xing, and Zhang (2006), Bali and Cakici (2008), Fu (2009), Huang, Liu, Ghee, and Zhang (2009), Boyer, Mitton, and Vorkink (2010), and Han and Kumar (2010)). The prospect of reducing risk without sacrificing return makes this new low-volatility investment style very attractive to investors, especially since the experience of the financial crises.[20] We contribute to this literature showing that the low volatility investment style works in the options market. By construction of delta-hedged option portfolio, the significant relation between delta-hedged option returns and idiosyncratic volatility of the underlying stock is distinct from and not driven by relation between stock return and idiosyncratic volatility.[21]

Existing theories for why assets with high volatility may have low average returns have difficulties explaining our results. One such explanation is investors' preference for positive skewness (e.g., Boyer, Mitton, and Vorkink (2010)). Options have positively skewed payoffs, and call option payoff skewness increases with the volatility of the underlying stock. Hence, it is possible that investors with skewness preference are willing to pay a higher price and accept a lower expected return for call options on high volatility stocks because such options offer more positive skewness. However, the same argument does not apply to the put options: put options on high volatility stocks offer lower, not higher, skewness. So skewness preference could not fully explain the negative relation between delta-hedged put options and the volatility of the underlying stocks.

Another explanation for why high volatility assets have low average returns is realization utility. Barberis and Xiong (2009) show that investors with realization utility hold onto risky asset till they have a sufficient gain. Our results are based on options with about one

[20]For example, MSCI launched a minimum volatility index in April 2008 to exploit volatility as an alpha source.

[21]For our sample of optionable stocks and for the 1996-2009 sample period, we find no significant relation between the average stock return and idiosyncratic volatility.

and a half months till maturity. Investors may not have the luxury of holding onto these short-term options until they have a gain. In addition, unlike stocks, options lose value over time. The time decay of option value is especially severe for high volatility stocks. Thus, it is unlikely that realization utility investors would find short-term options on high volatility stocks attractive.

5 Conclusions

This paper provides a comprehensive study of individual stock option returns after delta-hedging the exposure to the underlying stocks. The key new finding is that the average delta-hedged option return is negative and decreases monotonically with an increase in the idiosyncratic volatility of the underlying stock. This holds for both call options and put options. It is robust and significant, both statistically and economically. For example, when equal-weighted, the portfolio of delta-hedged call options on stocks ranked in the top idiosyncratic volatility quintile on average underperforms the portfolio of delta-hedged call options on stocks ranked in the bottom idiosyncratic volatility quintile by 1.4% per month.

Our finding is a new anomaly relative to the traditional option pricing models based on perfect markets and no arbitrage. Our tests rule out explanations based on common stock market risk factors or stock characteristics. Exposure to market volatility risk or common idiosyncratic volatility risk only explains a small portion of the underperformance of delta-hedged options on stocks with high idiosyncratic volatility. Further, controlling for proxies of volatility-related option mispricing exacerbates rather than explains our result.

We document that several proxies of limits to arbitrage between stocks and options importantly affect the cross-section of delta-hedged option returns. The relation between the delta-hedged option return and idiosyncratic volatility of the underlying stock is stronger when it is more costly to arbitrage between options and stocks. Controlling for several limits to arbitrage proxies reduces the strength of the negative relation between delta-hedged option return and idiosyncratic volatility by about 40%. We find only market participants who face relatively low transaction costs can take advantage of the negative relation between the delta-hedged option return and the idiosyncratic volatility of the underlying stock.

Our results are consistent with market makers charging a higher premium for options on high idiosyncratic volatility stocks because these options are more difficult to hedge and also have higher arbitrage costs. To the extent that options on high idiosyncratic volatility stocks are likely to attract large investor demand, demand-based option pricing models (e.g., Garleanu, Pedersen, and Poteshman (2009)) also suggest that option market makers charge a higher price for these options, thus leading to a lower future returns. Our results may be also consistent with informed trading in options.[22] It is likely that there is more private information in stocks with high idiosyncratic volatility (e.g., Durnev, Yeung and Zarowin (2003)). Back (1993) shows that asymmetric information can make it impossible to price options by arbitrage. Market makers get hurt by the informed trading in options. They charge a higher premium for options on high idiosyncratic volatility stocks because there are more informed trading.

Finally, another new empirical finding of this paper is that delta-hedged option returns for past winner stocks are significantly higher than delta-hedged option returns for past loser stocks. This "option momentum" pattern holds for both individual stock call options and put options. Further research is needed to better understand this option momentum phenomenon.

[22] See e.g., Cao, Chen, and Griffin (2005), Pan and Poteshman (2006) for evidence of informed trading in options.

Appendix 1: Volatility Risk Premium

Our measure of volatility risk premium follows closely previous studies such as Carr and Wu (2008) and Bollerslev, Tauchen, and Zhou (2009). In each month t and for each stock i with options traded, we measure the stock's volatility risk premium as

$$VRP_{i,t} = \sqrt{RV_{i,t}} - \sqrt{IV_{i,t}}$$

where $RV_{i,t}$ is realized return variance computed from high frequency return data over all trading days in the month t, and $IV_{i,t}$ is the risk-neutral expected variance extracted from equity options on the last trading day of each month t. Both $RV_{i,t}$ and $IV_{i,t}$ are annualized.

More precisely, we extract from TAQ intraday equity trading data spaced by $\Delta = 15$ minutes interval.[23] Let p_j^i denote the logarithmic price of stock i at the end of the jth 15-minutes interval in the month t. The month t realized variance is measured as:

$$RV_t^i = 12 \sum_{j=1}^{n} \left[p_j^i - p_{j-1}^i\right]^2. \tag{2}$$

where n is the number of 15-minutes interval in month t. We multiply by 12 to get an annualized variance estimate that is comparable to the risk-neutral expected variance implied from the options data.

The one-month risk-neutral expected variance is

$$\begin{aligned} IV_{i,t} &\equiv E^Q[\text{Return Variation } (t, t+1)_i] \\ &= 2\int_0^\infty \frac{C_i(t,t+1,K)/B(t,t+1) - max[0, S_{i,t}/B(t,t+1) - K]}{K^2} dK. \end{aligned} \tag{3}$$

where $S_{i,t}$ denotes the price of stock i at t, $C_i(t, t+1, K)$ denotes the date t price of a call option with a strike price K and time-to-maturity of one month. $B(t, t+1)$ denotes the present value of a zero-coupon bond that pays off one dollar next month.[24]

In our empirical estimation, the integral in (3) is evaluated numerically. On the last trading day of each month t, we first extract the implied volatilities for one-month call options

[23] All of our results are robust when we estimate the realized variance using stock prices sampled every 30 minutes or every hour.

[24] We have also computed the model–free implied variance based on prices of put options and obtained virtually the same estimates as those based on the call options.

from the standardized Volatility Surface provided by OptionMetrics, and then translate these implied volatilities into call option prices using the Black-Scholes model. We find that the number of strikes provided by the standardized Volatility Surface is fine enough so that the discretization in the numerical integration has minimal impact on the estimation of the risk-neutral expected variance.[25]

To estimate the variance risk premium for a stock in a given month, we require that at the end of the month, there are at least five traded call options on the stock with maturity between 15 days and 60 days that survive the option data filters described in Section 2. Among these options, we further require at least two are out of money, two in the money, one close to being at the money. This helps to ensure the reliability of the variance risk premium estimates. With these additional data filters, on average there are about 464 stocks in each month for which we estimate the volatility risk premium. The set of such stocks increases from about 350 in the beginning of our sample (1996-1997) to about 670 towards the end of the sample (2008-2009).

Appendix 2: Risk-neutral Skewness and Kurtosis

We use a model-free and ex-ante measure of risk-neutral skewness and kurtosis given by Bakshi, Kapadia, and Madan (2003). For each stock on date t, the skewness and kurtosis of the risk-neutral density of the stock return over the period $[t, t+\tau]$ can be inferred from the contemporaneous prices of out-of-the-money call options and put options as follows:

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

where

$$\mu(t,\tau) = e^{r\tau} - 1 - \frac{e^{r\tau}}{2}V(t,\tau) - \frac{e^{r\tau}}{6}W(t,\tau) - \frac{e^{r\tau}}{24}X(t,\tau), \tag{5}$$

and $V(t,\tau)$, $W(t,\tau)$ and $X(t,\tau)$ are the weighted sums of OTM call option prices $C(t,\tau,K)$ and put option prices $P(t,\tau,K)$, with time-to-maturity τ and strike price K, given the

[25] OptionMetrics computes the implied volatility of a traded option from its price using a proprietary pricing algorithm. OptionMetrics uses a kernel smoothing technique to compute a surface of option implied volatilities for standard maturities and strikes based on the implied volatilities of traded options. The standard strikes correspond to call option deltas of 0.20, 0.25, 0.30, 0.35, 0.40, 0.45, 0.50, 0.55, 0.60, 0.65, 0.70, 0.75, and 0.80. For options with strike prices beyond the available range, we use the endpoint implied volatility to extrapolate their option value.

underlying asset price S_t:

$$V(t,\tau)=\int_{S_t}^{\infty}\frac{2(1-ln(\frac{K}{S_t}))}{K^2}C(t,\tau,K)dK+\int_0^{S_t}\frac{2(1+ln(\frac{S_t}{K}))}{K^2}P(t,\tau,K)dK, \tag{6}$$

$$W(t,\tau)=\int_{S_t}^{\infty}\frac{6ln(\frac{K}{S_t})-3[ln(\frac{K}{S_t})]^2}{K^2}C(t,\tau,K)dK-\int_0^{S_t}\frac{6ln(\frac{S_t}{K})+3[ln(\frac{S_t}{K})]^2}{K^2}P(t,\tau,K)dK, \tag{7}$$

$$X(t,\tau)=\int_{S_t}^{\infty}\frac{12[ln(\frac{K}{S_t})]^2-4[ln(\frac{K}{S_t})]^3}{K^2}C(t,\tau,K)dK+\int_0^{S_t}\frac{12[ln(\frac{S_t}{K})]^2+4[ln(\frac{S_t}{K})]^3}{K^2}P(t,\tau,K)dK. \tag{8}$$

The integrals are approximated in (6), (7) and (8) using the trapezoidal method. For accuracy, we require at least three out-of-the-money call options and three out-of-the-money put options. Due to this data constraint, the option implied skewness and kurtosis are only available for about half of the sample.

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Table 1: Summary Statistics

This table reports the descriptive statistics of delta-hedged option returns for the pooled data. The option sample period is from Jan 1996 to Oct 2009. At the end of each month, we extract from the Ivy DB database of Optionmetrics one call and one put on each optionable stock. The selected options are approximately at-the-money with a common maturity of about one and a half months. We exclude the following option observations: (1) moneyness is lower than 0.8 or higher than 1.2; (2) option price violates obvious no-arbitrage option bounds; (3) reported option trading volume is zero; (4) option bid quote is zero or mid-point of bid and ask quotes is less than $1/8; (5) the underlying stock paid a dividend during the remaining life of the option. Delta-hedged gain is the change (over the next month or till option maturity) in the value of a portfolio consisting of one contract of long option position and a proper amount of the underlying stock, re-hedged daily so that the portfolio is not sensitive to stock price movement. The call option delta-hedged gain is scaled by (Δ*S – C), where Δ is the Black-Scholes option delta; S is the underlying stock price; C is the price of call option. Days to maturity is the number of calendar days till the option expiration. Moneyness is the ratio of stock price over option strike price. Vega is the option vega according to the Black-Scholes model scaled by stock price. Total volatility (VOL) is the standard deviation of daily stock returns over the previous month. Idiosyncratic volatility (IVOL) is the standard deviation of the residuals of the Fama-French 3-factor model estimated using the daily stock returns over the previous month. Volatility risk premium (VRP) is the difference between the square root of a model free estimate of the risk-neutral variance implied from stock options at the end of each month and the square root of realized variance estimated from intra-daily stock returns over the previous month. VOL_deviation is the log difference between VOL and Black-Scholes implied volatility for at-the-money options (IV). Option bid-ask spread is the ratio of the difference between ask and bid quotes of option over the mid-point of bid and ask quotes at the end of each month. Illiquidity is the average of the daily Amihud (2002) illiquidity measure over the previous month.

Variable		Mean	Median	StDev	10 Pctl	Lower Quartile	Upper Quartile	90 Pctl
Panel A: Call Options (213,640 Obs)								
Delta-hedged gain till maturity / (Δ*S – C)	(%)	-1.13	-1.29	8.07	-7.86	-4.05	1.09	4.87
Delta-hedged gain till month-end / (Δ*S – C)	(%)	-0.81	-0.92	5.13	-5.47	-2.86	0.90	3.76
Days to maturity		50	50	2	47	50	51	52
Moneyness = S/K	(%)	100.55	100.18	5.08	94.80	97.36	103.36	106.53
Vega		0.14	0.14	0.01	0.13	0.14	0.15	0.15

Variable		Mean	Median	StDev	10 Pctl	Lower Quartile	Upper Quartile	90 Pctl
Panel B: Put Options (199,198 Obs)								
Delta-hedged gain till maturity / (P - Δ*S)	(%)	-0.82	-1.17	6.46	-6.68	-3.57	1.18	4.95
Delta-hedged gain till month-end / (P - Δ*S)	(%)	-0.35	-0.73	4.67	-4.55	-2.44	1.08	3.93
Days to maturity		50	50	2	47	50	51	52
Moneyness = S/K	(%)	99.84	99.73	4.86	94.20	96.87	102.69	105.63
Vega		0.14	0.14	0.01	0.13	0.14	0.15	0.15

Variable	Mean	Median	StDev	10 Pctl	Lower Quartile	Upper Quartile	90 Pctl
Panel C: Stock Characteristics Summary (Time-Series Average of Cross-Sectional Statistics)							
Total volatility: VOL	0.50	0.44	0.24	0.24	0.32	0.62	0.82
Idiosyncratic volatility: IVOL	0.42	0.37	0.23	0.19	0.26	0.53	0.72
Volatility risk premium: VRP	0.05	0.05	0.09	-0.05	0.01	0.09	0.15
VOL deviation: Ln (VOL / IV)	-0.09	-0.08	0.29	-0.45	-0.27	0.10	0.28
(Option open interest / stock volume) $*10^3$	0.03	0.01	0.07	0.00	0.00	0.03	0.08
Option bid-ask spread	0.21	0.16	0.15	0.07	0.10	0.27	0.42
Ln (Illiquidity)	-6.33	-6.30	1.68	-8.56	-7.50	-5.15	-4.17

Panel D: Average Delta-hedged Gain till Maturity Scaled by (Δ*S – C) for Call or (P - Δ*S) for Put

Option Type	Total stocks	mean<0	t<-2	mean>0	t>2	P10	P25	P50	P75	P90
Call	6141	4759	1930	1382	64	-3.75%	-1.85%	-0.77%	-0.08%	0.77%
Put	6065	3926	1371	2139	104	-2.75%	-1.25%	-0.36%	0.30%	1.40%

Table 2: Delta-Hedged Option Returns and Stock Volatility

This table reports the average coefficients from monthly Fama-MacBeth regressions of call option delta-hedged gain till maturity scaled by (Δ*S – C) at the beginning of the period. All volatility measures are annualized. Total volatility (VOL) is the standard deviation of daily stock returns over the previous month. VOL2 is the square root of average of daily returns squared over the previous month**.** VOL_month is the standard deviation of monthly stock returns over the past 60 months. IV is the at-the-money Black-Scholes option implied volatility at the end of each month. Idiosyncratic volatility (IVOL) is the standard deviation of the residuals of the Fama-French 3-factor model estimated using the daily stock returns over the previous month. Systematic volatility (SysVOL) is the square root of (VOL^2-$IVOL^2$). IVOL_month is the standard deviation of the residuals of the CAPM model estimated using monthly stock returns over the past 60 months. SysVOL_month is the square root of (VOL_month^2 – $IVOL\_month^2$). Eidio_in is the fitted idiosyncratic volatility from a EGARCH (1,1) model estimated using all historical monthly returns. Eidio_out is the one-step ahead idiosyncratic volatility forecast from the EGARCH(1,1) model. Vega is the Black-Scholes option vega scaled by the underlying stock price at the beginning of the period. All independent variables are winsorized each month at 0.5% level. The sample period is from January 1996 to October 2009. To adjust for serial correlation, robust Newey-West (1987) t-statistics are reported in brackets.

Panel A: Delta-Hedged Call Option Returns and Stock Total Volatility

	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	0.0024	0.0219	0.0216	0.0284	0.0486
	(1.34)	(4.86)	(4.81)	(6.34)	(9.62)
VOL	-0.0299	-0.0297			
	(-8.72)	(-8.68)			
VOL2			-0.0287		
			(-8.54)		
VOL_month				-0.0340	
				(-10.88)	
IV					-0.0824
					(-21.40)
Vega		-0.1406	-0.1415	-0.1590	-0.1290
		(-3.99)	(-4.00)	(-4.38)	(-3.52)
Average Adj. R^2	0.0194	0.0206	0.0207	0.0228	0.0665

Panel B: Systematic vs. Idiosyncratic Volatility

	Model 1	Model 2	Model 3	Model 4
Intercept	0.0226	0.0285	0.0308	0.0302
	(5.35)	(6.19)	(5.41)	(5.17)
IVOL	-0.0405			
	(-15.38)			
SysVOL	0.0165			
	(3.93)			
IVOL_month		-0.0454		
		(-12.87)		
SysVOL_month		0.0273		
		(4.37)		
Eidio_in			-0.0348	
			(-10.61)	
Eidio_out				-0.0341
				(-10.68)
Vega	-0.1522	-0.1692	-0.1908	-0.1876
	(-4.64)	(-4.57)	(-4.17)	(-3.97)
Average Adj. R^2	0.0257	0.0277	0.0198	0.0196

Table 3: Controlling for Volatility Risk Premium and Jump Risk

This table reports the average coefficients from monthly Fama-MacBeth cross-sectional regressions. The dependent variable is call option delta-hedged gain till maturity scaled by (Δ*S – C) at the beginning of the period. Total volatility (VOL) is the standard deviation of daily stock returns over the previous month. Idiosyncratic volatility (IVOL) is the standard deviation of the residuals of the Fama-French 3-factor model estimated using the daily stock returns over the previous month. Systematic volatility (SysVOL) is the square root of (VOL^2-$IVOL^2$). Volatility risk premium (VRP) is the difference between the square root of a model free estimate of the risk-neutral variance implied from stock options and the square root of realized variance estimated from intra-daily stock returns over the previous month. All volatility measures are annualized. Option implied skewness and kurtosis are the risk-neutral skewness and kurtosis of stock returns inferred from a cross-section of out of the money calls and puts at the beginning of the period. Vega is the Black-Scholes option vega scaled by the underlying stock price at the beginning of the period. All independent variables are winsorized each month at 0.5% level. The sample period is from January 1996 to October 2009. To adjust for serial correlation, robust Newey-West (1987) t-statistics are reported in brackets.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	0.0275	0.0235	0.0149	0.0285	0.0246	0.0199
	(6.15)	(5.77)	(2.19)	(5.75)	(5.20)	(2.15)
VOL	-0.0125	-0.0090	-0.0095			
	(-2.92)	(-2.34)	(-2.54)			
IVOL				-0.0236	-0.0203	-0.0200
				(-7.02)	(-6.48)	(-7.92)
SysVOL				0.0202	0.0223	0.0190
				(4.46)	(5.26)	(3.81)
VRP		0.1048			0.1028	
		(22.70)			(20.55)	
Option Implied Skewness			-0.0036			-0.0036
			(-7.21)			(-7.37)
Option Implied Kurtosis			-0.1179			-0.1071
			(-8.71)			(-7.34)
Vega	-0.2219	-0.1632	-0.1404	-0.2315	-0.1747	-0.1785
	(-5.89)	(-4.84)	(-2.98)	(-5.76)	(-4.66)	(-2.78)
Average Adj. R^2	0.0135	0.0376	0.0400	0.0183	0.0412	0.0467

Table 4: Controlling for Volatility Related Mispricing

This table reports the average coefficients from monthly Fama-MacBeth cross-sectional regressions. The dependent variable in month t's regression is call option delta-hedged gain till maturity scaled by (Δ*S − C) at the end of month t-1. Idiosyncratic volatility (IVOL) is the standard deviation of the residuals of the Fama-French 3-factor model estimated using the daily stock returns over month t-1. Total volatility (VOL_{t-1}) is the standard deviation of daily stock returns over month t-1. VOL_deviation is the log difference between VOL_{t-1} and IV_{t-1}, the Black-Scholes implied volatility for at-the-money options at the end of month t-1. Change in volatility (ΔVOL) is the difference between VOL_{t-1} and the previous six months' average realized volatility. In addition to these lagged regressors, we also control for contemporaneous change in option implied volatility Ln (IV_t / IV_{t-1}). All volatility measures are annualized. Vega is the Black-Scholes option vega scaled by the underlying stock price at the beginning of the period. All independent variables are winsorized each month at 0.5% level. The sample period is from January 1996 to October 2009. To adjust for serial correlation, robust Newey-West (1987) t-statistics are reported in brackets.

	Model 1	Model 2	Model 3	Model 4
Intercept	0.0331	0.0416	0.0413	0.0097
	(6.55)	(8.78)	(8.79)	(2.24)
IVOL	-0.0325	-0.0741	-0.0665	-0.0570
	(-10.39)	(-20.33)	(-15.17)	(-14.25)
VOL_deviation		0.0590	0.0724	0.0563
		(18.50)	(16.24)	(14.85)
ΔVOL			-0.0361	-0.0233
			(-8.48)	(-5.90)
Ln (IV_t / IV_{t-1})				0.0826
				(25.39)
Vega	-0.2191	-0.1342	-0.1484	0.0248
	(-5.80)	(-3.80)	(-4.12)	(0.76)
Average Adj. R^2	0.0210	0.0694	0.0774	0.1333

Table 5: Controlling for Stock Characteristics

This table reports the average coefficients from monthly Fama-MacBeth cross-sectional regressions of call option delta-hedged gain till maturity scaled by (Δ*S – C) at the beginning of the period. Idiosyncratic volatility (IVOL) is the standard deviation of the residuals of the Fama-French 3-factor model estimated using the daily stock returns over the previous month. $Ret_{(-1, 0)}$ is the stock return in the prior month. $Ret_{(-12, -1)}$ is the cumulative stock return from the prior 2^{nd} through 12^{th} month. $Ret_{(-36, -13)}$ is the cumulative stock return from the prior 13^{th} through 36^{th} month. ME is the product of monthly closing price and the number of outstanding shares in previous June. Book-to-market (BE/ME) is the fiscal-yearend book value of common equity divided by the calendar-yearend market value of equity. Vega is the Black-Scholes option vega scaled by the underlying stock price at the beginning of the period. All independent variables are winsorized each month at 0.5% level. The sample period is from January 1996 to October 2009. To adjust for serial correlation, robust Newey-West (1987) t-statistics are reported in brackets.

	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	0.0254	0.0285	0.0258	0.0304	-0.0017
	(5.36)	(6.20)	(5.42)	(6.36)	(-0.31)
IVOL	-0.0395	-0.0383	-0.0376	-0.0423	-0.0294
	(-15.00)	(-14.32)	(-13.68)	(-18.35)	(-12.19)
$Ret_{(-1,0)}$	0.0237			0.0250	0.0250
	(5.73)			(6.31)	(6.55)
$Ret_{(-12,-1)}$		0.0066		0.0072	0.0072
		(3.75)		(4.19)	(4.43)
$Ret_{(-36, -13)}$			0.0020	0.0021	0.0018
			(4.93)	(4.81)	(4.53)
Ln (ME)					0.0046
					(9.60)
Ln (BE/ME)					0.0012
					(2.41)
Vega	-0.1544	-0.1862	-0.1603	-0.2073	-0.2465
	(-3.89)	(-4.82)	(-4.08)	(-5.20)	(-6.13)
Average Adj. R^2	0.0280	0.0301	0.0238	0.0400	0.0509

Table 6: Controlling for Limits to Arbitrage

This table reports the average coefficients from monthly Fama-MacBeth cross-sectional regressions of call option delta-hedged gain till maturity scaled by ($\Delta*S - C$) at the beginning of the period. Idiosyncratic volatility (IVOL) is the standard deviation of the residuals of the Fama-French 3-factor model estimated using the daily stock returns over the previous month. Stock volume is the stock trading volume over the previous month. Option bid-ask spread is the ratio of bid-ask spread of option quotes over the mid-point of bid and ask quotes at the beginning of the period. Illiquidity is the average of the daily Amihud (2002) illiquidity measure over the previous month. Stock price is closing price at the beginning of the period. Vega is the Black-Scholes option vega scaled by the underlying stock price at the beginning of the period. All independent variables are winsorized each month at 0.5% level. The sample period is from January 1996 to October 2009. To adjust for serial correlation, robust Newey-West (1987) t-statistics are reported in brackets.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	0.0252	0.0265	0.0330	0.0024	0.0158	0.0151
	(5.76)	(6.10)	(7.66)	(0.47)	(3.13)	(2.76)
IVOL	-0.0366	-0.0372	-0.0364	-0.0245	-0.0212	-0.0214
	(-12.75)	(-13.18)	(-13.14)	(-8.55)	(-8.02)	(-8.23)
(Option open interest / stock volume) $*10^3$		-0.0704				-0.0532
		(-7.91)				(-7.05)
Option bid-ask spread			-0.0363			-0.0081
			(-9.25)			(-2.62)
Ln (Illiquidity)				-0.0051		-0.0016
				(-9.77)		(-3.90)
Stock price					0.0005	0.0004
					(12.42)	(10.39)
Vega	-0.1535	-0.1478	-0.1594	-0.2473	-0.2387	-0.2565
	(-4.31)	(-4.15)	(-4.50)	(-6.54)	(-5.72)	(-5.99)
Average Adj. R^2	0.0221	0.0256	0.0286	0.0369	0.0428	0.0512

Table 7: Alternative Measures of Delta-Hedged Option Returns

This table reports the average coefficients from monthly Fama-MacBeth cross-sectional regressions, using alternative measures of delta-hedged option returns as the dependent variable, for both call options (Panel A) and put options (Panel B). The first model uses delta-hedged option gain till maturity defined in Equation (2) scaled by (Δ*S - C) for call, or scaled by (P - Δ*S) for put. In the second model, delta-hedged option positions are held for one month rather than till option maturity. In the third model, delta-hedged option positions are held for one week. All independent variables are the same as in Table 2 to 6, and winsorized each month at 0.5% level. The sample period is from January 1996 to October 2009. To adjust for serial correlation, robust Newey-West (1987) t-statistics are reported in brackets.

Panel A: Delta-Hedged Call Option Returns

Dependent Variables	Gain till maturity (Δ*S – C)	Gain till month-end (Δ*S – C)	Gain till next week (Δ*S – C)
Intercept	0.0773	0.0700	0.0204
	(13.18)	(16.61)	(11.45)
IVOL	-0.0904	-0.0680	-0.0158
	(-33.64)	(-31.84)	(-16.07)
Ret $_{(-1,0)}$	0.0051	0.0008	-0.0029
	(1.27)	(0.27)	(-2.11)
Ret $_{(-12,-1)}$	0.0035	0.0007	-0.0001
	(2.60)	(0.90)	(-0.44)
Ret $_{(-36, -13)}$	0.0013	0.0003	0.0003
	(3.42)	(1.23)	(2.46)
(Option open interest /	-0.0371	-0.0270	-0.0007
stock volume) *10^3	(-6.82)	(-6.59)	(-0.52)
Option bid-ask spread	-0.0240	-0.0155	-0.0042
	(-8.43)	(-7.65)	(-4.00)
Ln (Illiquidity)	-0.0043	-0.0015	-0.0004
	(-7.34)	(-4.69)	(-3.54)
Ln (ME)	-0.0055	-0.0037	-0.0011
	(-9.91)	(-11.32)	(-8.33)
VOL_deviation	0.0632	0.0504	0.0162
	(17.89)	(18.41)	(15.24)
Vega	-0.2208	-0.1954	-0.0460
	(-5.04)	(-6.51)	(-3.73)
Average Adj. R^2	0.0938	0.1229	0.0567

Panel B: Delta-Hedged Put Option Returns

Dependent Variables	Gain till maturity (P - Δ*S)	Gain till month-end (P - Δ*S)	Gain till next week (P - Δ*S)
Intercept	0.0134	0.0345	0.0217
	(1.48)	(5.84)	(8.93)
IVOL	-0.0633	-0.0511	-0.0110
	(-19.73)	(-21.84)	(-17.09)
Ret $_{(-1,0)}$	-0.0085	-0.0071	-0.0054
	(-2.52)	(-2.58)	(-4.45)
Ret $_{(-12,-1)}$	0.0018	0.0014	-0.0002
	(2.66)	(2.58)	(-0.97)
Ret $_{(-36, -13)}$	0.0013	0.0006	0.0003
	(4.99)	(4.26)	(3.85)
(Option open interest /	-0.0348	-0.0246	-0.0004
stock volume) $*10^3$	(-6.56)	(-5.90)	(-0.28)
Option bid-ask spread	-0.0018	-0.0065	-0.0022
	(-0.60)	(-2.82)	(-2.33)
Ln (Illiquidity)	-0.0036	-0.0012	-0.0005
	(-5.99)	(-3.81)	(-3.83)
Ln (ME)	-0.0045	-0.0028	-0.0009
	(-7.80)	(-8.43)	(-7.21)
VOL_deviation	0.0483	0.0382	0.0113
	(18.98)	(20.42)	(15.61)
Vega	0.1126	-0.0190	-0.0843
	(2.01)	(-0.54)	(-5.97)
Average Adj. R^2	0.0932	0.0967	0.0497

Table 8: Returns of Selling Delta-Hedged Calls: Portfolio Sorts by Stock Volatility

This table reports the average return of selling short-maturity at-the-money call options on stocks sorted by volatility. At the end of each month, we rank all stocks with options traded into five groups by their total volatility (VOL) or idiosyncratic volatility (IVOL). For each stock, we sell one contract of call option against a long position of Δ shares of the underlying stock, where Δ is the Black-Scholes call option delta. The delta-hedges are rebalanced daily. For each stock and in each month, we compound the daily returns of the rebalanced delta-hedged call option positions over the next month to arrive a monthly return. We use three weighting schemes in computing the average return of selling delta-hedged calls for a portfolio of stocks: equal weight, weight by the market capitalization of the underlying stock or by the market value of option open interest at the beginning of the period. All returns in this table are expressed in percent. Total volatility (VOL) is the standard deviation of daily stock returns over the previous month. Idiosyncratic volatility (IVOL) is the standard deviation of the residuals of the Fama-French 3-factor model estimated using the daily stock returns over the previous month. Systematic volatility (SysVOL) is the square root of (VOL^2-$IVOL^2$). The sample period is from January 1996 to October 2009. To adjust for serial correlation, robust Newey-West (1987) t-statistics are reported in the brackets.

Quintile	1-Low	2	3	4	5-High	5-1
Panel A: Return to Selling Delta-hedged Calls, Sorted by Stock Volatility						
Equal-weighted	0.85	0.97	1.15	1.42	2.05	1.20
	(6.97)	(6.37)	(6.42)	(6.55)	(8.30)	(6.10)
Stock-value-weighted	0.73	0.73	0.81	0.84	1.28	0.54
	(5.87)	(5.07)	(4.62)	(3.51)	(4.46)	(2.13)
Option-value-weighted	0.96	1.07	1.34	1.51	2.36	1.40
	(8.85)	(7.33)	(7.94)	(6.04)	(7.38)	(4.64)
Panel B: Return to Selling Delta-hedged Calls, Sorted by Stock Idiosyncratic Volatility						
Equal-weighted	0.80	0.92	1.12	1.41	2.20	1.40
	(6.42)	(5.94)	(5.97)	(6.53)	(9.62)	(8.11)
Stock-value-weighted	0.71	0.70	0.80	0.86	1.48	0.76
	(5.17)	(5.05)	(4.23)	(3.62)	(5.66)	(3.46)
Option-value-weighted	0.96	1.05	1.21	1.52	2.68	1.72
	(7.58)	(7.73)	(6.47)	(6.20)	(8.49)	(5.94)

Panel C: Subsample Results: Equal-weighted Portfolio Returns, Sorted by IVOL

	1-Low	2	3	4	5-High	5-1	t-stat
Size Quintile 1	1.82	2.06	2.38	2.43	3.45	1.63	(9.11)
Size Quintile 2	1.12	1.19	1.29	1.28	2.03	0.91	(5.37)
Size Quintile 3	0.87	0.86	0.81	1.06	1.60	0.73	(3.92)
Size Quintile 4	0.75	0.74	0.77	0.87	1.20	0.45	(1.98)
Size Quintile 5	0.62	0.60	0.63	0.58	0.94	0.32	(1.66)
January	0.75	1.06	1.27	1.46	2.90	2.15	(6.75)
Feb-Dec	0.80	0.90	1.10	1.40	2.14	1.34	(6.98)
1996 - 1999	0.74	0.82	1.04	1.42	2.27	1.53	(5.35)
2000 - 2003	0.86	1.00	1.11	1.36	1.87	1.01	(2.06)
2004 - 2006	0.76	1.00	1.29	1.62	2.49	1.72	(14.41)
2007 - 2009	0.82	0.86	1.06	1.23	2.28	1.45	(8.74)

Panel D: Control for Systematic Risk: Equal-weighted Portfolio Returns, Sorted by IVOL

	1-Low	2	3	4	5-High	5-1	t-stat
SysVOL Quintile 1	0.93	0.89	0.94	1.23	1.74	0.82	(6.05)
SysVOL Quintile 2	0.76	0.80	0.95	1.08	1.82	1.06	(7.18)
SysVOL Quintile 3	0.69	0.87	0.94	1.15	1.67	0.98	(5.46)
SysVOL Quintile 4	0.74	0.93	1.17	1.49	2.06	1.32	(8.65)
SysVOL Quintile 5	0.75	0.94	1.20	1.57	2.82	2.07	(13.20)

Panel E: Control for IVOL: Equal-weighted Portfolio Return, Sorted by SysVOL

	1-Low	2	3	4	5-High	5-1	t-stat
IVOL Quintile 1	0.93	0.87	0.76	0.72	0.70	-0.23	(-2.96)
IVOL Quintile 2	0.96	0.97	0.85	0.86	0.77	-0.19	(-1.66)
IVOL Quintile 3	1.24	1.06	0.98	1.00	0.85	-0.39	(-2.59)
IVOL Quintile 4	1.56	1.30	1.28	1.35	0.95	-0.61	(-2.84)
IVOL Quintile 5	2.05	1.82	2.19	2.01	2.08	0.03	(0.17)

Table 9: Return of Option Portfolio Strategy and Exposure to Common Risk Factors

This table reports the results of monthly time-series regressions of the return to the strategy of selling delta-hedged calls on high idiosyncratic volatility stocks and buying delta-hedged calls on low idiosyncratic volatility stocks on several common risk factors. The risk factors include Fama-French (1993) three factors (MKT-Rf, SMB, HML), the Carhart (1997) momentum factor (Mom), the Coval and Shumway (2001) zero-beta straddle return of S&P 500 index option (ZB-STRAD-Index), the value-weighted zero-beta straddle returns of S&P 500 individual stock options (ZB-STRAD-Stock), and change of CBOE's Volatility Index (ΔVIX). The sample period is from January 1996 to October 2009.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Alpha	1.385	1.376	1.210	1.234	1.413	1.318
	(7.74)	(8.47)	(5.05)	(6.31)	(8.35)	(6.62)
MKT-Rf	0.057	0.049				-0.009
	(1.11)	(1.12)				(-0.18)
SMB		0.068				0.063
		(1.96)				(2.00)
HML		-0.079				-0.094
		(-1.07)				(-1.26)
MOM		0.053				0.071
		(2.06)				(2.83)
ZB-STRAD-Index			-0.012			0.011
			(-1.87)			(1.97)
ZB-STRAD-Stock				-0.033		-0.048
				(-2.87)		(-4.38)
ΔVIX					-0.085	-0.020
					(-1.68)	(-0.41)
Adj. R^2	0.0137	0.0931	0.0345	0.0706	0.0321	0.1589

Table 10: Impact of Transaction Costs and Liquidity on the Return of Option Portfolio Strategy

This table reports the impact of liquidity and transaction costs of stock options on the profitability of our option trading strategy based on stock volatility. Each month and for each optionable stock, we sell one contract of short-maturity at-the-money option, delta-hedged with the underlying stock, rebalance the delta-hedges daily over the next month. In Panel A, each number of the columns under 5-1 (resp. 10-1) is the difference in the equal-weighted average returns of selling delta-hedged calls on stocks in the top idiosyncratic volatility quintile (resp. decile) versus selling delta-hedged calls on stocks in the bottom idiosyncratic volatility quintile (resp. decile). For the column "MidP" in Panel A (as well as for Panel B and all previous tables), we assume the options are transacted at the mid-point of the bid and ask quotes (i.e., effective spread is zero). The other columns correspond to different assumptions on the ratio of effective bid-ask spread (ESPR) to the quoted bid-ask spread (QSPR). Panel B reports the average return spread between selling delta-hedged calls on high versus low idiosyncratic volatility stocks in various subsamples. Each month, we first sort our sample into five quintiles (G1 to G5) by the Amihud (2002) stock illiquidity measure, stock price level or by the option bid-ask spread. Then within each quintile, we further sort by stock's idiosyncratic volatility. All the numbers in this table are expressed in percent. The sample period is from January 1996 to October 2009. To adjust for serial correlation, robust Newey-West (1987) t-statistics are reported in the brackets.

Panel A: Returns of IVOL Based Option Strategy for Different Option Transaction Costs

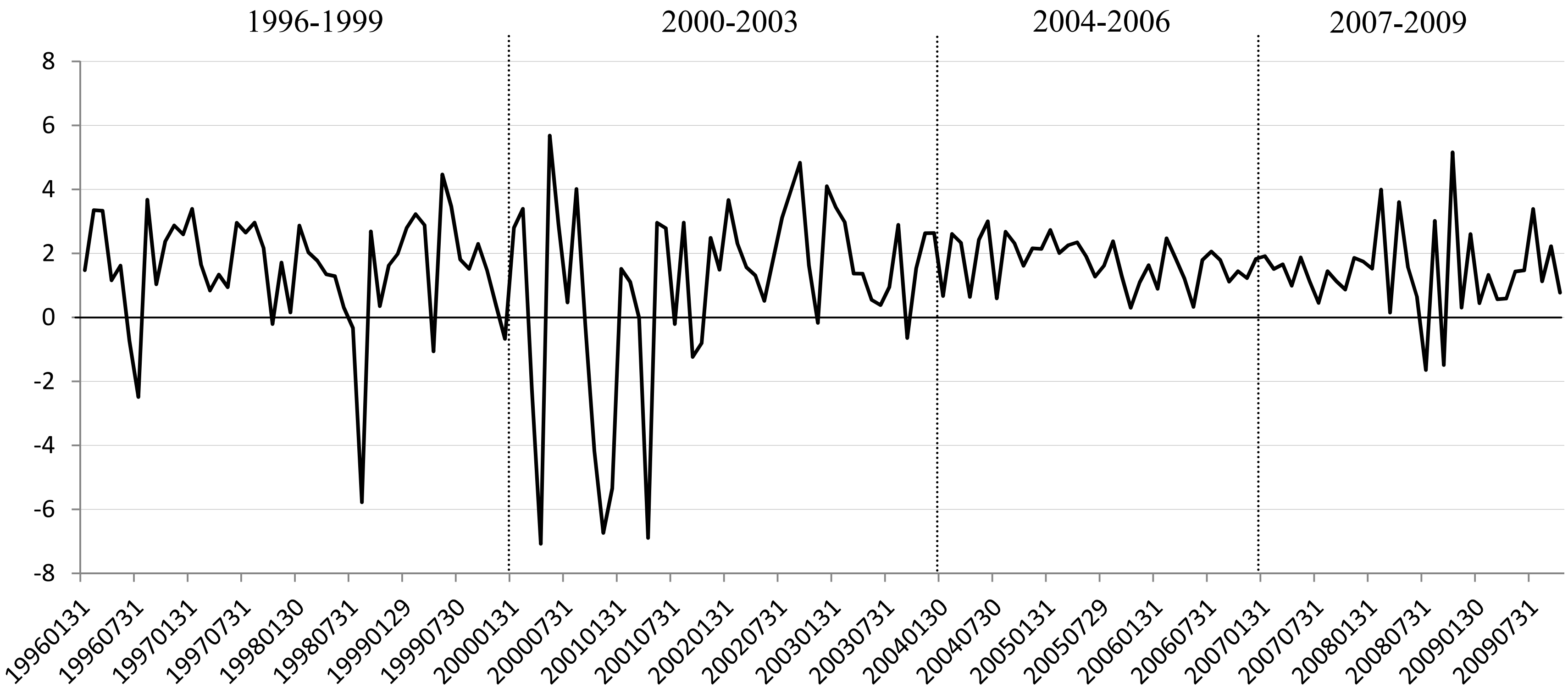
	5-1				10-1			
		ESPR/QSPR				ESPR/QSPR		
	MidP	10%	25%	50%	MidP	10%	25%	50%
Average Return	1.40	1.16	0.79	0.17	1.89	1.60	1.15	0.44
	(8.11)	(6.68)	(4.51)	(0.96)	(9.97)	(8.40)	(6.04)	(2.24)
FF-3 Alpha	1.41	1.17	0.80	0.18	1.89	1.60	1.15	0.44
	(8.67)	(7.16)	(4.88)	(1.09)	(9.92)	(8.37)	(6.02)	(2.23)

Panel B: Returns of IVOL Based Option Strategy in Subsamples of Different Liquidity

	Illiquidity	Stock Price
G1- Low	0.17	1.99
	(0.70)	(12.12)
G2	0.61	0.86
	(2.72)	(5.08)
G3	0.77	0.35
	(4.30)	(1.69)
G4	1.20	0.10
	(6.82)	(0.45)
G5 –High	2.04	-0.09
	(12.04)	(-0.37)
G5 – G1	1.87	-2.08
	(8.47)	(-8.15)

Figure 1: Time-Series of Returns of Option Portfolio Strategy

This figure plots the monthly time-series of the difference in the equal-weighted average returns of selling delta-hedged calls on stocks ranked in the top idiosyncratic volatility quintile and selling delta-hedged calls on stocks ranked in the bottom idiosyncratic volatility quintile. The delta-hedged option positions are rebalanced daily to be delta-neutral. Idiosyncratic volatility (IVOL) is the standard deviation of the residuals of the Fama-French 3-factor model estimated using the daily stock returns over the previous month. Our sample consists of short-term at-the-money call options on individual stocks. The sample period is from January 1996 to October 2009.



(5-1) Return Spread (%) Sorted on Idiosyncratic Volatility