Option Trading Volume and the Cross-Section of Option Returns

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Abstract

This paper examines a novel pattern of option return predictability. Specifically, we find option trading volume negatively and significantly predicts the cross-section of delta-hedged option returns. Our portfolio strategies of option trading volume yield significant returns in options across different moneyness and time to maturity. Furthermore, the evidence shows that the market capitalization and idiosyncratic volatility are able to explain the predictability of option trading volume on option returns. Our results are robust to alternative measures of option returns and option subsamples.

Keywords: Option trading volume; Cross-Section of option returns; Risk factor models

JEL Classification：G11, G12, G13, G14

Highlights

- We examine a novel pattern of option return predictability, where the option trading volume negatively and significantly predicts the option returns.
- We construct a portfolio strategy of option volume, which yields significant and negative monthly returns.
- We explore the explanations about the predictive power of option trading volume on option returns.

1. Introduction

We examine the predictability of option trading volume on the cross-section of delta-hedged options returns of individual stocks. The findings shed light on the risk factors that have predictive power for the option returns. It is worthwhile to ponder whether option trading volume carries predictive information for future options markets. The Black-Scholes (BS) model shows that in a perfectly competitive financial market where information is freely accessible and there are no transaction costs, derivatives are redundant securities. (Black and Scholes, 1973). However, in an uncompetitive financial market, the option trading process is not redundant, and option trading volume may contain information that forecasts future security prices (Easley et al., 1998). Several studies have documented that option trading volume predicts underlying stock returns (Johnson and So, 2012; Ge et al., 2016; Zhou, 2022). These patterns of predictability can be attributed to the informed investor's trade in both stock and option markets (Chakravarty, 2004; Pan, 2006)[1]. Considering the predictive power of option trading volume documented by the previous literature, it's interesting to examine whether it also significantly predicts option returns.

The nascent literature on the option returns predictability grows rapidly. Inspired by the connection between various measurements of volatility-risk-premium (Bakshi, 2003; Carr and Wu, 2009), Goyal and Saretto (2009) provide early empirical evidence of

1 Chakravarty (2004) provides empirical evidence that the higher option volume relative to stock volume increases the option market price discovery, implying that informed investors trade in both stock and option markets. While Pan (2006) demonstrates that option trading volume economically and significantly predicts the future stock price movements, suggesting that the predictability of option trading volume is attributed to non-public information possessed by option traders rather than market inefficiency.

option return predictability. They conclude that the difference between historical realized volatility and at-the-money implied volatility economically and significantly predicts the cross-section of stock option returns. Subsequently, several important studies have documented the predictability of option return by the moments of stock's return, including the stock's idiosyncratic volatility (Cao and Han, 2013), the stock's risk-neutral skewness (Bali and Murray, 2013), and the stock's momentum and reversal (An et al., 2014)[2]. Zhan, Han, Cao, and Tong (2022) also uncover various patterns of option return predictability related to the firm's fundamental financial characteristics and provide evidence of several economic channels.

However, these studies only focus on the information conveyed from the stock market to the option market (option pricing process), rather than from the option market to the stock market (option trading process). Carr and Wu (2020) point out that the option pricing process is equivalent to taking risk-neutral expectations of subsequent payoffs based on all information from the stock market to the option market. Consequently, these risk factors including volatility-risk-premium, several moments of stock's return, and the firm's fundamental financial characteristics belong to the option pricing process. The impact of the option trading process on stock returns, however, reflects the information that flows from the option market to the stock market; option trading thus has an impact on underlying stock prices which determine the option price (Ni et al., 2021). Our empirical analysis of the prediction of option trading volume on option

2 Cao and Han (2013) document that higher stock idiosyncratic volatility decreases the delta-hedged option returns in the cross section. Bali and Murray (2013) find a strong negative relation between risk-neutral skewness and the cross section of option portfolio returns by creating skewness assets. An et al (2014) illustrate high past returns of stocks are significant and positive in predicting the cross-section of option implied volatility, which reveals the predictability of option returns by the stock's momentum and reversal.

returns expands the option return predictability from the option pricing process to the option trading process. Our analysis of option trading volume provides significant incremental information for the option return predictability over previous findings.

To explore whether option trading volume significantly predicts the cross-section of option returns, we examine portfolio strategies based on trading volumes using univariate sorts, bivariate sorts, and regression analysis. For portfolio sorting, we sort all optionable stocks into quintile portfolios consisting of daily-rebalanced delta-neutral put options (long one put option and short delta underlying stocks) based on the put option trading volume at the end of the month.

The delta-hedged option returns are immune to changes in the underlying stock price and contain richer forward-looking information. The quintile portfolios are held until the end of the subsequent month. We calculate the monthly returns of our portfolio strategy as the return spread between the equal-weight return of high trading volume quintile and low trading volume quintile portfolios. Testing whether the portfolio strategy of option trading volume yields significant and economical returns is equivalent to testing whether the option trading volume significantly and economically predicts the cross-section of delta-hedged put option return. Furthermore, we stratify option samples into twenty-five categories across 5 moneyness and 5 maturities, and the portfolio strategies of option trading volume are implemented in all categories.

In the out-of-the-money and very-near term option category, the equally-weighted spread portfolio of delta-hedged options sorted by option trading volume yields an average return of -1.08% per month. The significant and negative portfolio strategy return indicates the option trading volume carries negative predictive information for option returns. The empirical evidence remains robust in all 5 option moneyness and 5 time-to-maturity categories. It is worth emphasizing that our empirical results hold for various alternative measures of option returns, samples of call options, samples of subperiods, samples segmented by different ranges of option trading volume, and value-weighted portfolio returns, including stock market capitalization-weighted and option open interest-weighted.

Our work differs from previous studies along several dimensions. First, we are the first to examine the effect of option trading volume on option return predictability at the firm level. Our paper contributes to the literature that examines the connection between the options market and the stock market at the firm level. Different from previous option return predictability focusing on whether the stock characteristics have predictive power, we expand the option return predictability to whether option trading volume has significant predictability.

Secondly, we construct an option portfolio strategy based on option trading volume. It yields significant and economically meaningful monthly excess returns. The excess returns of this portfolio strategy remain significant after controlling for various risk factors, indicating that the excess returns cannot be fully explained by the common risk factor model.

Finally, we find support for several economic channels. The bivariate portfolio sorts after controlling various stock characteristics still produce negative and significant monthly excess returns, suggesting the robustness of our portfolio strategy returns. For explanatory variables, the spreads display distinct patterns from the low control quintile to the high control quintile sorted by the firm market capitalization and the idiosyncratic volatility, indicating that the firm market capitalization and idiosyncratic volatility explain part of the predictability of option returns sorted by option trading volume.

The remainder of this paper is organized as follows. Section 2 provides the data and the summary statistics of major variables. Section 3 reports the empirical evidence that option trading volume predicts option return. Section 4 provides explanations for the option trading volume's predictability of option return. Section 5 shows the robustness of our results including alternative measures of options returns and option subsamples. Finally, Section 6 concludes.

2. Data and Variables

In this section, we discuss the major data (option price, stock price, and accounting data) and key variables (delta-hedged put option returns, option trading volume from option categories segmented by moneyness and maturity, and stock characteristics) employed in this study.

2.1. Data

We collect the daily option prices from the Ivy DB OptionMetrics database, including bid and ask prices of puts and calls, strike prices, trading volume, implied volatility, delta, gamma, and CUSIP. The primary results reported are based on put options, while results of call options are shown in Section 5 for robustness tests[3]. The daily option prices are employed to calculate the daily rebalanced delta-neutral put option returns. Our sample period spans from January 1996 to December 2022, consisting of 324 months. Several filters are performed on the option data as in Cao and Han (2013). Specifically,

(1) We exclude options with zero daily trading volume and open interest;

(2) We keep options with implied volatility between 1% and 100%;

(3) We exclude options with absolute delta values higher than 0.98 or lower than 0.02;

(4) We exclude options that violate obvious no-arbitrage conditions. Specifically, the no-arbitrage condition for call is $S \geq C \geq max\left(0, S - Ke^{-r\tau}\right)$, while the no-arbitrage condition for put is $Ke^{-r\tau} \geq P \geq max\left(0, Ke^{-r\tau} - S\right)$.

The stock data originate from the Center for Research on Security Prices (CRSP), including stock prices, stock returns, and stock trading volume. We then merge the stock data with option data by the date and Ticker. Considering the differences in properties between different options, we stratify option samples according to five moneyness (*Moneyness*) and five time-to-expiration (*Maturity*) into 25 categories as in Zhou (2022). We measure *Moneyness* using the absolute value of delta including deep-out-of-the-money (*DOTM*, 0-0.2), out-of-the-money (*OTM*, 0.2-0.4), at-the-money (*ATM*, 0.4-0.6), in-the-money (*ITM*, 0.6-0.8), and deep-in-the-money (*DITM*, 0.8-1). *Maturity* is measured as the number of days to expiration, including very near term

3 In line with Zhan, Han, Cao, and Tong (2022), we perform empirical analysis on both the call option and put option. To save space, we only report the empirical results of put options in the primary sections, while the results of call options are shown in Section 5 for robustness.

(*Very-Near*, 0-21 days), near term (*Near*, 22-59 days), middle term (*Middle*, 60-139 days), far term (*Far*,140-229 days), and very far term (*Very-Far*, 230-995 days).

In addition, we also obtain firm fundamentals from the Compustat, which are used to calculate the control variables, i.e., stock characteristics. Risk factors, used to test the explanatory power of risk factor models, are obtained from Kenneth French's website.

2.2. Delta-hedged option returns

Since the put option delta-hedged return is employed for the predicted variable, we elaborate on the detailed delta-hedged return formula and present the summary statistics of option returns in this section.

The delta-hedged option return is able to measure the market volatility risk premium (Bakish, 2003). The risk premium is the additional trading cost that risk-averse investors are willing to afford to hedge risks. Bakish (2003) demonstrates that the delta-hedged option returns are significantly negative, indicating the existence of a negative volatility risk premium in the financial market. The option delta-hedged gains $\Pi_{t,t+1}^{delta}$ is calculated as follows:

$$\Pi_{t,t+1}^{delta} \equiv O_{t+1} - O_t - \sum_{n=0}^{N-1} \Delta_{t_n}\left(S_{t_{n+1}} - S_{t_n}\right) - \sum_{n=1}^{N-1} r_{t_n}\left(O_t - \Delta_{t_n} S_{t_n}\right)\frac{1}{N} \qquad (1)$$

Where at the end of month t, O_t is the price of option, S_t is the price of the underlying stock, r_{t_n} is the risk-free interest rate of day t_n, and Δ_t is the Black-Scholes delta. There are *N* days between the end day of the month t (t_0) and the end day of the subsequent month $t+1$ (t_N). Thus $O_t = O_{t_0}$, $S_t = S_{t_0}$, $\Delta_t = \Delta_{t_0}$, $O_{t+1} = O_{t_N}$, $S_{t+1} = S_{t_N}$, and $\Delta_{t+1} = \Delta_{t_N}$. We hold the daily-rebalanced delta-neutral long option from t_0 to

t_N, and earn the monthly delta-hedged option gains $\Pi_{t,t+1}^{delta}$. $O_{t+1} - O_t$ is the put option gains produced by the changes in option prices (*option gains*), $-\sum_{n=0}^{N-1} \Delta_{t_n}(S_{t_{n+1}} - S_{t_n})$ is the stock gains yield by stock price changes (*stock gains*), and $-\sum_{n=0}^{N-1} r_{t_n}(O_t - \Delta_{t_n}S_{t_n})\frac{1}{N}$ is the risk free gains (*risk free gains*). The sum of these gains constitutes the total delta-hedged option gains (*total gains*).

According to Equation (1), we calculate the delta-hedged option gains for each put option. Due to the high skewness of option gains and different measurement scales of various options, we calculate the delta-hedged put options returns as in Zhan, Han, Cao, and Tong (2022). The option return OR_{t+1} equals to the option gains divided by the initial investment cost:

$$OR_{t+1} = \frac{\Pi_{t,t+1}^{delta}}{O_t - \Delta_{t_0}S_{t_0}} \quad (2)$$

For the robustness of the results, we also provide two alternative measures of delta-hedged option returns as in Darien and Christian (2018). The first ($OR_{S,t+1}$) equals the gains divided by the initial stock price (S_{t_0}) and the second ($OR_{O,t+1}$) equals the gains divided by the initial option price (O_{t_0}). The formulas used for these calculations are as follows:

$$OR_{S,t+1} = \frac{\Pi_{t,t+1}^{delta}}{S_{t_0}}, \quad OR_{O,t+1} = \frac{\Pi_{t,t+1}^{delta}}{O_t} \quad (3)$$

We present the descriptive statistics of the various gains and returns in Table 1 (winsorized at the 1% and 99% level). The sample periods span from January 1996 to December 2022. The average total gains (*total gains* = -6.4%) and the delta-hedged option gains, (*gains/(O-delta*S* = -0.53%, *gains/S* = -0.12%, and *gains/O* = -6.54%), are all negative. It is worth noting that the average option gain (*option gains* = -19.85%)

is more negative than the average stock gain (*stock gains* = -15.2%), indicating that even after excluding the impact of stock price changes, investors pay more risk-hedged costs when long options. Our findings are consistent with extant evidence of negative volatility risk premiums. Moreover, the delta-hedged option returns used in our paper are daily delta-rebalanced while they are not in Zhan, Han, Cao, and Tong (2022). Our delta-hedged option returns are thus more immunized from the impact of stock price changes.

[Insert Table 1 here]

2.3. Option trading volume

We introduce the sorting variable (option trading volume) and report the summary statistics in this subsection. We mainly refer to Zhou (2022) to calculate option trading volume. In each respective moneyness and maturity option category, the option trading volume $(ROTV_t)$ is calculated as the ratio of the monthly option trading volume (OTV_t) to the monthly underlying stock trading volume (STV_t) in month t:

$$ROTV_t = \frac{OTV_t}{STV_t} \quad (4)$$

The option trading volume in ratio form $(ROTV_t)$ is closer to a normal distribution than in raw form (OTV_t). As the skewness is closer to 0 and with lower kurtosis, $ROTV_t$ contains richer predictive information. We present the descriptive statistics of option trading volume across various moneyness and maturity in Panel A of Table 2. Irrespective of moneyness, options with shorter maturity (i.e., *Very-Near* and *Near*) have larger trading volume, hence higher liquidity than options with longer maturity (i.e., *Far* and *Very-Far*). Similarly, out-of-the-money options (e.g., *OTM*) are more liquid than in-the-money options (e.g., *ITM*).

[Insert Table 2 here]

2.4. Control variables: Stock characteristics

We introduce the control variables and report the summary statistics in this subsection. We identify a host of firm and stock characteristics as control variables. These control variables include:

Size: the logarithm of firm market capitalization as in Banz (1981). Considering the prevalence of the size effect, in which firms with smaller market capitalization produce higher returns, the size may affect the option return predictability.

lnBM: the logarithm of the book-to-market ratio as in Bhandari (1988).

Mom: the momentum calculated as the cumulative stock returns from month *t-12* to *t-1*, as in Jegadeesh and Titman (1993).

Rev: the short horizon reversals as in Jegadeesh (1990), calculated as a stock's return for the current month *t*, and the predicted variable is the portfolio strategy return of month *t+1*.

Illiq: the Illiquidity as in Amihud (2002), calculated as the daily-stock-dollar-volume-weighted average of daily stock absolute return over one month.

Skew: the monthly realized skewness of stock returns estimated from daily data over the previous one month as in Amaya (2015).

IVol: the idiosyncratic volatility as in Han and Lesmond (2011), measured as the residual standard error of the Fama-French 3-factor (FF3) regression model, where the dependent variable is the monthly stock return.

The summary statistics of these control variables are reported in panel B of Table 2.

3. Empirical Evidence: Univariate Portfolio Sorts

In this section, we provide empirical evidence that option trading volume negatively and significantly predicts the cross-section of delta-hedged put option returns.

3.1. Portfolio strategy of option trading volume

To investigate whether option trading volume significantly predicts cross-sectional option returns, we construct a portfolio strategy of option trading volume and apply it to each option moneyness and maturity category. At the end of each month, we sort all optionable stocks into quintile portfolios in ascending order by put option trading volume of the month.

Our strategy consists of buying the high quintile portfolio and writing the low quintile simultaneously, and the delta hedges are rebalanced daily. The monthly portfolio equal-weight return (RPT_{t+1}) of month $t+1$ is calculated as the spread between the high quintile return (RQT_{t+1}^{High}) and the low quintile (RQT_{t+1}^{Low}) as follow:

$$RPT_{t+1} = RQT_{t+1}^{High} - RQT_{t+1}^{Low} \tag{5}$$

$$RQT_{t+1}^{k} = \frac{\sum_{i=0}^{I} \left(OR_{t+1}^{delta,i}\right)}{I} \tag{6}$$

Where at the end of month t, each option quintile consisting of I options O_t^i underlying the stock S_t^i and BlackScholes delta Δ_t^i, the subsequent month $t+1$

delta-hedged return of put option O_t^i is represented as $OR_{t+1}^{delta,i}$. The option samples are sorted into five quintiles. For each quintile k, $k \in \{Low, 2,3,4, High\}$, the option quintile return is RQT_{t+1}^{k} as shown in Equation (6). Testing whether the portfolio strategy of option trading volume yields significant returns is equivalent to testing whether the option trading volume significantly predicts the cross-section of delta-hedged option return. Given that the risk-free gains have been removed from the put option delta-hedged portfolio (Equation (1)) for each quintile, the portfolio strategy return measures excess return.

We perform the univariate portfolio sorts for each moneyness and maturity option categories. Table 3 reports the empirical results of the portfolio strategy. Overwhelmingly, the average returns decrease monotonously from low quintile to high quintile portfolios irrespective of maturity and moneyness with few exceptions. The returns of High-Low portfolios (Column 7) are mostly statistically significant, indicting option trading volume has significant and negative predictability for the cross-section of delta-hedged put option returns.

[Insert Table 3 here]

Furthermore, the absolute magnitude of the portfolio strategy returns decreases from *DOTM* to *DITM* because in-the-money options are more expensive, hence lower leverage effect. The absolute magnitude of the returns also decreases from *Very-Near* to *Very-Far* as the very-far term options lack liquidity. For example, as show in Panel A of Table 2, the number of observations for the *ATM/Very-Far* option category is 230,562, which is much less than the *ATM/Very-Near* (391,674).

It is worth noting that most of the High quintile returns are statistically significant, while other quintiles are not. The option quintiles with higher trading volume yield significantly and more negative returns, which may imply that herding investors pay more risk premium (Bernales and Verousis, 2020).

In summary, we construct a portfolio strategy of option trading volume, in which all optionable stocks are sorted by option trading volume across all the moneyness and maturity categories. The empirical results indicate that option trading volume significantly and negatively predicts the delta-hedged put option returns.

3.2. Alphas and risk factor sensitivities

In this subsection, we examine whether common risk factors can provide an explanation of our portfolio strategy returns. If the portfolio Alphas adjusted by common risk factors are statistically significant, it indicates that option trading volume provides incremental new information for the predictive power for option returns as common risk factors cannot fully explain the portfolio returns.

We regress the returns of the portfolio strategy on various risk factors as follows:

$$RPT_{t+1} = \alpha_{t+1}^{i} + \sum_{j=1}^{J_i} \beta_{j,t+1}^{i} RF_{j,t+1}^{i} + \varepsilon_{t+1}^{i} \tag{7}$$

Where RPT_{t+1} is the High-Low spread return of the portfolio (*Raw Return*[4]) held from the end of month t to $t+1$, under risk factor model i ,$i \in [0, I]$ and I is the number of models. α_{t+1}^{i} is the Alpha under model i, measuring the portfolio strategy return adjusted by risk factor model i. Low statistical significance of α_{t+1}^{i}, or the

4 Raw Return is the high-minus-low spread returns of the portfolio (Zhan, Han, Cao, and Tong, 2022).

absolute magnitude of α_{t+1}^{i} decreases significantly from the *Raw Return* implies that risk factor model i explains a substantial portion of the option return predictability. $\beta_{j,t+1}^{i}$ measures the exposure of RPT_{t+1} to the risk factor $RF_{j,t+1}^{i}$, $j \in [1, J_i]$ and J_i is the number of risk factors in model i. ε_{t+1}^{i} is the regression residual.

The risk factor models in our analysis include the Sharpe (1964) capital asset pricing model (CAPM), the Fama and French (1993) three factors model (FF3), the Carhart (1997) four factors model (FFC), the Fama and French (2015) five factors model (FF5), and FFC+REV，FF5+MOM，and FF5+MOM+REV, where REV is the short horizon reversals factor as in Jegadeesh (1990), and MOM is the momentum factor as in Carhart (1997).

[Insert Table 4 here]

Table 4 reports the Alphas, portfolio strategy returns adjusted for the risk factors, under various risk factor models. For comparison, portfolio strategy returns of option trading volume (High-Low return spread as in Table 3) are shown in Column 2 as *Raw Return*. Overwhelmingly, the alphas from almost all the risk factor models are significant and negative, suggesting that the portfolio strategy produces abnormal return distinct from the common risk factors. In particular, the risk-adjusted returns, Alphas, reported in Table 4 are similar in absolute magnitudes as the *Raw Return*, demonstrating that the portfolio returns are insufficiently explained by the common risk factors.

To summarize, results in Table 4 show that our portfolio strategy returns cannot be explained by the common risk factors, implying that option trading volume contains new incremental information for the option return predictability beyond the mainstream risk factor models. Interestingly, the risk-adjusted returns tend to be more negative with the increase of the number of risk factors (i.e., from CAPM to FF5+MOM+REV), implying that the risk factors positively but weakly explain our portfolio strategy returns.

4. Explanations for the Predictability: Bivariate Portfolio Sorts

In this section, we perform various bivariate portfolio sorts after controlling for a range of firm and stock characteristics. We follow the approach of An, Ang, Bali, and Cakici (2014). These documented characteristics may explain the returns of our portfolio strategy.

For this purpose, we first sort the optionable stocks into quintiles by the control variables (the firm and stock characteristics) at the end of the month. The control variable quintiles (*Control Low, Control 2, Control 3, Control 4,* and *Control High*) represent the quintile portfolios sorted by the control variables. In each control variable quintile, we further sort the optionable stocks into quintiles by the option trading volume (*Vol Low, Vol 2, Vol 3, Vol 4,* and *Vol High*). In this way, we construct the bivariate portfolios sorted by option trading volume after controlling the firm/stock characteristics. There are 5 spread portfolios across all control variable quintiles. We hold the 5 spread portfolios until the end of the subsequent month and then liquidate all investment positions.

In each control variable quintile, we construct a spread portfolio following the previous section, in which we buy the high-volume quintile portfolio and simultaneously short the low-volume quintile portfolio (shown as *Vol High-Low* in the last row of each Panel of Table 5 and Table 6).

Next, we calculate the returns of the spread portfolios between the high control variable quintile (*Control High*) and the low control variable quintile (*Control Low*), shown as *Control High-Low* in the last column of Table 5 and Table 6. The returns of this spread portfolio reflects whether the portfolio returns uphold the predictability of portfolio strategy returns after controlling for the firm/stock characteristics.

[Insert Table 5 here]

We report the results of the bivariate sort portfolios in Table 5 and Table 6. Table 5 reports the empirical results of portfolios sorted by option trading volume controlling for firm fundamental characteristics (firm size, log of book-to-market ratio, and illiquidity), while Table 6 reports the empirical results of portfolios sorted by option trading volume controlling for the stock return moment characteristics (momentum, short horizon reversals, realized return skewness, and idiosyncratic volatility). For brevity, we only report the results in option category of *OTM/Very-Near*, which are of higher liquidity thus more effective option pricing. The results of other option categories, nevertheless, are materially similar with fewer exceptions.[5]

4.1. Firm market capitalization

We first examine whether the firm market capitalization can explain the predictive power of trading volume on the option returns in this subsection. Literature shows that

[5] Results are available upon request.

stocks with large market capitalization often yield lower returns than the small (Fama French 1992; Lakonishok and Shapiro, 1986). The CAPM has been shown to be mis-specified because of the size effect. For this purpose, we implement the bivariate portfolio sorts of option trading volume after controlling the firm's market capitalization, and the results are reported in the Panel A of Table 5. Across control variable quintiles, we observe that the return spreads (*Vol High-Low*) have a tendency to decline in absolute magnitude from *Control-Low* portfolio (small size firms) to *Control-High* portfolio (large size firms), suggesting that market capitalization may be able to explain part of the prediction effect of options trading volume on option returns. Statistic in the last column of Table 5, Panel A (i.e., *Control High-Low*) is significant at the 5% level, which reconfirms the explanatory power of *Size* on the prediction effect of trading volume.

4.2. Book-to-market ratio

We next examine whether the firm's book-to-market ratio explains the predictive power of trading volume on option returns. Studies have documented that it is risky to short the high book-to-market portfolio and buy the low book-to-market portfolio simultaneously when there exists high risk premium (e.g., Zhang, 2005). Because the delta-hedged option return represents the volatility risk premium (Bakish, 2003), the book-to-market ratio may affect the prediction power of option trading volume. Panel B of Table 5 presents the bivariate sort portfolio results of option returns sorted by the option trading volume after controlling for the logarithm of the book-to-market ratio (lnBM) as in Bhandari (1988).

As shown in the last column of Table 5, Panel B (i.e., *Control High-Low*), the return spread (*Vol High-Low*) between the high book-to-market quintile and the low quintile is insignificant, suggesting the inability of book-to-market ratio to explain the prediction power of trading volume.

4.3. Illiquidity

This subsection empirically tests whether the predictability of option trading volume on option returns can be explained by the illiquidity risk factor. Since our option trading volume is calculated as the ratio of monthly option trading volume to the monthly stock trading volume and high liquidity is accompanied by high trading volume, it is probable that liquidity is a significant factor in determining the prediction effect of option trading volume on option returns. We control for the illiquidity as in Amihud (2002). The last column in the Panel C of Table 5 shows that the statistic in the column *Control High-Low* is insignificant suggesting that Illiquidity is unable to explain the trading volume effect.

4.4. Momentum

Stocks that have yielded high returns in the past are likely to yield higher returns in the future due to the momentum effect. Does stock momentum affect the prediction of option return ? The rational models suggest that stocks' expected returns are persistent in the cross-section (Conrad and Kaul, 1989). Thus, this persistence may have an impact on the stock's future volatility risk premium (the option delta-hedged returns). We perform the bivariate portfolio sorts by controlling for the momentum effect (*Mom*), and the results are presented in the Panel A of Table 6. The return spread in the column of *Control High-Low*, however, is insignificant, suggesting that there are little significant differences for the option return spreads between the quintiles with high vs. low momentum.

[Insert Table 6 here]

4.5. Short horizon reversals

The current stock returns are also likely to have an impact on future volatility risk premiums. Literature has documented the power of short-term reversals in predicting future cross-sectional stock returns, suggesting that the short-term reversals may play a role in the prediction of option returns. After controlling the reversal effect, the results are shown in the Panel B of Table 6. In the last column of the table, i.e., in the column of *Control High-Low*, however, the statistic is statistically insignificant, suggesting that short term reversal has little power to explain the prediction ability of trading volume on option returns.

4.6. Realized skewness

Literature has documented that jump risk is a considerable factor affecting option volatility risk premium, and plays an important role in the option pricing (e.g., Bali and Murray, 2003). We examine whether jump risk affects the prediction of cross-sectional option returns sorted by option trading volume. We measure the jump risk as the realized skewness of stock returns. The results are reported in Panel C of Table 6. The statistic in the column of *Control High-Low* is insignificant, suggesting that jump risk provides little explanation of the prediction of option trading volume on option returns.

4.7. Idiosyncratic volatility

Ang, Hodfick, Xing and Zhang (2006) investigate if the stock's idiosyncratic volatility significantly and negatively predicts the future cross-section of stock returns. Although the effect is still subject to debate, idiosyncratic volatility may explain the portfolio returns of the option trading volume strategy. We report the results of idiosyncratic volatility in the Panel D of Table 6. The results in the column of *Control High-Low* show that the return spread is statistically significant at the 1% level indicating that idiosyncratic volatility explains some of the trading volume-based trading return variations.

5. Robustness Tests

In this section, we provide various robustness checks of the empirical results reported in the previous sections. Our robustness checks include value-weighted portfolios returns (stock market capitalization-weighted and option open interest-weighted), option subsamples, alternative option returns, and call option samples.

5.1. Value-weighted portfolio returns

The portfolio strategy returns reported in the previous sections are based on the equal-weighted average returns. This subsection replaces the equal-weighted average return of the portfolio with value-weighted average return, and the weights are the firm's market capitalization and the option open interest as in Huang et al. (2019), respectively. Then we repeat the portfolio strategy as in the previous sections: compute delta-hedged option portfolio returns sorted by option trading volume. Table 7 reports the results of *Near* and *Very-Near* option maturity categories. The results, though not tabulated for brevity, also hold for other maturity categories.

[Insert Table 7 here]

In Panel A of Table 7, all value-weighted average returns of the portfolio strategy (*High-Low*) are negative and significant, suggesting that the portfolio strategy returns are robust to the value-weighted average returns. In Panel B of Table 7, the option open interest-weighted average returns are significant for the *ITM/Near, DITM/Near, DOTM/Very-Near*, and *OTM/Very-Near* portfolios, suggesting that option open-interest weighted portfolios returns are sensitive to option maturity and moneyness.

5.2. Subsamples

In this section, we first examine whether the prediction of option returns by option trading volume differs in subsample period. The potential mechanism of the empirical patterns may depend on the formation of the sample data. As a consequence, we repeat the previous empirical test in different sampling periods. We perform identical univariate portfolio sorts of the option trading volume in option samples of different subperiods. Following the sample division of Huang et al. (2019), we divide the option samples into two subperiods: 1996/01-2012/12, 2013/01-2022/12.

[Insert Table 8 here]

Table 8 reports the empirical results in different subperiods. In the Panel A of Table 8 where the first subsample period results are reported, most of the portfolio strategy returns are negative and statistically significant except *DITM* category. In the Panel B of Table 8 where the results for the second subperiod are reported, most of the portfolio strategy returns are also negative and statistically significant.

The second robustness test conducted in this section is based on the option trading volume subsamples. We set two nodes for the option trading volume (the 70% quantile and the 30% quantile of the option trading volume), and the whole sample is divided into three subsamples (high option volume: >70th percentile, medium option volume: 30th percentile<volume<=70th percentile, low option volume: <= 30th percentile). We conduct similar portfolio strategy of option trading volume in the three volume subsamples, and reports the results in the three panels of Table 9, respectively. Most of the portfolio strategy returns are still negative and statistically significant with weaker results seen in the *ITM/Low Volume, DITM/Low Volume* and the *DITM/Medium Volume* categories.

[Insert Table 9 here]

5.3. Option return computation

This paper calculates the delta-hedged option return as the ratio of delta-hedged option gain to the total initial investment cost as shown in Equation (2). In this section, we explore whether how the option return is calculated affects the empirical results. We provide two alternative computations as shown in Equation (3). The alternative computation methods of option returns refer to Huang et al. (2019).

The first alternative option return is calculated as the ratio of the option gain to the option price. This computation focuses more on the initial option price. We repeat the previous tests, and report the empirical results in the Panel A of Table 10. Obviously, the vast majority of portfolio strategy returns are negative and statistically significant across all the option categories of moneyness and maturity. In line with the previous empirical results, except the option categories with deep-in-the-money (*DITM*) and long maturity (*Far* and *Very-Far*), option trading volume predicts option return negatively and significantly.

The second alternative option return is calculated as the ratio of the option gains to the initial stock price. We repeat the previous tests, and report the empirical results in the Panel B of Table 10. Our previous results continue to hold.

[Insert Table 10 here]

5.4. Results of call options

In the previously reported results, we mainly use put options. Therefore, confirming whether call options result in different patterns is important. For this purpose, we replace put options with call options, and perform identical tests as in the previous analyses. The results are reported in Table 11. Clearly, most portfolio returns are significantly negative. This indicates that call option trading volume similarly predicts option returns negatively and significantly.

[Insert Table 11 here]

6. Conclusion

We investigate the cross-sectional option return predictability by incorporating the information convey by option trading volume. For this purpose, we perform a portfolio strategy in which the delta-hedged put option returns are sorted into quintile by the option trading volume. The portfolio strategy returns are calculated as the return spreads between the high trading volume quintile and the low trading volume quintile portfolios. We provide evidence that this portfolio strategy yields statistically significant and negative monthly returns, suggesting that option volume predicts the cross-section of option delta-hedged returns. Moreover, the strategy returns adjusted by an array of risk factor models such as the FF3 and the FF5 risk factor models are still significant and negative, indicating that the excess returns of our portfolio strategy can't be fully explained by the existing risk factors.

We further construct bivariate sorts portfolios based on option trading volume and various firm and stock characteristics (market capitalization, book-to-market ratio, illiquidity, momentum, short horizon reversals, realized skewness, and idiosyncratic volatility). Many of the strategy returns continued to be negative and significant after controlling these various firm and stock characteristics. Among these characteristics, firm market capitalization and idiosyncratic volatility show evidence of affecting option return predictability. Our results are robust to the alternative measures of value-weighted portfolio returns, option return computations, call options, and various sampling periods.

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Table 1 Summary statistics of option returns

Returns	Obs.	Mean	Standard deviation	10th percentile	Lower quartile	Median	Upper quartile	90th percentile
risk free gains (%)	216277	-1.53	2.7	-4.77	-1.87	-0.27	0	0
stock gains (%)	214092	-15.2	110.88	-112.52	-54.46	-18.73	9.3	79.88
option gains (%)	214106	-19.85	120.5	-117.5	-65	-29.5	-2.5	80
total gains (%)	214092	-6.4	72.34	-70	-32.96	-9.37	11.09	56.14
gains/(O-delta*S) (%)	214013	-0.53	6	-6.48	-3.62	-1.23	1.44	5.86
gains/S (%)	214092	-0.12	1.38	-1.48	-0.79	-0.26	0.31	1.31
gains/O (%)	214092	-6.54	67.61	-73.5	-46.94	-17.82	19.25	70.2

This table reports the summary statistics of monthly delta-hedged put option returns. Obs. represents the number of option observations. Mean represents the mean returns. Option returns (total gains) are calculated as : $\Pi_{t,t+1}^{delta} \equiv O_{t+1} - O_t - \sum_{n=0}^{N-1} \Delta_{t_n}(S_{t_{n+1}} - S_{t_n}) - \sum_{n=0}^{N-1} r_{t_n}(O_t - \Delta_{t_n} S_{t_n})\frac{1}{N}$. Different from Zhan, Han, Cao, and Tong (2022), we daily rebalance the delta hedges. $O_{t+1} - O_t$ is the long option gains resulting from the changes in option prices, denoted as option gains. $-\sum_{n=0}^{N-1} \Delta_{t_n}(S_{t_{n+1}} - S_{t_n})$ is the short stock gains denoted as stock gains. $-\sum_{n=0}^{N-1} r_{t_n}(O_t - \Delta_{t_n} S_{t_n})\frac{1}{N}$ is the risk-free gains, denoted as risk free gains. The option returns OR_t equal to total gains over initial investment denoted as gains/(O-delta*S). Alternative option returns are denoted as gains/S and gains/O.

Table 2 Summary statistics of option trading volume and control variables

Panel A: Option trading volume (%) in option categories segmented by Moneyness and Maturity

Moneyness	Maturity	Obs.	Mean	Standard deviation	10th percentile	Lower quartile	Median	Upper quartile	90th percentile
DOTM (0-0.2)	Very-Near	417783	45.67	107.55	0.48	1.84	8.28	35.72	118.43
	Near	470715	40.92	80.62	0.69	2.51	10.58	40.07	110.93
	Middle	418025	19.62	40.85	0.41	1.39	5.14	17.86	50.92
	Far	382862	12.44	26.48	0.3	0.97	3.36	11.09	31.39
	Very-Far	220006	14.47	29.65	0.29	1	3.81	13.57	37.89
OTM (0.2-0.4)	Very-Near	410030	40.9	83.05	0.59	2.18	9.38	37.98	113.26
	Near	518996	48.99	82.29	1.15	4.31	17.14	55.99	132.53
	Middle	488860	23.82	44.46	0.66	2.18	7.66	24.42	62.47
	Far	494390	16.64	31.95	0.52	1.63	5.38	16.61	42.41
	Very-Far	260858	15.32	27.4	0.38	1.26	4.68	16.27	42.44
ATM (0.4-0.6)	Very-Near	391674	31.04	62.74	0.49	1.74	7.19	28.72	86.32
	Near	501394	34.33	59.12	0.85	3.07	11.74	38.3	92.38
	Middle	458819	15.78	29.6	0.46	1.49	5.1	16.15	40.94
	Far	449286	10.76	21.38	0.32	1.02	3.4	10.58	27.09
	Very-Far	230562	8.37	15.53	0.21	0.71	2.58	8.73	22.44
ITM (0.6-0.8)	Very-Near	375589	16.78	34.11	0.3	1.03	4.03	15.48	46.02
	Near	443395	13.55	26.22	0.37	1.21	4.19	13.38	34.94
	Middle	359051	6.39	13.74	0.19	0.57	1.91	5.82	15.33
	Far	304863	4.38	10.06	0.12	0.38	1.24	3.75	10.11
	Very-Far	161176	3.07	6.46	0.09	0.28	0.94	2.87	7.5
DITM	Very-Near	373549	13.09	28.21	0.22	0.74	2.92	11.41	34.79

(0.8-1)	Near	350381	7.43	17.72	0.16	0.49	1.74	5.94	17.71
	Middle	232943	3.74	9.5	0.08	0.25	0.86	2.84	8.42
	Far	156317	2.31	5.98	0.06	0.16	0.53	1.73	5.15
	Very-Far	89872	1.7	4.31	0.04	0.12	0.4	1.32	3.85

Panel B: Control variables (time-series average of cross-sectional statistics)

Control variables	Obs.	Mean	Standard deviation	10th percentile	Lower quartile	Median	Upper quartile	90th percentile
Size	599032	6.96	1.79	4.6	5.7	6.95	8.19	9.37
lnBM	599032	-0.81	0.77	-1.85	-1.27	-0.72	-0.27	0.08
Mom	599032	0.13	0.43	-0.35	-0.13	0.08	0.32	0.64
Rev (%)	599032	0.95	10.92	-12.1	-5.3	0.75	6.84	14
Illiq (%)	599032	11.34	41.44	0.01	0.06	0.33	2.76	21.68
Skew	599032	0.13	0.76	-0.75	-0.3	0.11	0.55	1.04
IVol (%)	599032	2.03	1.18	0.84	1.16	1.72	2.6	3.69

This table reports the summary statistics of monthly put option trading volume (option trading volume / stock trading volume) and control variables (firm and stock characteristics). These variables are winsorized each month at the 1% and 99% level. The sample period is from January 1996 to December 2022. Panel A reports the descriptive statistics of monthly option trading volume ratio (%) in option categories segmented by Moneyness and Maturity. The Moneyness is determined by the option delta absolute value, including DOTM (0-0.2), OTM (0.2-0.4), ATM (0.4-0.6), ITM (0.6-0.8), DITM (0.8-1). The Maturity is days to maturity, including Very-Near (0-21 days), Near (22-59 days), Middle (60-139 days), Far (140-229 days), Very-Far (230-995 days). Panel B reports the time-series average of cross-sectional statistics of stock characteristics. Size is the logarithm of the market value of common stocks as in Banz (1981). lnBM is the logarithm of the book-to-market ratio as in Bhandari (1988). Mom is the momentum calculated as the cumulative stock returns from the previous 11 months starting month t+1, as in Rossi and Paul (2013). Rev (%) is the short horizon reversals as in Jegadeesh (1990), calculated as a stock's return for the month. Illiq (%) is the Illiquidity as in Amihud (2002). Skew is the monthly realized skewness of stock returns estimated from daily data over the previous one month as in Amaya (2015). IVol (%) is the idiosyncratic volatility as in Han and Lesmond (2011).

Table 3 Returns of univariate portfolio sorts by option trading volume

Moneyness	Low	2	3	4	High	High-Low
Panel A: Very Near term (Very-Near) (0-21 days)						
DOTM	0.412(1.427)	0.026(0.102)	-0.083(-0.292)	-0.463*(-1.892)	-0.668***(-2.762)	-1.08***(-6.023)
OTM	0.351(1.33)	0.064(0.232)	0.001(0.002)	-0.417(-1.588)	-0.669***(-2.776)	-1.019***(-5.903)
ATM	0.383(1.48)	0.113(0.435)	-0.12(-0.399)	-0.309(-1.188)	-0.728***(-2.976)	-1.11***(-5.77)
ITM	0.12(0.435)	0.053(0.202)	-0.159(-0.565)	-0.143(-0.535)	-0.633***(-2.746)	-0.753***(-4.156)
DITM	0.14(0.512)	-0.1(-0.386)	-0.145(-0.542)	-0.277(-0.969)	-0.316(-1.185)	-0.456**(-2.338)
Panel B: Near term (Near) (22-59 days)						
DOTM	0.599**(1.992)	0.237(0.793)	-0.008(-0.032)	-0.311(-1.151)	-0.697***(-3.304)	-1.296***(-6.462)
OTM	0.602**(2.193)	0.164(0.61)	-0.033(-0.126)	-0.28(-1.093)	-0.708***(-3.222)	-1.31***(-8.114)
ATM	0.377(1.371)	0.108(0.394)	0.01(0.037)	-0.313(-1.263)	-0.54**(-2.295)	-0.917***(-5.37)
ITM	0.304(1.032)	0.089(0.34)	0.061(0.228)	-0.256(-0.953)	-0.541**(-2.358)	-0.845***(-5.087)
DITM	-0.035(-0.133)	-0.023(-0.09)	0.022(0.075)	-0.067(-0.237)	-0.373(-1.464)	-0.338**(-2.416)
Panel C: Middle term (Middle) (60-139 days)						
DOTM	0.246(0.923)	0.097(0.374)	-0.174(-0.681)	-0.351(-1.438)	-0.694***(-3.212)	-0.94***(-6.388)
OTM	0.517*(1.687)	0.137(0.559)	-0.113(-0.442)	-0.446*(-1.784)	-0.564**(-2.542)	-1.081***(-5.753)
ATM	0.346(1.309)	0.194(0.71)	-0.177(-0.673)	-0.374(-1.48)	-0.562**(-2.516)	-0.908***(-5.386)
ITM	0.063(0.235)	0.138(0.476)	-0.196(-0.772)	-0.329(-1.348)	-0.452*(-1.722)	-0.515***(-3.677)
DITM	-0.101(-0.383)	-0.25(-0.911)	-0.14(-0.547)	-0.154(-0.589)	-0.282(-0.914)	-0.181(-0.929)
Panel D: Far term (Far) (140-229 days)						
DOTM	0.156(0.56)	0.07(0.261)	-0.121(-0.473)	-0.428(-1.644)	-0.618***(-2.593)	-0.774***(-4.711)

OTM	0.269(1.013)	0.178(0.669)	0.108(0.381)	-0.497**(-2.193)	-0.502**(-2.023)	-0.771***(-5.677)
ATM	0.257(0.936)	0.068(0.273)	-0.007(-0.027)	-0.39(-1.557)	-0.408(-1.638)	-0.665***(-3.856)
ITM	-0.116(-0.477)	0.063(0.216)	-0.205(-0.791)	-0.157(-0.539)	-0.349(-1.379)	-0.233*(-1.649)
DITM	-0.321(-1.205)	-0.138(-0.492)	-0.077(-0.23)	-0.077(-0.252)	-0.029(-0.086)	0.291(1.288)
Panel E: Very far term (Very-Far) (230-995 days)						
DOTM	0.082(0.279)	-0.308(-1.259)	-0.336(-1.243)	-0.492*(-1.893)	-0.518**(-2.048)	-0.6***(-2.883)
OTM	0.136(0.461)	-0.042(-0.171)	-0.363(-1.474)	-0.497*(-1.873)	-0.55**(-2.16)	-0.685***(-3.933)
ATM	0.004(0.014)	-0.217(-0.821)	-0.213(-0.81)	-0.412(-1.558)	-0.54**(-2.339)	-0.544***(-3.655)
ITM	-0.133(-0.566)	-0.449*(-1.807)	-0.157(-0.539)	-0.387(-1.204)	-0.385(-1.246)	-0.252(-1.225)
DITM	-0.566**(-2.256)	-0.205(-0.731)	-0.334(-1.051)	-0.259(-0.772)	-0.349(-0.97)	0.217(0.784)

This table reports the average monthly returns of univariate portfolio sorts strategy based on put option trading volume segmented by moneyness and maturity. Moneyness is determined by the absolute value of option delta, including DOTM (0-0.2), OTM (0.2-0.4), ATM (0.4-0.6), ITM (0.6-0.8), and DITM (0.8-1). The Maturity is measured by days to maturity, including Very-Near (0-21 days), Near (22-59 days), Middle (60-139 days), Far (140-229 days), and Very-Far (230-995 days). At the end of each month, we rank all put options into quintiles by the option trading volume. The position is held for 1 month with daily rebalance. The table reports the equal-weight returns for each option quintile as well as the High - Low spread return (i.e., difference between the returns of the top and bottom quintile portfolios). The sample consists of 599032 firm-months spanning January 1996 through December 2022. Newey-West (1987) corrected t-values with 6 lags are reported in the parentheses. *, ** and *** indicate significance at the 10% 5% and 1% levels, respectively.

Table 4 The portfolio Alphas of option trading volume strategies adjusted by different risk factors

Moneyness	Alphas of different models							
	Raw Return (Return Spread)	Model (1) CAPM	Model (2) FF3	Model (3) FFC	Model (4) FFC+REV	Model (5) FF5	Model (6) FF5+MOM	Model (7) FF5+MOM+REV
Panel A: Very near term (Very-Near) (0-21 days)								
DOTM	-1.08***(-6.023)	-1.166***(-5.408)	-1.186***(-5.431)	-1.198***(-5.118)	-1.215***(-5.151)	-1.259***(-5.291)	-1.266***(-5.078)	-1.288***(-5.188)
OTM	-1.019***(-5.903)	-1.039***(-5.136)	-1.053***(-5.13)	-1.064***(-4.942)	-1.071***(-4.907)	-1.158***(-5.254)	-1.162***(-5.128)	-1.17***(-5.131)
ATM	-1.11***(-5.77)	-1.181***(-5.312)	-1.192***(-5.31)	-1.204***(-5.246)	-1.225***(-5.28)	-1.233***(-5.264)	-1.24***(-5.21)	-1.268***(-5.403)
ITM	-0.753***(-4.156)	-0.83***(-3.946)	-0.843***(-3.878)	-0.869***(-3.76)	-0.881***(-3.764)	-0.923***(-4.002)	-0.94***(-3.929)	-0.955***(-3.979)
DITM	-0.456**(-2.338)	-0.492**(-2.25)	-0.5**(-2.244)	-0.526**(-2.319)	-0.533**(-2.34)	-0.609**(-2.45)	-0.622**(-2.496)	-0.635**(-2.54)
Panel B: Near term (Near) (22-59 days)								
DOTM	-1.296***(-6.462)	-1.382***(-5.735)	-1.403***(-5.575)	-1.393***(-5.125)	-1.402***(-5.118)	-1.463***(-5.315)	-1.452***(-5.013)	-1.464***(-5.008)
OTM	-1.31***(-8.114)	-1.379***(-7.353)	-1.383***(-7.082)	-1.388***(-6.598)	-1.399***(-6.604)	-1.452***(-6.843)	-1.452***(-6.526)	-1.467***(-6.601)
ATM	-0.917***(-5.37)	-0.989***(-4.911)	-0.999***(-4.777)	-1.007***(-4.606)	-1.024***(-4.684)	-1.022***(-4.728)	-1.028***(-4.604)	-1.05***(-4.748)
ITM	-0.845***(-5.087)	-0.92***(-4.605)	-0.928***(-4.473)	-0.94***(-4.356)	-0.955***(-4.335)	-0.998***(-4.88)	-1.004***(-4.763)	-1.024***(-4.801)
DITM	-0.338**(-2.416)	-0.349**(-2.394)	-0.361**(-2.52)	-0.379***(-2.66)	-0.389***(-2.739)	-0.427***(-2.736)	-0.436***(-2.802)	-0.452***(-2.979)
Panel C: Middle term (Middle) (60-139 days)								
DOTM	-0.94***(-6.388)	-1.001***(-6.204)	-1.01***(-6.193)	-1.013***(-6.013)	-1.025***(-6.047)	-1.089***(-6.209)	-1.088***(-6.085)	-1.104***(-6.154)
OTM	-1.081***(-5.753)	-1.179***(-5.217)	-1.187***(-4.975)	-1.185***(-4.687)	-1.198***(-4.678)	-1.232***(-4.778)	-1.229***(-4.585)	-1.245***(-4.591)
ATM	-0.908***(-5.386)	-0.971***(-5.172)	-0.989***(-5.105)	-0.995***(-5.033)	-1.01***(-4.991)	-1.02***(-4.858)	-1.023***(-4.837)	-1.044***(-4.886)
ITM	-0.515***(-3.677)	-0.542***(-3.662)	-0.548***(-3.797)	-0.532***(-3.918)	-0.536***(-3.935)	-0.599***(-3.824)	-0.583***(-3.944)	-0.591***(-3.972)
DITM	-0.181(-0.929)	-0.175(-0.887)	-0.163(-0.835)	-0.123(-0.671)	-0.118(-0.646)	-0.179(-0.819)	-0.147(-0.718)	-0.143(-0.692)
Panel D: Far term (Far) (140-229 days)								
DOTM	-0.774***(-4.711)	-0.848***(-4.388)	-0.862***(-4.449)	-0.885***(-4.38)	-0.893***(-4.369)	-0.99***(-4.855)	-1.001***(-4.749)	-1.013***(-4.771)
OTM	-0.771***(-5.677)	-0.832***(-5.64)	-0.847***(-5.858)	-0.828***(-5.666)	-0.84***(-5.673)	-0.89***(-5.902)	-0.873***(-5.799)	-0.888***(-5.933)

ATM	-0.665***(-3.856)	-0.731***(-3.797)	-0.727***(-3.734)	-0.738***(-3.718)	-0.739***(-3.705)	-0.688***(-3.407)	-0.7***(-3.422)	-0.699***(-3.402)
ITM	-0.233*(-1.649)	-0.222(-1.52)	-0.231(-1.643)	-0.255*(-1.825)	-0.247*(-1.792)	-0.253(-1.545)	-0.269*(-1.646)	-0.261(-1.621)
DITM	0.291(1.288)	0.34(1.429)	0.34(1.502)	0.346(1.582)	0.356(1.627)	0.345(1.407)	0.35(1.463)	0.363(1.515)
Panel E: Very far term (Very-Far) (230-995 days)								
DOTM	-0.6***(-2.883)	-0.652***(-2.836)	-0.661***(-2.923)	-0.631***(-2.72)	-0.628***(-2.73)	-0.694***(-2.726)	-0.669***(-2.579)	-0.666**(-2.569)
OTM	-0.685***(-3.933)	-0.731***(-3.62)	-0.732***(-3.613)	-0.728***(-3.429)	-0.726***(-3.453)	-0.763***(-3.438)	-0.758***(-3.303)	-0.757***(-3.327)
ATM	-0.544***(-3.655)	-0.615***(-3.589)	-0.602***(-3.593)	-0.621***(-3.532)	-0.627***(-3.514)	-0.597***(-3.638)	-0.611***(-3.602)	-0.62***(-3.596)
ITM	-0.252(-1.225)	-0.233(-1.067)	-0.229(-1.018)	-0.211(-0.977)	-0.2(-0.925)	-0.245(-1.138)	-0.231(-1.117)	-0.218(-1.033)
DITM	0.217(0.784)	0.263(0.852)	0.279(0.905)	0.288(0.937)	0.304(0.977)	0.214(0.679)	0.223(0.706)	0.246(0.773)

This table reports the results of portfolio returns adjusted by various risk factor models. The Raw Return represents the return spread of univariate portfolio sorts as shown in Table 3. The risk factors include the momentum factor MOM as in Carhart (1997) and the short horizon reversals factor REV as in Jegadeesh (1990). We regress the returns of portfolio strategies under seven different risk factors models, including: the Sharpe (1964) capital asset pricing model (CAPM), the Fama and French (1993) three factors model (FF3), the Carhart (1997) four factors model (FFC), the Fama and French (2015) five factors model (FF5), FFC+REV， FF5+MOM， and FF5+MOM+REV. The Moneyness is measured by the absolute value of option delta, including DOTM (0-0.2), OTM (0.2-0.4), ATM (0.4-0.6), ITM (0.6-0.8), and DITM (0.8-1). The Maturity is measured by the days to maturity, including Very-Near (0-21 days), Near (22-59 days), Middle (60-139 days), Far (140-229 days), and Very-Far (230-995 days). The sample consists of 599032 firm-month observations spanning from January 1996 through December 2022. Newey-West (1987) corrected t-values with 6 lags are reported in the parentheses. *, ** and *** indicate significance at the 10% 5% and 1% levels, respectively.

Table 5 Results of bivariate portfolio sorts by option trading volume controlling for firm fundamental characteristics

Panel A: Control for the firm market capitalization (Size)

	Control Low	Control 2	Control 3	Control 4	Control High	Control High - Low
Vol Low	1.076	0.732	0.039	-1.973	-0.552	
Vol 2	0.277	0.301	0.176	-0.992	-1.21	
Vol 3	-0.106	0.077	-0.578	-0.631	-0.59	
Vol 4	-0.16	-0.086	-0.047	-0.65	-0.7	
Vol High	-0.623	-0.378	-0.445	-0.414	-0.579	
Vol High - Low	-1.699***(-3.149)	-1.11***(-2.975)	-0.484(-0.462)	1.56(1.626)	-0.027(-0.047)	1.673**(2.119)

Panel B: Control for the logarithm of the book-to-market ratio (lnBM)

	Control Low	Control 2	Control 3	Control 4	Control High	Control High - Low
Vol Low	1.368	0.489	0.191	0.057	-0.153	
Vol 2	0.47	0.146	-0.231	-0.298	-0.25	
Vol 3	0.331	0.202	0.16	0.125	-0.497	
Vol 4	0.685	-0.089	-0.144	-1.072	-0.605	
Vol High	0.286	0.07	0.651	-1.395	-0.532	
Vol High - Low	-1.083**(-2.192)	-0.418(-1.086)	0.46(0.675)	-1.452**(-2.028)	-0.379(-0.73)	0.704(1.027)

Panel C: Control for the Illiquidity (Illiq)

	Control Low	Control 2	Control 3	Control 4	Control High	Control High - Low
Vol Low	-0.663	-0.391	-0.269	-0.219	-0.413	
Vol 2	0.074	0.087	-0.166	-0.411	-0.205	
Vol 3	-0.195	0.121	-0.085	-0.581	-0.755	
Vol 4	0.384	0.045	-0.174	-1.86	-1.779	
Vol High	0.955	0.924	0.148	-0.206	0.294	
Vol High - Low	1.617***(3.962)	1.315***(2.838)	0.417(0.418)	0.013(0.011)	0.706(0.711)	-0.911(-0.808)

This table reports the results of bivariate portfolio sorts strategy based on put option trading volume and firm fundamental characteristics. we first sort the optionable stocks into quintiles by the control variables (the firm and stock characteristics) at the end of the month. The control variable quintiles (Control Low, Control 2, Control 3, Control 4, Control High) represent the quintile portfolios sorted by the control variables. In each control variable quintile, we further sort the optionable stocks into quintiles by option trading volume (Vol Low, Vol 2, Vol 3, Vol 4, Vol High). In each control variable quintile, we construct a spread portfolio, in which we buy the high volume quintile and simultaneously short the low volume quintile portfolios (Vol High - Low). Moreover, we calculate the returns of the spread portfolios between the high control variable quintile and the low control variable quintile (Control High-Low). Size is the logarithm of the market value of common stocks as in Banz (1981). lnBM is the logarithm of the book-to-market ratio as in Bhandari (1988). Illiq is the Illiquidity as in Amihud (2002), expressed as a percentage (%). For brevity, we only report the results of OTM/Very-Near option category, which are of higher liquidity. The sample consists of 599032 firm-months spanning from January 1996 through December 2022. Newey-West (1987) corrected t-values with 6 lags are reported in the parentheses. *, ** and *** indicate significance at the 10% 5% and 1% levels, respectively.

Table 6 Results of bivariate portfolio sorts based on option trading volume and stock return moment characteristics

Panel A: Control for momentum (Mom)

	Control Low	Control 2	Control 3	Control 4	Control High	Control High - Low
Vol Low	1.019	0.753	0.271	-2.024	-0.93	
Vol 2	0.311	-0.103	-0.208	-1.189	-0.653	
Vol 3	-0.093	-0.025	0.045	-0.146	-0.147	
Vol 4	0.272	0.143	-0.616	-0.193	-0.57	
Vol High	1.029	0.381	0.541	-0.005	-0.588	
Vol High - Low	0.01(0.025)	-0.372(-1.123)	0.27(0.369)	2.019**(2.464)	0.342(0.89)	0.332(0.671)

Panel B: Control for short horizon reversals (Rev)

	Control Low	Control 2	Control 3	Control 4	Control High	Control High - Low
Vol Low	1.077	0.966	1.302	-0.638	0.062	
Vol 2	0.818	0.303	0.708	-0.19	-0.644	
Vol 3	0.12	0.011	-0.798	-1.252	-0.017	
Vol 4	-0.377	-0.107	-1.457	-0.676	-1.015	
Vol High	0.245	-0.429	-0.479	-0.845	-1.209	
Vol High - Low	-0.831**(-2.03)	-1.395***(-3.472)	-1.781***(-3.297)	-0.207(-0.292)	-1.271**(-2.527)	-0.439(-0.721)

Panel C: Control for realized skewness (Skew)

	Control Low	Control 2	Control 3	Control 4	Control High	Control High - Low
Vol Low	0.835	0.155	0.212	-0.014	-0.35	
Vol 2	0.327	0.305	-0.294	-0.746	-0.377	
Vol 3	0.064	-0.15	0.403	-0.681	-1.143	
Vol 4	0.422	0.316	0.019	-0.637	-0.181	
Vol High	0.179	0.12	-0.34	-0.716	-0.346	
Vol High - Low	-0.656*(-1.804)	-0.035(-0.109)	-0.551(-0.735)	-0.703(-1.391)	0.004(0.01)	0.66(1.38)

Panel D: Control for idiosyncratic volatility (IVol)

	Control Low	Control 2	Control 3	Control 4	Control High	Control High - Low
Vol Low	-0.161	-0.162	-0.405	-0.104	-0.642	
Vol 2	0.035	0.01	-0.201	-0.627	-0.559	
Vol 3	0.485	0.29	-0.035	-0.399	-0.499	
Vol 4	1.237	0.494	0.775	-1.188	0.138	
Vol High	0.878	0.551	0.808	-0.172	-0.976	
Vol High - Low	1.039**(2.571)	0.713**(2.014)	1.214(1.509)	-0.068(-0.165)	-0.334(-1.002)	-1.373***(-2.822)

This table reports the results of bivariate portfolio sorts strategy of put option trading volume and stock return moment characteristics. We first sort the optionable stocks into quintiles by the control variables (stock characteristics) at the end of the month. The control variable quintiles (Control Low, Control 2, Control 3, Control 4, Control High) represent the quintile portfolios sorted by the control variables. In each control variable quintile, we further sort the optionable stocks into quintiles by the option trading volume (Vol Low, Vol 2, Vol 3, Vol 4, Vol High). In each control variable quintile, we construct a spread portfolio in which we buy the high volume quintile and simultaneously short the low volume quintile portfolios (Vol High - Low). Moreover, we calculate the returns of the spread portfolios between the high control variable quintile and the low control variable quintile (Control High-Low). Mom is the momentum calculated as the cumulative stock returns from t-12 month to t-1 month, as in Rossi and Paul (2013). Rev is the short horizon reversals as in Jegadeesh (1990), calculated as a stock's return for the month and expressed as a percentage (%). Skew is the monthly realized skewness of stock returns estimated from daily data over the previous one month as in Amaya (2015). IVol is the idiosyncratic volatility as in Han and Lesmond (2011), expressed as a percentage (%). For brevity, we only report the results in OTM/Very-Near option category, which are of higher liquidity. The sample consists of 599032 firm-month observations spanning from January 1996 through December 2022. Newey-West (1987) corrected t-values with 6 lags are reported in the parentheses. *, ** and *** indicate significance at the 10% 5% and 1% levels, respectively.

Table 7 Results of univariate portfolio sorts based option trading volume (value-weighted returns)

Maturity/Moneyness	Near term (Near) (22-59 days)			Very near term (Very-Near) (0-21 days)		
	Low	High	High-Low	Low	High	High-Low
Panel A: Stock market capitalization-weighted average returns (Size)						
DOTM	0.009(1.247)	-0.013*(-1.866)	-0.022***(-3.179)	0.009(1.375)	-0.014***(-3.11)	-0.023***(-3.803)
OTM	0.003(0.495)	-0.016**(-2.513)	-0.019***(-2.602)	0.012**(2.182)	-0.019***(-3.793)	-0.03***(-4.64)
ATM	0.013*(1.653)	-0.018**(-2.559)	-0.031***(-2.979)	0.007(1.256)	-0.013***(-2.816)	-0.02***(-4.036)
ITM	0.004(0.567)	-0.019***(-3.276)	-0.023***(-3.336)	0.006(1.097)	-0.014**(-2.457)	-0.019***(-3.233)
DITM	0.006(0.814)	-0.007(-0.941)	-0.013(-1.452)	-0.005(-1.119)	-0.016**(-2.198)	-0.011*(-1.78)
Panel B: Option open interest-weighted average returns (Open interest)						
DOTM	-0.008(-1.0)	-0.013(-1.531)	-0.005(-0.693)	-0.01(-0.02)	-0.021***(-3.748)	-0.021**(-2.131)
OTM	-0.009(-1.08)	-0.016**(-2.357)	-0.007(-0.7)	0.007(0.825)	-0.016***(-2.813)	-0.023***(-2.709)
ATM	-0.004(-0.462)	-0.017**(-2.045)	-0.013(-1.044)	-0.003(-0.44)	-0.012*(-1.803)	-0.01(-1.424)
ITM	0.004(0.321)	-0.021***(-3.206)	-0.025**(-2.003)	-0.004(-0.49)	-0.017***(-3.238)	-0.014(-1.518)
DITM	0.012(1.308)	-0.014(-1.616)	-0.026**(-2.414)	-0.009(-1.01)	-0.021**(-2.53)	-0.012(-1.168)

This table reports the value-weighted average monthly returns of univariate portfolio sorts strategy based on put option trading volume. Panel A reports the stock market capitalization-weighted average returns; Panel B reports the option open-interest-weighted average returns. Moneyness is determined by the absolute value of option delta, including DOTM (0-0.2), OTM (0.2-0.4), ATM (0.4-0.6), ITM (0.6-0.8), and DITM (0.8-1). The Maturity is measured by days to maturity, including Very-Near (0-21 days), and Near (22-59 days). The sample consists of 599032 firm-month observations spanning from January 1996 through December 2022. Newey-West (1987) corrected t-values with 6 lags are reported in the parentheses. *, ** and *** indicate significance at the 10% 5% and 1% levels, respectively.

Table 8 Portfolios returns sorted by option trading volume in different subperiods

Maturity/Moneyness	Very-Near	Near	Middle	Far	Very-Far
Panel A:1996-2012					
DOTM	-0.975***(-5.853)	-1.166***(-6.803)	-0.97***(-5.249)	-0.779***(-3.736)	-0.419(-1.538)
OTM	-0.952***(-4.931)	-1.236***(-7.803)	-0.941***(-5.505)	-0.739***(-3.947)	-0.689***(-2.882)
ATM	-1.107***(-4.66)	-0.687***(-3.821)	-0.923***(-4.713)	-0.679***(-3.266)	-0.53***(-2.603)
ITM	-0.682***(-3.555)	-0.803***(-4.426)	-0.58***(-2.914)	-0.301(-1.475)	-0.337(-1.088)
DITM	-0.396(-1.614)	-0.27(-1.387)	-0.437(-1.56)	-0.004(-0.013)	0.12(0.295)
Panel B:2013-2022					
DOTM	-1.259***(-3.24)	-1.516***(-3.364)	-0.89***(-3.665)	-0.765***(-2.882)	-0.908***(-2.947)
OTM	-1.134***(-3.449)	-1.437***(-4.222)	-1.319***(-3.226)	-0.826***(-4.563)	-0.679***(-2.884)
ATM	-1.116***(-3.418)	-1.308***(-4.007)	-0.883***(-2.865)	-0.641**(-2.124)	-0.566***(-2.774)
ITM	-0.874**(-2.408)	-0.916***(-2.833)	-0.405**(-2.498)	-0.116(-0.768)	-0.108(-0.632)
DITM	-0.559*(-1.744)	-0.452**(-2.549)	0.257(1.41)	0.794***(3.303)	0.382(1.327)

This table reports the portfolios returns sorted by option trading volume in different subperiods. Panel A reports the results in option samples between 1996/01 and 2012/12, while Panel B reports the results in option samples between 2013/01 and 2022/12. Moneyness is determined by the absolute value of option delta, including DOTM (0-0.2), OTM (0.2-0.4), ATM (0.4-0.6), ITM (0.6-0.8), and DITM (0.8-1). The Maturity is measured by days to maturity, including Very-Near (0-21 days), Near (22-59 days), Middle (60-139 days), Far (140-229 days), and Very-Far (230-995 days). Newey-West (1987) corrected t-values with 6 lags are reported in the parentheses. *, ** and *** indicate significance at the 10% 5% and 1% levels, respectively.

Table 9 Portfolios returns of the option subsamples sorted by the option trading volume

Maturity/Moneyness	Very-Near	Near	Middle	Far	Very-Far
Panel A: High volume option samples (volume>70th percentile)					
DOTM	-0.54(-1.382)	-1.217***(-3.124)	-0.864*(-1.89)	-0.749*(-1.684)	-0.395(-0.958)
OTM	-0.625(-1.61)	-0.95**(-2.301)	-0.814**(-2.031)	-0.798**(-2.123)	-0.766**(-2.234)
ATM	-0.237(-0.431)	-1.051**(-2.164)	-1.075**(-2.561)	-0.451(-1.191)	-0.055(-0.176)
ITM	-0.493(-1.268)	-0.641(-1.414)	-0.537(-1.485)	-0.059(-0.122)	-0.19(-0.544)
DITM	-0.464*(-1.739)	-0.338(-0.977)	0.412(1.085)	0.637(1.153)	0.765**(2.354)
Panel B: Medium volume option samples (30th percentile<volume<=70th percentile)					
DOTM	-0.594**(-2.202)	-1.304***(-3.707)	-0.537(-1.534)	-0.587**(-2.107)	-0.44(-1.064)
OTM	-0.815***(-3.252)	-1.159***(-3.409)	-1.27***(-2.625)	-0.972***(-2.58)	-0.105(-0.254)
ATM	-1.206***(-3.96)	-0.818*(-1.942)	-0.957**(-2.172)	-0.718(-1.625)	-0.181(-0.501)
ITM	-1.092***(-3.479)	-0.708*(-1.728)	-0.883**(-2.057)	-0.554(-1.528)	-0.768*(-1.798)
DITM	-0.084(-0.311)	0.421(0.971)	-0.017(-0.032)	0.991(1.638)	0.618(1.346)
Panel C: Low volume option samples (volume <= 30th percentile)					
DOTM	-0.953***(-2.916)	-1.2***(-3.74)	-0.399(-1.273)	-0.333(-1.061)	-0.67(-1.106)
OTM	-0.457(-1.111)	-0.886**(-2.299)	-0.581(-1.459)	-0.571*(-1.717)	-0.768(-1.556)
ATM	-0.646(-1.619)	-0.714**(-1.978)	-0.736**(-2.068)	-0.254(-1.06)	-1.008**(-2.232)
ITM	-0.272(-0.909)	-0.071(-0.217)	-0.039(-0.119)	0.314(0.961)	0.04(0.107)
DITM	-0.24(-0.564)	0.124(0.364)	0.383(0.81)	-0.144(-0.225)	-1.227(-1.521)

This table reports the portfolios returns of the option subsamples sorted by the option trading volume. We set two nodes for the option trading volume (the 30% quantile and the 70% quantile of the option trading volume), and the whole sample is divided into three subsamples. Panel A reports the results of high option volume sample (option volume > 70th percentile), Panel B reports the results of medium option volume sample (30th percentile

< option volume <= 70th percentile), and Panel C reports the results of low option volume sample (option volume <= 30th percentile). Moneyness is determined by the absolute value of option delta, including DOTM (0-0.2), OTM (0.2-0.4), and ATM (0.4-0.6). Maturity is measured by days to maturity, including Very-Near (0-21 days), Near (22-59 days), Middle (60-139 days), Far (140-229 days), and Very-Far (230-995 days). The sample consists of 599032 firm-month observations spanning from January 1996 through December 2022. Newey-West (1987) corrected t-values with 6 lags are reported in the parentheses. *, ** and *** indicate significance at the 10% 5% and 1% levels, respectively.

Table 10 Alternative portfolios returns sorted by option trading volume

Moneyness/Maturity	DOTM	OTM	ATM	ITM	DITM
Panel A: The option gains to option price (gains/O)					
Very-Near	-13.656***(-5.699)	-12.215***(-5.892)	-13.371***(-6.357)	-8.781***(-4.337)	-6.096**(-2.424)
Near	-16.652***(-6.702)	-16.242***(-8.351)	-11.042***(-5.73)	-10.985***(-5.733)	-4.852***(-3.405)
Middle	-11.526***(-7.094)	-12.766***(-5.857)	-12.712***(-6.669)	-7.664***(-4.618)	-3.253(-1.601)
Far	-11.401***(-5.714)	-10.193***(-5.731)	-8.963***(-4.728)	-3.663***(-2.724)	2.941(1.136)
Very-Far	-7.745***(-3.501)	-8.702***(-4.305)	-8.088***(-4.79)	-4.076*(-1.932)	2.78(1.119)
Panel B: The option gains to stock price (gains/S)					
Very-Near	-0.215***(-5.366)	-0.212***(-5.093)	-0.228***(-5.079)	-0.151***(-3.832)	-0.076*(-1.842)
Near	-0.248***(-5.416)	-0.282***(-7.635)	-0.191***(-4.621)	-0.155***(-4.448)	-0.058(-1.624)
Middle	-0.195***(-5.681)	-0.225***(-5.845)	-0.183***(-4.931)	-0.093**(-2.48)	-0.027(-0.531)
Far	-0.144***(-3.511)	-0.144***(-4.292)	-0.133***(-3.206)	-0.017(-0.449)	0.078(1.309)
Very-Far	-0.11**(-2.404)	-0.142***(-3.493)	-0.094***(-2.774)	-0.03(-0.527)	0.058(0.641)

This table reports the alternative average monthly delta-hedged option returns sorted by option trading volume. The alternative measures of average monthly delta-hedged returns include option gains to option price (gains/O) in Panel A, and option gains to stock price (gains/S) in Panel B. Moneyness is determined by the absolute value of option delta, including DOTM (0-0.2), OTM (0.2-0.4), ATM (0.4-0.6), ITM (0.6-0.8), and DITM (0.8-1). The Maturity is measured by days to maturity, including Very-Near (0-21 days), Near (22-59 days), Middle (60-139 days), Far (140-229 days), and Very-Far (230-995 days). Newey-West (1987) corrected t-values with 6 lags are reported in the parentheses. *, ** and *** indicate significance at the 10% 5% and 1% levels, respectively.

Table 11 Call option portfolios returns sorted by option trading volume samples

Moneyness/Maturity	DOTM	OTM	ATM	ITM	DITM
Very-Near	-0.972***	-1.153***	-1.02***	-1.121***	-0.971***
	(-4.64)	(-7.393)	(-6.702)	(-5.641)	(-6.323)
Near	-1.163***	-1.199***	-1.292***	-1.228***	-0.938***
	(-6.267)	(-8.14)	(-8.405)	(-7.644)	(-6.402)
Middle	-0.816***	-1.065***	-0.956***	-0.919***	-0.606***
	(-4.243)	(-6.37)	(-5.538)	(-5.255)	(-3.435)
Far	-0.401*	-0.803***	-0.73***	-0.592***	-0.155
	(-1.652)	(-5.749)	(-5.68)	(-3.952)	(-1.043)
Very-Far	0.123	-0.402*	-0.6***	-0.375**	-0.348*
	(0.29)	(-1.914)	(-3.306)	(-2.054)	(-1.917)

This table reports portfolios returns sorted by option trading volume in call option samples. Moneyness is determined by the absolute value of option delta, including DOTM (0-0.2), OTM (0.2-0.4), ATM (0.4-0.6), ITM (0.6-0.8), and DITM (0.8-1). The Maturity is measured by days to maturity, including Very-Near (0-21 days), Near (22-59 days), Middle (60-139 days), Far (140-229 days), and Very-Far (230-995 days). The sample consists of 599032 firm-month observations spanning from January 1996 through December 2022. Newey-West (1987) corrected t-values with 6 lags are reported in the parentheses. *, ** and *** indicate significance at the 10% 5% and 1% levels, respectively.