Out-of-the-Money Option Trading and Market Segmentation*

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Abstract

We find evidence of slow information diffusion in stock and option markets. Larger unsigned out-of-the-money call (put) trading volume, which is publicly observable data, predicts positive (negative) future stock returns. The return predictability is significant both in daily and weekly horizons, and interestingly, it is more significant in larger stocks but unrelated to stock short interests. Larger out-of-the-money call (put) trading volume also predicts persistently positive returns of at-the-money call (put) delta hedged portfolio. Using the out-of-the-money option trading volume, we propose an implementable investment strategy that offers 20 bp weekly returns (equivalently, about 10% annual returns). We also find evidence that the option volume measure predicts the occurrence of material corporate events such as takeover announcement or earnings surprise. Our findings support the segmentation between stock and option markets and between the contracts in the same option class.

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1 Introduction

The speed of information diffusion in financial markets is a long-standing issue in financial economics. A growing number of studies examine the effect of market segmentation on the information diffusion process, and find that, along with the investors' limited attention, it can reduce the speed of information diffusion among market participants (e.g., Menzly and Ozbas 2010). While the market segmentation hypothesis explains empirically observed return predictabilities, it also casts doubt on the standard view that option contracts enhance the market efficiency (Ross 1976). If investors who have information about the fundamental value of a firm have limits to arbitrage (Shleifer and Vishny 1997) and trade only a subset of contracts in the corresponding option class, is the information revealed by the trading activities promptly incorporated into the prices of underlying stock and other option contracts?

We answer this question by exploiting the information contained in option market trading activities. Since the seminal work of Easley et al. (1998), previous studies have reported evidence of a stock price discovery function of option markets.[1] Notwithstanding these findings, their implication on market efficiency is ambiguous because the studies using publicly available option trading data finds mixed results in the magnitude and persistence of stock return predictability. Building on these empirical findings, we characterize a group of option contracts of which informed trading activities is easily measured from publicly available data and investigate how soon the information contained in trading activities of these contracts is diffused into their underlying stock price and the premia of other option contracts in the same class (i.e. those who have the same underlying stock).

Specifically, we focus our analysis on the information content of *unsigned* out-of-the-money (OTM) option trading volume and investigates the corresponding price

[1] See, e.g., Pan and Poteshman 2006, Johnson and So 2012, and Ge et al. 2016.

adjustment in stock and at-the-money (ATM) option markets. More specifically, we hypothesize that larger OTM call (resp. put) trading volume, relative to the total trading volume of the corresponding option class, contains positive (resp. negative) information about the underlying stock price. Our hypothesis is built on two stylized facts of option markets. First, as predicted by Easley et al. (1998), previous studies found that informed investors buy options, in particular, OTM options to utilize their leverage effect.[2] Second, the margin requirements of option exchanges make it more costly for informed investors to take naked short positions on OTM options.[3]

Formally, we examine whether larger unsigned OTM call (resp. put) trading volume, standardized by the total trading volume of the corresponding option class, predicts positive (resp. negative) stock returns and ATM call (resp. put) returns. It is noteworthy that our analysis is likely to underestimate the speed of information diffusion in stock and option markets, and, thus, stock and ATM option return predictability of unsigned OTM trading volume does not overstate the market inefficiency. First, the informational advantage of buy-initiated trading volume implies that our analysis offers the lower bound of return predictability that investors can acquire from publicly observable OTM option volume. Furthermore, the procedure to back out the buy-initiated trading volume, e.g., Lee and Ready (1991) algorithm, requires a computationally heavy data process that may limit arbitrage in reality (Shleifer and Vishny 1997).

We first test the stock return predictability of unsigned OTM option volumes using Fama and MacBeth (1973) regression in a daily horizon. Consistent with our prediction, we find that larger OTM call (put) trading volume, standardized by total

[2]Using proprietary data, Pan and Poteshman 2006 and Ge et al. 2016 found the strongest return predictability from the buy-initiated OTM trading volume. See also Frazzini and Pedersen (2012) who measure the leverage offered by each moneyness of options.

[3]Santa-Clara and Saretto (2009) empirically test the effect of margin requirements on the return from writing OTM options.

option trading volume, predicts a positive (negative) stock returns. This finding suggests that the return predictability of unsigned OTM option trading volume is dominantly originated from the buy-initiated volume. The return predictability lasts significant for three to five trading days. We then investigate the return predictability of OTM put-call ratio, defined as OTM put volume to all OTM option volume, which aggregates the information contained in OTM calls and OTM puts.[4] Higher OTM put-call ratio predicts negative stock returns up to the sixth trading day ahead, which is more persistent than the finding of Pan and Poteshman (2006). The results are consistent with the market segmentation hypothesis which predicts slow information diffusion between stock and option markets (Menzly and Ozbas 2010).

Next, we examine stock return predictability of OTM trading volume in a weekly horizon and then investigate the profitability of long-short portfolio formed and rebalanced by weekly OTM put-call ratio. After controlling for option volume-based and price-based measures proposed by previous studies, we find that OTM volume predicts stock returns of the following week as in the daily horizon analysis. Consistent with this finding, the portfolio using the information contained in OTM put-call ratio offers substantial alpha. The value-weighted portfolio that buys (short-sells) stocks of the top (bottom) OTM put-call ratio decile offers nearly 20 basis point of weekly 4-factor alpha, or equivalently 10.4% annual alpha. Interestingly, the equal-weighted portfolio offers lower alpha than value-weight portfolio, implying that the OTM put-call ratio predicts the return of large-cap stocks more precisely.

Regarding the information diffusion within the option markets, we find that higher OTM put-call ratio predicts lower delta-hedge ATM call returns up to 5 trading days. The return predictability for delta-hedged ATM put options disappears within a day. These findings suggest that the information diffusion within the option market can be

[4] Our OTM put-call ratio differs from the put-call ratio considered in Pan and Poteshman (2006). See section 3.2 for more details.

even slower than the diffusion across option and stock markets, and, thus, the option markets are segmented by the moneyness of each option class.

We also test how OTM put-call ratio is associated with contemporaneous and lead OTM option returns. The slow information diffusion process between segmented markets implies that the information contained in OTM put-call ratio is already incorporated in OTM option prices and, thus, the ratio has stronger explanatory power for contemporaneous OTM option returns and weaker predictability for future OTM option returns relative to the corresponding stock or ATM option returns. Our finding supports the prediction: higher OTM put-call ratio predicts higher (resp. lower) delta-hedged OTM call (resp. put) returns over 10 trading days, while the ratio is negatively (resp. positively) associated with the contemporaneous delta-hedged OTM call (resp. put) return.

We further examine the key factors of return predictability by running a number of additional robustness checks. Motivated by information-based market microstructure models (e.g., Glosten and Milgrom 1985), we first study the effect of OTM option market liquidity on informed trading by estimating the return predictability of OTM option volume in the subsample of large and small stocks. Our analysis shows that the return predictability of OTM option volume is economically and statistically significant in large stocks (i.e., top size quintile) but not in small stocks (i.e., bottom size quintile). Consistent with the prediction of information-based models, our finding suggests that informed investors are unlikely to trade small stock OTM options which are very illiquid in the market.

We also examine whether the return predictability of OTM volume is related to the short-selling costs of stock market. Previous studies reported inconclusive findings about the effect of stock short-selling constraint on informed option trading. Johnson and So (2012) find that higher ratio of option trading volume to stock trading volume predicts negative future stock returns and the return predictability is stronger in high short-interest stocks. In contrast, using proprietary data, Ge et al. (2016) find that both synthetic short (i.e., buying puts and writing calls) and long portfolios have significant return predictability. We estimate the daily Fama and MacBeth (1973) return regression with stocks of which short-interest is larger than 10% and find that return predictability of OTM put volume is insignificant while OTM call volume predicts positive returns. This result suggests that the stock short-selling cost is, at least, not a main factor of the return predictability of OTM option trading volume.

To understand the informational contents of OTM option volume, we examine the presence of informed OTM option trading around two material corporate events, takeover announcements and earnings announcements.[5] Regarding takeover announcement, we find that the ratio of OTM call volume to total option volume of target firms are much higher than that of matched firms since 4 to 6 weeks ahead of the announcement week. Regarding earnings announcement, our weekly Fama and MacBeth (1973) regression shows that larger OTM call volume predicts positive earnings surprise of the following week. In both analyses, OTM put volume does not show a significant predictability.

Finally, we show that our results are robust to financial crisis. While the predictability of OTM put volume becomes somewhat weaker in more recent period (2011–15), the predictability of OTM call volume remains strong in magnitude and statistical significance over the entire sample period. We also check the robustness of our findings to finer classification of "out-of-the-money" option. In the analysis using a finer classification of option moneyness, we find that the predictability of very deep OTM options (i.e., 20% OTM[6] or above) is relatively weaker. This result is not

[5]The predictability of option order flow on these events were also examined by Cao et al. (2005) and Hu (2014).

[6]20% OTM call option has a moneyness (strike-to-spot ratio) of 1.20, and 20% OTM put option has a moneyness of 0.8.

surprising, given the illiquidity of these options.

This paper contributes to the literature of informed option trading. Previous studies found that return predictability obtained from publicly observable option trading data is somewhat limited. Using the signed option trading volume obtained from Lee and Ready (1991) algorithm, Cao et al. (2005) find significant stock return predictability around the takeover announcement period but not in normal times, and Pan and Poteshman (2006) find return predictability that decays in two trading days. Our paper shows that, by considering the moneyness of traded options, stronger and more persistent return predictability can be obtained from publicly observable option volume. Furthermore, we propose a profitable and implementable investment strategy using our unsigned OTM option volume measure which does not require computationally heavy data process.

Our paper is also related to the literature of multi-market trading. Previous studies reported the return predictability of option price-based measures, which are also publicly observable data, such as implied volatility spread between calls and puts, implied volatility smirk, and monthly change in implied volatility (e.g., Cremers and Weinbaum 2010, Xing et al. 2010 and An et al. 2014). In contrast, Goncalves-Pinto et al. (2016) suggest that the return predictability of option price-based measures could arise from the liquidity shock in stock markets rather than informed trading in option markets. We find that the return predictability of OTM option volume is more significant in larger stock and unrelated to short interest in stock markets, implying that our results are not, at least, entirely driven by the liquidity shock in stock markets. This paper also complements the findings of Johnson and So (2012) who report stock return predictability of unsigned option trading volume to stock volume ratio. While they attribute the return predictability to stock short-selling costs, Ge et al. (2016) find that embedded leverage of options can explain their findings. Our analysis also sheds light on the role of high leverage offered by OTM options and, furthermore, finds opposite information content of OTM calls and OTM puts, in contrast to Johnson and So (2012).

The paper is organized as follows. Section 2 describes the data and provides summary statistics of OTM option trading volume measures and other key variables. Section 3 presents evidence of return predictability of OTM option volume in daily and weekly horizons. Section 4 discusses the investment strategy using OTM option volume and its profitability. Section 5 presents the results of robustness checks, and Section 6 concludes.

2 Data and variables

Our sample period spans from 1996 to 2014. We use various datasets in this study. From the IvyDB OptionMetrics database, we collect information about individual equity options, such as maturity date, strike price, daily closing quotes, trading volume, implied volatility and option Delta. We also obtain the number of shares outstanding, daily stock price and trading volume from the Center for Research in Security Prices (CRSP) database and financial/accounting information from Compustat database. Finally, we collect information about takeover announcements from SDC Platinum database and analyst earnings forecast from Thomson Reuters I/B/E/S. Variables used in this analysis is described in appendix.

Following Johnson and So (2012), we reduce the measurement error associated with illiquidity of option markets by filtering our sample as follows; first, for each trade date, we include only the option contracts that mature in 30 trading days beginning five days from the trade date; then, we exclude the firm-weeks in which less than 25 call or 25 put contracts are traded, or the closing stock price went below one dollar on at least one trading day; finally, our sample includes only the firm-weeks in which at least six months of past weekly data is available after applying the previous filtering rules.[7] Our final sample for the main analysis consists of 2,898,532 firm-trading days (768,209 firm-weeks) of 5,546 unique firms.[8]

Table 1 describes the market capitalization and the book-to-market value ratio of our sample and CRSP universe each year. Relative to stocks in CRSP universe, our sample stocks are larger and have more growth opportunities (i.e., lower book-to-market value ratio) over the entire sample period. The difference in market capitalization between the two groups is, at least, partly due to our filtering rule that excludes penny stocks and the stocks with illiquid options.

Our key variables are the trading volume of OTM calls and that of OTM puts. Following Bollen and Whaley (2004) and Ge et al. (2016), we first classify a call option as OTM if $0.02 <$ option delta ≤ 0.375, and a put option as OTM if $-0.375 <$ option delta ≤ -0.02.[9] Then, for each stock i and date t, we measure OTM call (put) trading volume, standardized by the total option trading volume, as follows:

$$\text{OTMC}_{i,t}\ (\text{OTMP}_{i,t}) = \frac{\text{OTM call (put) trading volume of stock } i \text{ at date } t}{\text{Total option trading volume of stock } i \text{ at date } t}. \quad (1)$$

Notice that $\text{OTMC}_{i,t}$ and $\text{OTMP}_{i,t}$ capture how heavily the daily option trading volume of stock i is concentrated in OTM calls and OTM puts, respectively. We also measure the OTM put trading volume relative to the OTM call volume for each stock i and date t:

$$\text{OTMPC}_{i,t} = \frac{\text{OTMP}_{i,t}}{\text{OTMP}_{i,t} + \text{OTMC}_{i,t}}. \quad (2)$$

Table 2 presents the summary statistics of the OTMC, OTMP, and OTMPC

[7]In the analysis that requires estimating the market beta (i.e., CAPM-, three factor- or four factor-adjusted returns), we restrict the sample to the stocks that have at least one year past daily returns.

[8]The sample size varies across analyses, depending on the availability of control variables. The number of observations used in each analysis is reported in each table.

[9]We consider finer classification of OTM options in section 6.2.

each year during the sample period. OTM calls are on average more actively traded than OTM puts during the entire sample period. Table 2 also presents the summary statistics of the ratio of total put option trading to total option trading (PC). Relative to PC, OTMPC is on average higher during the sample period, implying that put trading volume is more concentrated in OTM options than call trading volume.

3 Stock return predictability of OTM option volume

In this section, we study the stock return predictability of OTM trading volume ratios. Easley et al. (1998) analyze a multi-market trading model in which informed investors can sequentially trade in stock and option markets, and show that informed investors may choose to buy options because of leverage embedded in options. Using proprietary option trading data, Pan and Poteshman (2006) and Ge et al. (2016) find that the strongest stock return predictability is obtained from the buy-initiated trading volume of OTM options that offer higher leverage than other moneyness of options. Furthermore, Santa-Clara and Saretto (2009) show that the option exchange margin requirements substantially reduce the return from writing OTM options. From these findings of previous studies, we predict that the return predictability of unsigned OTM volume is likely to be originated from information contained in the buy-initiated trading volume, i.e., higher OTMC (OTMP) predicts positive (negative) stock returns. In what follows, we first test the return predictability of OTM volume ratios in a daily horizon, and then extend the analysis to a weekly horizon.

3.1 Daily horizon: OTMC and OTMP

We first test the stock return predictability of OTMC and OTMP ratios in a daily horizon. To control for other firm characteristics that may affect stock returns, we estimate the following Fama and MacBeth (1973) regression: for stock i and trading date t,

$$
\begin{aligned}
r_{i,t+1} = \beta_0 &+ \beta_1 \text{OTMC}_{i,t} + \beta_2 \text{OTMP}_{i,t} \\
&+ \gamma_1 (\text{Log size})_{i,t} + \gamma_2 (\text{Log book-to-market ratio})_{i,t} \\
&+ \gamma_3 (\text{Momentum})_{i,t} + \gamma_4 (\text{Illiquidity})_{i,t} + \gamma_5 (\text{Weekly lag return})_{i,t} + \varepsilon_{i,t}, \quad (3)
\end{aligned}
$$

where the dependent variable is the (raw or risk-adjusted) daily return at date $t+1$. We control for log market capitalization, book-to-market ratio, past six-month stock returns (momentum) and Amihud (2002) illiquidity measure. Weekly lagged return is also included to control for the weekly reversal in stock returns. All variables are defined in Appendix.

Table 3 presents the regression results. In models (1)–(6), the dependent variable is daily raw stock returns. Models (1) and (2) include OTMC and OTMP ratio, respectively, as the main independent variable. Higher OTMC (OTMP) ratio predicts significantly positive (negative) stock returns of the next trading day. Specifically, OTMC ratio has a coefficient of 0.0006 with a t-statistic of 7.575 and OTMP ratio has a coefficient of -0.0010 with a t-statistic of -11.056. The return predictability of two measures is also significant in economic magnitude. One standard deviation increase in OTMC ratio (of which lower bound is 0.27 in 2013) predicts more than 1.62 basis points of daily returns while one standard deviation decrease in OTMP ratio (of which lower bound is 0.22 in 2000) predicts more than 2.2 basis point of returns.

Model (3) includes both OTMC and OTMP ratios. Consistent with our prediction, the information contained in OTMC and OTMP ratios are orthogonal to each other. The magnitude of coefficients of OTMC and OTMP decreases only marginally from those in models (1) and (2), and they are still statistically significant at 1% level. Furthermore, adjusted R^2 also increases, at least, marginally after including both ratios, implying that the overall return predictability improves by considering both measures simultaneously. Notably, our findings of return predictability of OTMC and OTMP are distinct from previous studies that have focused on aggregate option trading volume (e.g., the put-call volume ratio of Pan and Poteshman (2006) or the option-stock volume ratio of Johnson and So 2012).

Models (4)–(6) estimate the return predictability of OTMC and OTMP after controlling for two option and stock trading volume measures—option trading volume to stock trading volume ratio (OS ratio, hereafter) and short interest—of which return predictability is reported in the literature. Johnson and So (2012) find that higher OS ratio predicts negative stock returns in a weekly horizon and that the return predictability is stronger when stock short-selling is more costly.[10] Following their methodology, we control for the decile of OS ratio to address the econometric issues arising from non-normality of OS ratio. Diether et al. (2009) also find that higher short interest predicts negative returns in the subsequent trading days. The estimation results in models (4)–(6) show that the return predictability of OTMC and OTMP remains significant after controlling for the decile of OS ratio and short interest, while higher OS ratio and short interest predict negative stock returns in the next trading day, as in Johnson and So (2012) and Diether et al. (2009), respectively. The results suggest that the information contained in OTM volume ratios is not nested by the information embedded in OS ratio or short interest.

[10] Ge et al. (2016) suggest that the return predictability of OS ratio may not be entirely driven by stock short-selling constraint.

Model (7) tests whether OTM volume ratios predict the four-factor risk-adjusted stock returns. As pointed out by Pan and Poteshman (2006) who also consider risk-adjusted stock returns in their Fama-MacBeth regression analysis, the use of risk-adjusted returns can improve the testing power if informed traders tend to have private information about the idiosyncratic component of stock returns, rather than about the systematic component. As a robustness check, we also test the characteristic-adjusted return (i.e., DGTW-adjusted return) predictability of OTM volume ratios in model (8). Our estimation results show that higher OTMC (OTMP) ratio predicts significantly positive (negative) risk-adjusted and benchmark-adjusted returns, and the coefficients are not significantly different from the those of raw return regressions. These findings suggest that OTMC and OTMP contain information more about idiosyncratic components of stock returns.

Next, we examine the persistence of return predictability of OTM volume ratios by extending our Fama-MacBeth regression analysis to longer daily horizons: for stock i and date t,

$$\begin{aligned} r_{i,t+k} = {} & \beta_0 + \beta_1 \mathrm{OTMC}_{i,t} + \beta_2 \mathrm{OTMP}_{i,t} \\ & + \gamma_1 (\text{Log size})_{i,t} + \gamma_2 (\text{Log book-to-market ratio})_{i,t} \\ & + \gamma_3 (\text{Momentum})_{i,t} + \gamma_4 (\text{Illiquidity})_{i,t} + \gamma_5 (\text{Weekly lag return})_{i,t} + \varepsilon_{i,t}, \end{aligned} \tag{4}$$

where $r_{i,t+k}$ $(k = 1, 2, 3, ..., 10)$ corresponds to the daily return in k-trading days ahead of the option trade date t.

Table 4 reports the coefficient estimates and t-statistics of OTMC and OTMP with respect to $r_{i,t+1}$ through $r_{i,t+10}$. Previous studies (e.g., Pan and Poteshman 2006) document that volume measures from public data only predict stock returns for one day horizon. Our results show that the predictability of OTMC and OTMP ratio last significant for subsequent three trading days and signs of coefficients stay the same up to six trading days. Consistent with the findings of Pan and Poteshman (2006), however, the economic magnitudes and statistical significance of return predictability decrease over the horizon. The persistence of return predictability of OTM option ratios also alleviates the concern that our results are driven by daily return reversal, since the autocorrelation can be significantly reduced by skipping one or longer days.

3.2 Daily horizon: OTMPC

We turn to the return predictability of OTMPC ratio, an aggregate measure of informed trading activities in OTM calls and puts. We first estimate the Fama-MacBeth daily-return regression in (3) by replacing OTMC and OTMP with OTMPC ratio, and report the results in Table 5. Models (1)–(3) differ in the dependent variable: raw returns, DGTW-adjusted returns, and four-factor adjusted returns. In model (1), the coefficient estimate of OTMPC ratio is -0.0009 which is statistically significant at 1% level. The economic magnitude of return predictability of OTMPC ratio is also substantial: one standard deviation decrease in OTMPC ratio (of which lower bound is 0.35 in 2014) predicts more than 3.15 basis points of daily returns. In the estimation of models (2) and (3), we also find that OTMPC ratio predicts DGTW-adjusted and four-factor adjusted returns at the same magnitude with raw-returns. These results are consistent with the Fama-MacBeth regression results of OTMC and OTMP ratios reported in Table 3.

Next, we examine the persistence of return predictability of OTMPC ratio, and compare with the return predictability of PC ratio. Specifically, we estimating the Fama-MacBeth daily return regression model in (4) by replacing OTMC and OTMP with OTMPC and PC ratios. Table 6 presents the coefficient estimates and t-statistics of OTMPC and PC ratios in the daily return regression over a 10-trading day horizon.

Model (1), which is the baseline model, does not include PC ratio as an independent variable. The estimation results show that OTMPC ratio has a statistically significant return predictability over the next six trading days, and the magnitude of coefficients declines exponentially over horizon. The persistence of predictability of OTMPC ratio is surprising, given that the information is obtained from publicly observable data. We do not find a return reversal after the predictability dies out, suggesting that the return predictability is unlikely driven by the price pressure.

We demonstrate the economic magnitude of our results by referring to the findings of Pan and Poteshman (2006).[11] Their analysis shows that the return predictability of buy-initiated PC ratio obtained from publicly observable trading data (using Lee and Ready (1991) algorithm) disappears in two trading days while the predictability of PC ratio obtained from proprietary data remains significant around 15 trading days. Our finding of significant return predictability of OTMPC ratio in six trading day horizon suggest that the price adjustment to the public information contained in OTM option trading activities is slower than the adjustment to information embedded in publicly observable option trade process, but quicker than the adjustment to the private information which cannot be retrieved from publicly observable trade data. Consistent with our findings, Pan and Poteshman (2006) also find that the return predictability of PC ratio obtained from proprietary data decays exponentially and there is no return reversal afterward.

The estimation results of Model (2) allow us to compare the predictive power of OTMPC with that of PC ratio. Relative to the estimation results of Model (1), the coefficient estimates of OTMPC are are the same magnitude or even higher except the coefficient in the regression of the next trading day return. The return predictability also dies out on the seventh trading day ahead. In contrast, the predictability of PC

[11] Pan and Poteshman (2006) focus on the four-factor adjusted return predictability of option trading volume, but as shown in Table 6, our findings are robust to the four-factor adjusted returns.

ratio is statistically significant only for the next day return and it shows reversal in the subsequent trading day returns. Notwithstanding that we do not use Lee and Ready (1991) algorithm, our finding is consistent with the aforementioned result of Pan and Poteshman (2006). Overall, the results suggest that OTMPC ratio captures the information contained in the OTM call put trading activities, while stock price adjusts to the information slower than to other public information embedded in option trading volume.

3.3 Weekly horizon

We now examine return predictability of OTMC, OTMP and OTMPC ratios in a weekly horizon. The volume ratios are reconstructed with aggregated trading volumes during a calendar week. Our baseline Fama-MacBeth weekly return regression model is as follows:

$$\begin{aligned} r_{i,t+1} = \beta_0 &+ \beta_1 \text{OTMC}_{i,t} + \beta_2 \text{OTMP}_{i,t} \\ &+ \gamma_1 (\text{Log size})_{i,t} + \gamma_2 (\text{Log book-to-market ratio})_{i,t} \\ &+ \gamma_3 (\text{Momentum})_{i,t} + \gamma_4 (\text{Illiquidity})_{i,t} + \gamma_5 (\text{Weekly lag return})_{i,t} + \varepsilon_{i,t} \quad (5) \end{aligned}$$

The estimation results are presented in Table 7. Model (1), which is the baseline model, shows that higher OTMC (OTMP) predicts positive (negative) returns of the following week. The coefficient estimate of OTMC (OTMP) is 18bp (-14bp), which is statiscally significant at 1% level. In model (2), we additionally control weekly OS ratio and short interest as in the analysis of daily returns, and other option price-based measures, namely, ΔCVOL and ΔPVOL, defined as monthly changes in the implied volatility of at-the-money calls and puts with 30-day maturity, respectively. An et al. (2014) find that increase in call (put) implied volatilities predicts positive (negative) stock return even in a monthly horizon. The estimation results of model (2) show that the coefficient estimates of OTMC and OTMP are at the same magnitude and significance with those of model (1), implying that the information contained in these ratios are orthogonal to the information embedded in other predictors.[12] Consistent with this result, adjusted R^2 is 3.5 percent point higher in model (2).

Models (3) and (4), which are analogous to models (1) and (2), test the return predictability of OTMPC ratio, and their estimation results suggest that higher OTMPC ratio predicts negative returns of the following week. After controlling for other return predictors, the coefficient estimate of OTMPC is -14 bp, which is statistically significant at 1% level. In models (5) and (6), we estimate the return predictability of the weekly change in OTMC and OTMP ratios, namely, ΔOTMC and ΔOTMP, and find that an increase in OTMC (OTMP) ratio over a week predicts positive (negative) stock returns of the following week. These findings suggest that the return predictability of OTMC and OTMP in models (1) and (2) are at least partly originated from the weekly time-series variation which can capture the informed OTM option trading activities over the week.

Finally, in models (7) and (8), we examine whether the information contained in OTM option trading volume can be well captured by alternative measures, OTMCS and OTMPS, which standardize OTM call and OTM put volume by stock volume, respectively. The estimation results show that only OTMPS predicts negative return without controlling OS decile, short interest and option price-based measures, while, after controlling these measures, only OTMCS predicts positive returns. The results suggest that OTMPS and OTMCS are noisier proxies of informed OTM option trading activities than OTMC and OTMP.

[12] As shown in Table 9 below, the change in call implied volatility ΔCVOL are highly correlated with that in put implied volatility ΔPVOL. To address the multicollinearity problem, we also run a regression of model (2) with excluding either ΔCVOL or ΔPVOL and find that it does not affect the statistical significance of OTMC and OTMP.

The findings in Fama-MacBeth weekly return regressions are also consistent with the correlation matrix, presented in Table 9, between our OTM option volume measures and other stock return predictors. First, the correlations between our OTM volume measures and other predictors such as OS decile, short interest and option price-based measures are small, implying that the information contained in our measures is unlikely to be redundant to the information incorporated in other predictors. While OTMC are negatively correlated with OTMP, the correlation between OS decile, OTMCS and OTMPS are all positive. This contrasting result between two sets of measures suggest that the variation in option volume measures standardized by stock volume may be driven by the change in stock trading volume rather than option volume and, thus, may be noisier in capturing the information contained in OTM option trading activities.

4 Option return predictability

In this section, we test the option return predictability of OTMPC ratio. If OTMPC ratio has a stock return predictability, it might suggest that stock markets incorporate information more slowly than options markets do, which implies an inefficiency in stock markets in a multi-market context. This could be the case in the perspective of slow moving capital and market segmentation, in which it would take time for the information released in options markets to be disseminated to stock markets. However, the stock return predictability of OTMPC ratio may not be a sufficient condition for this argument, because it is possible that option prices incorporate the information contained in OTMPC ratio as slowly as stock prices do. This is possible because OTMPC ratio is constructed using option trading volumes, not prices or returns, and the information contained in option trading volume might not be incorporated into option prices in a timely manner. If this is the case, it would be difficult to argue that stock markets incorporate information more slowly than options markets do. Given this, to fully support the argument that the stock return predictability of OTMPC ratio implies an inefficiency in stock markets, one still needs to show that OTMPC ratio does not predict option returns.

To compare the option return predictability and stock return predictability, we employ delta hedged option returns to measure the profitability in options markets while considering the availability of option prices for multiple strike prices. Delta hedging is commonly used by market makers and option traders to hedge exposure on underlying stock price changes. Using delta hedged option returns, we can make the heterogeneous option contracts comparable with each other becasue the different delta levels for heterogeneous option contracts are offset. The delta hedged option returns provide the option returns in excess of underlying stock returns. Combining with the stock market predictability of OTMPC, predictability analysis using delta hedged option returns allow us to assess the relative predictable power in option returns against the power in stock prices. If the coefficient of a predictor is significantly positive for delta hedged call option returns, a predictor has a stronger return predictability for call option prices than that for stock prices.

We follow Cao and Han (2013) to define the daily delta hedged option return. For each call i, the discrete delta hedged return $\Pi_{i,t,t+\tau}$ between trading days t and $t+\tau$ is defined as

$$\Pi_{i,t,t+\tau} \approx (C_{i,t+\tau} - C_{i,t}) - \Delta_{i,t} (S_{t+\tau} - S_t), \quad (6)$$

where $C_{i,t}$ and $\Delta_{i,t}$ are the price and delta of the call i on t, respectively, and S_t is the underlying price on t. To calculate the delta hedged return of call i, we scale the delta hedged gain by the absolute price of delta hedged portfolio, which is $\Delta_t S_t - C_{i,t}$

for call options, after which the delta hedged return $r^{dh}_{i,t,t+\tau}$ is defined as

$$r^{dh}_{i,t,t+\tau} = \frac{(C_{t+\tau} - C_t) - \Delta_{i,t}\left(S_{t+\tau} - S_t\right)}{\Delta_{i,t} S_t - C_t}. \tag{7}$$

Similarly, for each put j, the delta hedged return $r^{dh}_{j,t,t+\tau}$ is defined as

$$r^{dh}_{j,t,t+\tau} = \frac{(P_{j,t+\tau} - P_{j,t}) - \Delta_{j,t}\left(S_{t+\tau} - S_t\right)}{P_{j,t} - \Delta_{j,t} S_t}, \tag{8}$$

where $P_{j,t}$ and $\Delta_{j,t}$ are the price and delta of the put j on t, respectively.

We employ the trading volume weighted average of delta hedged returns for four different option types as dependent variables. Specifically, we classify the options as one of the following types: call ATM, call OTM, put ATM, and put OTM. We again follow Ge et al. (2016)[13] to determine whether an option is ATM or OTM. Separating option returns by moneyness would enable to examine heterogeneous speeds of information incorporation process within the same asset class and illuminate the potential option market segmentation by moneyness.

After collecting the weighted average of delta hedged returns, we estimate the following Fama-MacBeth regression for each option type i and trading period between trading days $t + k - 1$ and $t + k$:

$$\begin{aligned} r^{dh}_{i,t+k-1,t+k} = & \beta_0 + \beta_1 \text{OTMPC}_{i,t} \\ & + \gamma_1 \left(\text{Log size}\right)_{i,t} + \gamma_2 \left(\text{Log book-to-market ratio}\right)_{i,t} \\ & + \gamma_3 \left(\text{Momentum}\right)_{i,t} + \gamma_4 \left(\text{Illiquidity}\right)_{i,t} \\ & + \gamma_5 \left(\text{Lagged weekly delta-hedged return}\right)_{i,t} + \varepsilon_{i,t}, \end{aligned} \tag{9}$$

[13] A call option is defined as OTM if 0.02 ¡ option delta $\leq$ 0.375 and as ATM if 0.375 ¡ option delta $\leq$ 0.625, and a put option is defined as OTM if -0.375 ¡ option delta $\leq$ 0.02 and as ATM if -0.625 ¡ option delta $\leq$ 0.375

where the control variables are corresponding to the underlying stock of the options. The lagged weekly delta-hedged return is defined as $r^{dh}_{i,t-4,t}$ when $k > 0$ and $r^{dh}_{i,t-5,t-1}$ when $k = 0$ to avoid overlapping. k is set to have an integer value between 0 and 10.

Table 8 presents the regression results of OTMPC on delta hedged option returns, $r^{dh}_{i,t}$ through $r^{dh}_{i,t+10}$. Model (1) shows the predictability of delta hedged option returns for OTM call options. To simplify the analysis, we assume that lower value of OTMPC at date 0, i.e. out-of-the-money call option volumes are larger than out-of-the-money put option volumes. The significantly negative coefficient of date 0 implies that call option buyers would make more profits relative to delta matched stock buyers.[14] But the significantly positive coefficients of date 1 through 6 means that call option holders earns lower returns using the information of OTM option volumes than stock holders. Significantly positive coefficients over six days matches to the horizon of stock return predictability, that is six days. In other words, the embedded information in OTMPC are revealed quicker in the option prices than in the stock prices. This finding is consistent with slow moving capital hypothesis and market segmentation between option and stock markets. Model (2) reports the delta hedged option return predictability of put options. The delta hedged option return of put option is opposite to that of call option, and therefore negative sign implies less predictability of OTMPC for put option returns than for stock returns. The predictability patterns of put option returns are similar to those of call option returns while put option buyers earn more returns at date 0 using the information.

Model (3) and (4) display the predictability of delta hedged option returns for ATM call and ATM put options. For ATM call options, the negative signs of date 2 through 4 means that ATM option returns are more predictable than stock returns.

[14]This is consistent with the argument that OTM trading is buyer-initiated in general. For instance, given the thin liquidity of OTM options, a larger call trading volume would push up the call price if the trading tends to be buyer-initiated.

Except a few significant coefficients, we find the insignificant difference between stock return predictability and ATM option return predictability.

Our results suggest that stock markets incorporate the information contents in OTMPC more slowly than OTM options markets do, but ATM option markets also incoporate this information as slowly as stock markets do. These results are surprising in a sense that the degree of segmentation between ATM option market and OTM option market is similar to that between OTM option market and stock market.

5 Portfolio analysis

In this section, we propose an implementable investment strategy that exploits the information contained in OTM option trading activities. Specifically, we examine the profitability of a long-short stock portfolio constructed and rebalanced using the weekly OTMPC ratio, which aggregates the information embedded in both OTM call and OTM put trading volumes. As shown in Section 3, OTMPC ratio has a significant return predictability both in daily and weekly horizons, but we focus on the portfolio rebalanced on a weekly basis, rather than on a daily basis, and save the rebalancing costs.

Our analysis methodology is as follows: we first sort the stocks by their weekly OTMPC ratio in each week t and then build the OTMPC decile portfolios accordingly; Next, we calculate the weekly excess return of each decile portfolio in week $t+1$, and then estimate alpha of each decile by regressing the excess returns on the contemporaneous weekly risk factor returns, i.e., market return (CAPM), Fama-French three factors and Cahart's four factors.

Table 10 reports the estimated results of OTMPC decile portfolio analysis as follows: models (1) and (2) presents equal-weighted and value-weighted excess returns; (3) and (4) presents CAPM alphas of equal-weighted and value-weighted portfolio; (5)

and (6) reports Fama-French three factor alphas of equal-weighted and value-weighted portfolio; and (7) and (8) shows Carhart's four factor alphas of equal-weighted and value-weighted portfolio. In all models, we find that high OTMPC decile portfolio tend to have lower excess returns or portfolio alphas.

To better illustrate the performance of portfolio strategy built on OTMPC ratio, we also present the excess returns and factor-adjusted alphas of long-short portfolio (i.e., buy the top decile and short sell the bottom decile) in the last row of Table 10. In all factor models, the value-weighted long-short portfolio yields about 20 bp of risk-adjusted weekly returns, which is equivalent to 10.4% annual returns, and the equal-weighted portfolio earns around 13 bp of risk-adjusted return. The outperformance of value-weighted portfolios, relative to equal-weighted ones, suggest that OTMPC ratio has stronger return predictability in larger stocks. In Section 6.1 below, we examine how the return predictability of option volume ratios is associated with the market capitalization of firms. In both portfolio weighting schemes, the performance is most significant in Cahart's four-factor model. In an untabulated analysis, we find that long-short decile portfolios built on OTMC and OTMP ratios are also profitable.[15]

Before concluding this section, let us discuss the implementability of OTMPC decile portfolio strategy. While the annual return 10.4% of value-weighted long-short portfolio is substantial, it does not take into account the rebalancing costs that may arise from stock market illiquidity. Such a transaction cost, however, has a limited effect on the profitability of the value-weighted portfolio strategy, since larger stock are more liquid in the market. Furthermore, the profitability of portfolios built on OTMPC ratio is not completely offset by the stock short-selling costs, because the value-weighted returns of long-short portfolio is dominantly originated from the long position (i.e, the bottom decile). Finally, investors do not have to restrict the long-

[15]The analysis results are available upon request.

short portfolio to the top and bottom decile stocks. As shown in Table 10, the portfolio returns decreases in OTMPC ratio deciles almost monotonically. Overall, these results supports the implementability and profitability of portfolio strategy built on OTMPC.[16]

6 Robustness checks

6.1 Subsample analysis

To further examine the return predictability of OTM option trading volume, we run a number of subsample analyses and discuss the results in this section. We first test whether the return predictability is stronger in large stocks. Information-based market microstructure models (e.g., Glosten and Milgrom 1985) show that market illiquidity reduces the informed trading volume. We predict that the return predictability of OTM option volume is weaker in small stocks which have illiquid OTM option markets.

To test this prediction, we estimate a Fama-MacBeth daily return regression with large stock subsample (i.e., top market cap quintile stocks) and separately with small stock subsample (i.e., bottom market cap quintile stocks). Table 11 presents the large stock subsample results in models (1) and (2), and the small stock subsample results in models (3) and (4). The table shows that OTMC predicts positive daily returns in large stocks but not in small stocks. As shown in model (2), the return predictability in the large stock subsample is robust to controlling for OS ratio and short interest, and is stronger than the return predictability in the full sample reported in Table

[16]For instance, the estimated average trading costs of institutional investors, excluding the largest trading size quintiles, are about five basis points for the first quarter of 2011. On the other hand, the weekly turnover of the long portfolio is approximately 0.75 for the lowest OTMPC quintile, which implies that the transaction costs of the long portfolio is about 7.5 basis points ($= 2 \times 5 \times 0.75$) per week. Given the weekly return of 20 basis points for the long portfolio, this suggests that the long strategy is profitable even with trading costs taken into account.

3. While OTMP also predicts negative daily returns in both subsamples, its return predictability in small stock subsample disappears after controlling for OS ratio and short interest. Our findings suggest that the market liquidity could be a key factor that determines the size of informed OTM option trading volume. The stronger return predictability in large stocks also shows that our result is, at least, not entirely driven by the stock market illiquidity.[17]

Next, we investigate whether the return predictability of OTMP is related to the short-selling cost in stock market. Previous studies reported inconclusive findings about the effect of stock short-selling constraint on informed option trading. Johnson and So (2012) find that higher OS ratio predicts negative future stock return and the return predictability is stronger for the stocks with higher short interest. In contrast, using proprietary data, Ge et al. (2016) find that both synthetic short (i.e., buying puts and writing calls) and long (i.e., buying calls and writing puts) portfolios have significant return predictability.

To test the effect of short-selling costs, we estimate a Fama-MacBeth daily return regression with a subsample of stocks with high short interest, i.e., those for which short interest ratio exceeds 10%. The results are reported in models (5) and (6) of Table 11. The table shows that OTMP does not predict the stock returns of the stocks with high short interest, whereas OTMC predicts positive returns after controlling for OS ratio and short interest. This result suggests that, consistent with the finding of Ge et al. (2016), higher leverage offered by OTM options, rather than the short-selling cost in stock markets, is a crucial factor that makes informed investors favor to trade OTM options.

Finally, we run a Fama-MacBeth daily return regression for three subperiods, 1996–2005, 2006–2010, and 2011–2014. Table 12 presents the results. The table

[17]See Goncalves-Pinto et al. (2016) for the issue of stock market illiquidity in the literature of informed option trading.

suggests that the predictive power of OTMC is stable over the entire sample period, whereas that of OTMP is weaker during the 2011–2014 period. While the predictability of OTMP becomes somewhat weaker in more recent period (2011–2014), the predictability of OTMC remains strong in terms of magnitude and statistical significance over the entire sample period. The results also show that the return predictability of OTM option volume persists even in the financial crisis period.

6.2 Finer classification of OTM options

In this subsection, we investigate whether our empirical results can change if we define OTM option in a different way. Santa-Clara and Saretto (2009) document that margin requirements make it more costly for informed investors to take naked short position on OTM options. As they point out, there are certain moneyness points at which the short margin rule changes abruptly, and this market structure may affect the moneyness at which informed traders are shorting OTM options. Hence, the OTM trading volume ratios may obtain better return predictability if we adjust them to reflect these abrupt changes in short margin rule. Based on this idea, we subdivide OTM options into subgroups to determine whether the OTM options with different moneyness level affect the return predictability of OTMC and OTMP ratios differently, while considering the changes in short margin rule. Specifically, OTM options are categorized into three subgroups using the ratio of strike price to underlying stock price K/S: An option is specified as 1) OTM(5, 10) if $0.9 \leq K/S < 0.95$ for puts and $1.05 < K/S \leq 1.1$ for calls; 2) OTM(10, 20) if $0.8 \leq K/S < 0.9$ for puts and $1.1 < K/S \leq 1.2$ for calls; and 3) OTM(20, ∞) if $K/S < 0.8$ for puts and $1.2 < K/S$ for calls. Since the short margin rule changes at the strike prices for which $K/S = 1.1$ and $K/S = 8/9 \approx 0.89$, respectively, the newly calculated OTMC and OTMP ratios can tell us how the short margin rule affects the return predictability of the ratios. After identifying trading volume for each OTM subgroup, OTMC and OTMP are calculated separately and then included as independent variables for Fama-Macbeth regressions. Table 13 presents some summary statistics for the newly calculated ratios.

Table 14 summarizes the regression results. Overall, the results suggest that the return predictability of OTMC and OTMP is most stable when the ratios are constructed using OTM(10, 20) options. Although this might suggest that the short margin rule may affect the behavior of informed traders, it is not conclusive because the difference between the results for OTM(5, 10) and OTM(10, 20) does not seem to be significant, and it is also possible that the difference is purely due to leverage effect. In contrast, the ratios based on OTM(20, ∞) options exhibit relatively weak predictive power. This implies that although the return predictability is mostly originating from deep-out-of-the-money options, the predictive power of trading volume does not increase monotonically as options go more OTM. This phenomenon can be attributed to the higher transaction costs and illiquidity of extremely deep-out-of-the-money options. Furthermore, given that we analyze options maturing in 5 through 35 days, it is very unlikely that the sample stocks have experienced sufficiently large shocks that make OTM(20, ∞) options profitable. Table 13 supports this argument by showing that the mean level of OTMC(20, ∞) and OTMP(20, ∞) are much lower than the other ratios.

6.3 Stock return reversal

OTMPC ratio can be negatively associated with the contemporaneous stock returns since higher return reduces (resp. increases) the moneyness of traded put (resp. call) options. Autocorrelation of underlying stock return may generate a spurious stock return predictability of OTMPC ratio. To address this possibility, we conduct another set of Fama-Macbeth regressions while controling the impact of past stock returns, and report the result in this section. Specifically, we employ a two-stage regression which is constructed as follows. In the first stage, we regress daily OTMPC ratio on trading day t on daily returns on day t and $t-1$, which are denoted as r_t and r_{t-1}, respectively, the weekly return from trading day $t-4$ to t, which is denoted as $r_{t-4,t}$, and the square of these returns, and then collect the residual ε_t below:

$$\text{OTMPC}_t = \beta_0 + \beta_1 r_t + \beta_2 r_{t-1} + \beta_3 r_{t,t-4} + \beta_4 r_t^2 + \beta_5 r_{t-1}^2 + \beta_5 r_{t,t-4}^2 + \varepsilon_t \qquad (10)$$

In the second stage, we include ε_t as the main independent variable and conduct the same Fama-Macbeth regressions that are conducted in previous sections to test the stock return predictability of the part of OTMPC ratio that is orthogonal to previous stock returns.

Table 8 presents the regression results. The table shows that the magnitude of coefficient estimates for ε_t are comparable to those for OTMPC ratio in Table 6. For instance, the coefficient estimate for ε_t on trading day $t+1$ is -0.0009, which is statistically signicant at 1% level and is as large as that for OTMPC ratio on the same trading day, $t+1$, Furthermore, the corresponding t-statistic is larger for ε_t. In addition, the table reveals that the statistical significance of the predictive power of ε_t lasts for five trading days. Overall, the results suggest that the stock return predictability of OTMPC ratio is not merely due to stock return autocorrelation.

6.4 Return predictability around corporate events

We finally examine whether the return predictability of OTM volume ratios is associated with two major corporate events, M&A announcements (of target firms) and earnings surprise, which lead to significant changes in future stock prices. Notably, these two events differ in their regularity of occurrence and the direction of stock market reaction. While M&A announcements occurs irregularly and are mostly accompanied with positive return of target firms, earnings announcements occur regularly and can be followed by either positive or negative stock returns, depending on the ex-ante forecast of investors. These distinctive features of two events allow us to test the robustness of our findings.

To examine the predictive power of OTM volume ratios on the M&A announcements, we first match each target firm with control firms that belong to the same Fama-French 49 industries and size quintiles and do not have a M&A announcement in the quarter, and then compare OTMC and OTMP ratios of the two groups in (-16,4) weeks window around the announcement. Our final sample used in this analysis consists of 432 M&A cases that occur between 1999 and 2012. Table 17 reports the OTM volume ratios of target and matched firms, as well as the differences in the ratios between the two groups. The table shows that the two groups of firms exhibits substantial differences in their OTM volume ratios before and after M&A announcements. Specifically, relative to control firms, target firms have higher (lower) OTMC and lower (higher) OTMP volume ratios before (after) the announcement. The difference is more significant for OTMC ratio before the announcement, whereas most of the differences are statistically insignificant for OTMP ratio before the announcement. OTMC is approximately 2% higher in the target firm during the pre-announcement period $(-6, -1)$ weeks, while the ratio becomes lower approximately by 3.5% in the target firms in the post-announcement period. Although it might can be argued that the relative decrease in OTMC for the target firms after the announcement is due to stock price increase, it is unlikely that the decrease would persist for three weeks as in Table 17 if it is purely driven by stock price change.

Next, we test whether OTM volume ratios predict earnings surprise which is unknown to public investors before earnings announcement. Specifically, we estimate the following regression: for each firm i and time t,

$$
\begin{aligned}
r_{i,t+1} = \alpha &+ \beta_0 \mathrm{OTMC}_{i,t} + \beta_1 \mathrm{OTMP}_{i,t} \\
&+ \gamma_0 (\text{Log size})_{i,t} + \gamma_1 (\text{Log book-to-market ratio})_{i,t} \\
&+ \gamma_2 (\text{Momentum})_{i,t} + \gamma_3 (\text{Illiquidity})_{i,t} + \gamma_4 (\text{Weekly lag return})_{i,t} + \varepsilon_{i,t}.
\end{aligned}
\tag{11}
$$

We consider three dependent variables: 1) SUE_{AF}, i.e., the standard unexplained earnings based on IBES reported analyst forecasts and actual EPS, which is defined as the difference between the actual and the most recent consensus EPSs divided by the stock price, 2) $\mathrm{CAR}(-1,1)$, i.e., the cumulative benchmark-adjusted return in the trading day window $(t-1, t+1)$ centered at the earnings announcement date t, and 3) SUE_{ER}, i.e., the standard unexplained earnings based on last quarters earnings, which is EPS of this quarter minus EPS of last quarter divided by its share price. The independent variables are defined in Appendix.

Table 18 provides the regression results of earnings surprise on OTMC and OTMP. The table shows that higher OTMC predicts higher $\mathrm{CAR}(-1,1)$ and SUE_{ER}, while OTMP does not predict the earnings surprise. Both OTM ratios do not have significant predictive power for SUE_{AF}, although the signs are in line with the hypothesis of informed trading. A possible reason for this weak predictive power is the fixed earnings announcement dates. If uninformed traders observe an abnormally large OTM trading volume right before the predetermined announcement date, they will be likely to interpret the large volume as a consequence of informed trading that is related to the announcement. As a result, trading OTM options may have a larger price impact on the underlying stock, which will boost price adjustment and thereby weaken the predictive power of the OTM volume ratios. Another notable point is that, consistent with the results in Table 17, the predictive power of OTMC over earnings surprise is stronger than that of OTMP.

7 Conclusion

This paper examines the information content of unsigned out-of-the-money (OTM) option trading volume, which is publicly observable data, and investigates how quickly stock prices adjust to such information. We find strong evidence that larger OTM call (put) trading volume, relative to the total option trading volume, predicts positive (negative) future stock returns in both daily and weekly horizons. Interestingly, return predictability of OTM option trading volume is more significant in larger stocks but unrelated to short interest levels. Using the out-of-the-money option trading volume, we also propose an implementable and profitable investment strategy. While some previous studies show that the stock return predictability of option volume or price measures can be related to stock market illiquidity rather than the informed option trading, we find that, as suggested by information-based multi-market trading models, OTM option trading volumes predict the occurrence of material corporate events such as takeover announcement or earnings surprise.

The level and persistence of return predictability of OTM option trading volumes are striking since the information is obtained from publicly observable data. Our findings may be related to the limited attention of stock market investors to option markets. Interestingly, our subsample period analysis shows that while stock price adjustments to the information contained in OTM put trading volume becomes quicker in more recent years (after 2011), the stock market still adjusts slowly to the information embedded in OTM calls. This finding cannot be explained by a limited arbitrage argument such that the investors who have negative information about a firm may trade in put option markets, rather than the stock market, to save the short-selling costs. Future studies can further explore how investors obtain information contained in trading activities in other markets.

Table 1: Summary statistics: firm size and book-to-market ratio

This table presents the summary statistics of firm size (total market capitalization) and the book-to-market value ratio of our sample stocks during 1996–2014. The details about constructing these variables are available in Appendix.

Year	# of firms	Size ($million)						Book-to-market					
		Sample			CRSP			Sample			CRSP		
		Mean	Std	Median	Mean	Std	Median	Mean	Std	Median	Mean	Std	Median
1996	1,489	3,956.79	10,453.91	990.92	999.63	5,003.18	104.85	0.50	0.61	0.39	0.66	0.87	0.51
1997	1,817	4,540.39	13,418.32	966.91	1,318.92	6,956.50	122.01	0.45	0.41	0.36	0.60	0.57	0.47
1998	2,038	5,197.48	18,191.23	920.41	1,658.89	10,009.00	117.74	0.55	0.75	0.40	0.73	0.79	0.55
1999	2,098	6,379.49	24,674.50	1,098.73	2,152.79	13,838.66	136.60	0.56	0.70	0.38	0.78	0.86	0.59
2000	2,108	7,081.68	27,596.46	1,131.87	2,395.06	15,671.25	122.74	0.72	1.18	0.42	1.08	2.09	0.68
2001	1,869	6,302.15	23,647.65	1,124.60	2,216.20	13,748.17	152.22	0.56	0.52	0.43	0.93	1.28	0.65
2002	1,765	5,290.37	18,542.35	1,037.17	1,956.24	11,160.55	145.77	0.72	0.80	0.54	0.96	1.09	0.70
2003	1,670	6,635.36	21,634.30	1,452.40	2,486.70	13,074.63	249.33	0.54	0.46	0.43	0.68	0.62	0.54
2004	1,837	6,868.94	22,572.61	1,542.51	2,849.03	14,304.11	323.41	0.49	0.42	0.40	0.56	0.44	0.47
2005	1,885	7,149.05	22,089.02	1,581.91	3,039.32	14,259.90	342.37	0.49	0.45	0.40	0.57	0.45	0.50
2006	2,051	7,368.47	23,433.75	1,625.42	3,420.92	15,820.93	402.47	0.47	0.35	0.40	0.55	0.39	0.48
2007	2,160	7,470.90	24,132.83	1,572.68	3,615.61	16,832.12	369.74	0.55	0.48	0.42	0.66	0.67	0.55
2008	2,055	5,109.17	18,217.58	1,018.01	2,545.91	12,844.03	241.10	0.97	1.37	0.66	1.26	1.82	0.81
2009	1,925	5,951.97	18,779.10	1,308.80	2,961.99	13,348.71	293.35	0.72	0.66	0.57	1.00	1.05	0.74
2010	1,966	6,968.21	21,157.42	1,631.21	3,596.73	15,287.54	406.07	0.61	0.46	0.51	0.78	0.69	0.64
2011	1,987	7,092.34	22,666.19	1,565.85	3,753.11	16,499.57	417.07	0.71	0.68	0.55	0.93	0.97	0.71
2012	1,847	8,456.59	27,707.66	1,834.80	4,390.08	19,888.05	492.30	0.63	0.51	0.51	0.84	0.90	0.67
2013	2,014	10,234.70	29,596.85	2,305.71	5,916.77	22,657.06	733.42	0.50	0.37	0.42	0.65	0.66	0.53
2014	2,125	11,259.74	32,934.69	2,289.12	6,867.19	25,968.35	796.41	0.53	0.58	0.40	0.68	0.79	0.52

Table 2: Summary statistics: option trading volume ratios

This table presents the summary statistics of daily option trading volume ratios during 1996–2014. OTMC (resp. OTMP) is the ratio of out-of-the-money (OTM) call (resp. put) trading volume to total option trading volume, and OTMPC is the ratio of OTM put trading volume to total OTM option trading volume. PC is the ratio of put trading volume to total option trading volume. The details about constructing these variables are available in Section 2.

Year	Number of firms	OTMC		OTMP		OTMPC		PC	
		Mean	Std	Mean	Std	Mean	Std	Mean	Std
1996	1,489	0.229	0.291	0.139	0.233	0.396	0.402	0.313	0.314
1997	1,817	0.223	0.286	0.136	0.231	0.394	0.401	0.306	0.312
1998	2,038	0.228	0.286	0.139	0.233	0.390	0.399	0.324	0.319
1999	2,098	0.226	0.279	0.142	0.225	0.407	0.396	0.303	0.302
2000	2,108	0.248	0.277	0.143	0.220	0.381	0.378	0.298	0.292
2001	1,869	0.236	0.284	0.172	0.251	0.418	0.385	0.361	0.319
2002	1,765	0.219	0.280	0.183	0.256	0.458	0.387	0.401	0.323
2003	1,670	0.215	0.280	0.188	0.255	0.482	0.385	0.376	0.310
2004	1,837	0.230	0.288	0.180	0.254	0.453	0.386	0.374	0.310
2005	1,885	0.234	0.285	0.182	0.250	0.449	0.381	0.381	0.306
2006	2,051	0.232	0.281	0.183	0.249	0.450	0.379	0.388	0.302
2007	2,160	0.252	0.288	0.195	0.256	0.443	0.373	0.393	0.306
2008	2,055	0.268	0.285	0.213	0.260	0.445	0.365	0.427	0.308
2009	1,925	0.244	0.280	0.226	0.267	0.488	0.365	0.415	0.303
2010	1,966	0.258	0.288	0.218	0.265	0.468	0.365	0.398	0.305
2011	1,987	0.273	0.281	0.229	0.260	0.462	0.353	0.405	0.301
2012	1,847	0.260	0.274	0.228	0.258	0.474	0.352	0.412	0.296
2013	2,014	0.253	0.269	0.227	0.255	0.480	0.350	0.402	0.292
2014	2,125	0.267	0.276	0.214	0.252	0.451	0.350	0.400	0.298

Table 3: Fama MacBeth - daily return predictability

This table reports the result of Fama and MacBeth (1973) regressions of underlying stock return on trading day $t+1$ on OTMC and OTMP ratios. The dependent variables are the raw underlying stock return, DGTW benchmark adjusted return, and Carhart's four factor risk adjusted return on trading day $t+1$. The main independent variables are daily OTMC and OTMP ratios, which are defined as the daily trading volume of out-of-the-money (OTM) calls and puts, respectively, divided by the total option trading volume on trading day t. The control variables include log firm size, log book-to-market ratio, momentum, illiquidity measure of Amihud (2002), and lagged weekly return, all of which are for trading day t. Book-to-market ratio is the book equity for the fiscal year ending in the previous calendar year divided by the market equity at the end of December in the previous calendar year. OS is the O/S ratio in Johnson and So (2012). Momentum is defined as the cumulative underlying stock return during the previous six months. Illiquidity is defined as the ratio of absolute daily stock return to daily dollar trading volume, averaged over the previous six months. Weekly lag return is the weekly raw return of underlying stock, one week lagged to the dependent variable. t-statistics are shown in parentheses below the coefficient estimates and are based on Newey and West (1987) adjusted standard errors with four-week lags. ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Raw return	Raw return	Raw return	Raw return	Raw return	Raw return	Four factor risk adjusted return	DGTW adjusted return
OTMC ratio	0.0006***		0.0005***	0.0005***	0.0003***	0.0003***	0.0005***	0.0006***
	(7.575)		(5.412)	(5.904)	(4.229)	(4.359)	(6.548)	(7.096)
OTMP ratio		−0.0010***	−0.0009***	−0.0008***	−0.0007***	−0.0007***	−0.0009***	−0.0008***
		(−11.056)	(−9.590)	(−9.155)	(−7.636)	(−7.662)	(−10.001)	(−9.559)
OS decile				−0.0000***		−0.0000**		
				(−2.759)		(−2.465)		
Short interest					−0.0025***	−0.0022**		
					(−2.710)	(−2.442)		
Log Size	−0.0001**	−0.0001**	−0.0001**	−0.0001*	−0.0001***	−0.0001**	−0.0001***	−0.0002***
	(−2.375)	(−2.034)	(−2.134)	(−1.781)	(−2.956)	(−2.309)	(−3.161)	(−7.700)
Log BM	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	−0.0000	−0.0000
	(0.615)	(0.386)	(0.524)	(0.278)	(0.642)	(0.506)	(−1.121)	(−1.042)
Momentum	−0.0001	−0.0000	−0.0000	−0.0001	−0.0001	−0.0001	−0.0001	−0.0017***
	(−0.293)	(−0.191)	(−0.181)	(−0.301)	(−0.629)	(−0.555)	(−0.332)	(−11.815)
Illiquidity	−0.0023	−0.0025	−0.0025	−0.0022	0.0084	0.0097	−0.0017	0.0013
	(−0.573)	(−0.619)	(−0.602)	(−0.542)	(1.209)	(1.404)	(−0.450)	(0.332)
Weekly lag return	−0.0050***	−0.0051***	−0.0050***	−0.0049***	−0.0034***	−0.0034***	−0.0051***	−0.0074***
	(−6.279)	(−6.387)	(−6.242)	(−6.197)	(−4.002)	(−3.984)	(−7.060)	(−10.992)
Constant	0.0012***	0.0014***	0.0013***	0.0014***	0.0014***	0.0014***	0.0007***	0.0017***
	(2.640)	(3.034)	(2.855)	(3.082)	(3.697)	(3.681)	(3.368)	(8.490)
Adjusted R^2	0.069	0.069	0.071	0.076	0.081	0.086	0.047	0.045
N	2,898,532	2,898,532	2,898,532	2,870,918	2,610,013	2,609,995	2,898,495	2,857,125

Table 4: Different horizon return predictability

This table reports the result of Fama and MacBeth (1973) regressions of daily underlying stock return on trading days from $t+1$ to $t+10$ on OTMC and OTMP ratios. The two ratios are defined as the daily trading volume of out-of-the-money (OTM) calls and puts, respectively, divided by the total option trading volume on trading day t. Log firm size, log book-to-market ratio, momentum, Amihud (2002) illiquidity measure, and lagged weekly return are included as control variables, although they do not appear in the table. t-statistics are estimated based on Newey and West (1987) adjusted standard errors with four-week lags. ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

	OTMC ratio		OTMP ratio	
Day	Coeff.	t	Coeff.	t
+1	0.0005***	(5.412)	−0.0009***	(−9.590)
+2	0.0003***	(4.257)	−0.0005***	(−5.366)
+3	0.0002**	(2.437)	−0.0002***	(−2.739)
+4	0.0001	(1.596)	−0.0001	(−0.840)
+5	0.0000	(0.231)	−0.0002*	(−1.839)
+6	0.0001	(0.945)	−0.0001	(−1.475)
+7	−0.0001	(−1.140)	0.0000	(0.356)
+8	0.0001	(0.670)	0.0000	(0.450)
+9	0.0000	(0.186)	0.0000	(0.106)
+10	−0.0001	(−0.904)	−0.0001	(−1.482)

Table 5: Fama MacBeth - daily return predictability

This table reports the result of Fama and MacBeth (1973) regressions of underlying stock return on trading day $t+1$ on OTMPC ratio. The dependent variables are raw underlying stock return, DGTW benchmark adjusted return, and Carhart's four factor risk adjusted return on trading day $t+1$. The main independent variable is OTMPC ratio, which is defined as the daily OTM put trading volume divided by the daily OTM option trading volume on trading day t. The control variables include log size, log book-to-market ratio, momentum, illiquidity measure of Amihud (2002) and lagged weekly return. OS is the O/S ratio in Johnson and So (2012). Momentum is defined as the cumulative underlying stock return during the previous six months. Illiquidity is defined as the ratio of absolute daily stock return to daily dollar trading volume, averaged over the previous six months. Weekly lag return is the weekly raw return of underlying stock, one week lagged to the dependent variable. t-statistics are shown in parentheses below the coefficient estimates and are based on Newey and West (1987) adjusted standard errors with four-week lags. ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)
	Raw return	DGTW adjusted return	Four factor risk adjusted return
OTMPC ratio	-0.0009^{***}	-0.0009^{***}	-0.0010^{***}
	(−12.285)	(−13.742)	(−14.229)
Log Size	−0.0001	-0.0000^{*}	-0.0001^{***}
	(−1.389)	(−1.651)	(−5.951)
BM	0.0000	−0.0001	−0.0001
	(0.234)	(−1.476)	(−1.168)
Momentum	0.0001	0.0000	-0.0016^{***}
	(0.264)	(0.132)	(−10.671)
Illiquidity	−0.0055	−0.0045	−0.0001
	(−0.944)	(−0.847)	(−0.017)
Weekly lag return	-0.0053^{***}	-0.0054^{***}	-0.0075^{***}
	(−6.445)	(−7.223)	(−10.758)
Constant	0.0014^{***}	0.0008^{***}	0.0018^{***}
	(2.881)	(3.446)	(8.269)
Adjusted R^2	0.077	0.052	0.049
N	2,485,071	2,485,038	2,451,314

Table 6: Different horizon return predictability

This table reports the result of Fama and MacBeth (1973) regressions of daily underlying stock return on trading days from $t+1$ to $t+10$ on OTMPC ratio. OTMPC ratio is defined as the daily OTM put trading volume divided by the daily OTM option trading volume on trading day t. Log firm size, log book-to-market ratio, momentum, Amihud (2002) illiquidity measure, and lagged weekly return are included as control variables, although they do not appear in the table. Model 1 includes OTMPC ratio and control variables. Model 2 includes both OTMPC PC ratios to contrast the persistence of embedded information in the trading volume of OTM and entire options. t-statistics are estimated based on Newey and West (1987) adjusted standard errors with four-week lags. ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

	(1)		(2)			
	OTMPC ratio		OTMPC ratio		PC ratio	
Day	Coeff.	t	Coeff.	t	Coeff.	t
+1	−0.0009***	(−12.285)	−0.0007***	(−7.465)	−0.0006***	(−5.026)
+2	−0.0006***	(−8.077)	−0.0006***	(−7.185)	0.0002*	(1.829)
+3	−0.0002***	(−2.987)	−0.0002**	(−1.962)	−0.0001	(−1.024)
+4	−0.0001**	(−2.131)	−0.0003***	(−3.119)	0.0002**	(2.379)
+5	−0.0001**	(−1.962)	−0.0002**	(−2.434)	0.0002	(1.628)
+6	−0.0001**	(−1.987)	−0.0002***	(−2.763)	0.0002*	(1.877)
+7	0.0000	(0.042)	−0.0001	(−1.007)	0.0002*	(1.748)
+8	−0.0000	(−0.086)	−0.0000	(−0.209)	0.0000	(0.432)
+9	−0.0000	(−0.281)	−0.0001	(−1.594)	0.0003***	(2.599)
+10	−0.0000	(−0.036)	−0.0000	(−0.283)	0.0000	(0.324)

Table 7: Fama MacBeth - weekly return predictability

This table reports the result of Fama and MacBeth (1973) regressions of weekly underlying stock return on OTM volume ratios. The dependent variables is the weekly raw return of the underlying stock on week $t+1$. The main independent variables are variation of OTM volume ratios, (OTMC, OTMP), (OTMPC), (ΔOTMC, ΔOTMP), which are calculated for week t. The control variables include log size, log book-to-market ratio, momentum, illiquidity measure of Amihud (2002) and lagged weekly return, all of which are for week t. Book-to-market ratio is the book equity for the fiscal year ending in the previous calendar year divided by the market equity at the end of December in the previous calendar year. OS is the O/S ratio in Johnson and So (2012). Momentum is defined as the cumulative underlying stock return during the previous six months. Illiquidity is defined as the ratio of absolute daily stock return to daily dollar trading volume, averaged over the previous six months. Weekly lag return is the weekly raw return of underlying stock, one week lagged to the dependent variable. t-statistics are shown in parentheses below the coefficient estimates and are based on Newey and West (1987) adjusted standard errors with four-week lags. ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
OTMC ratio	0.0018***	0.0019***						
	(3.805)	(3.815)						
OTMP ratio	−0.0014***	−0.0015***						
	(−3.244)	(−3.168)						
OTMPC ratio			−0.0013***	−0.0014***				
			(−4.442)	(−4.341)				
ΔOTMC ratio					0.0010***	0.0010***		
					(2.798)	(2.593)		
ΔOTMP ratio					−0.0007*	−0.0012***		
					(−1.903)	(−2.994)		
OTMCS ratio							0.0059	0.0148**
							(0.925)	(2.359)
OTMPS ratio							−0.0130**	−0.0032
							(−2.068)	(−0.479)
OS decile		−0.0001*		−0.0001**		−0.0001*		−0.0001**
		(−1.854)		(−2.076)		(−1.782)		(−2.439)
Short interest		−0.0144***		−0.0144***		−0.0127***		−0.0151***
		(−4.066)		(−4.056)		(−3.291)		(−4.282)
ΔCVOL		0.0240***		0.0253***		0.0268***		0.0239***
		(5.541)		(5.769)		(4.919)		(5.521)
ΔPVOL		−0.0293***		−0.0305***		−0.0334***		−0.0292***
		(−6.474)		(−6.581)		(−5.923)		(−6.481)
Log Size	0.0000	−0.0003	0.0000	−0.0002	0.0002	−0.0002	0.0000	−0.0003
	(0.306)	(−1.548)	(0.272)	(−1.454)	(0.977)	(−0.956)	(0.181)	(−1.567)
BM	0.0003*	0.0001	0.0003*	0.0002	0.0003	0.0001	0.0002	0.0001
	(1.762)	(0.565)	(1.848)	(0.779)	(1.472)	(0.400)	(1.107)	(0.582)
Momentum	0.0001	0.0003	0.0002	0.0002	0.0000	0.0003	0.0003	0.0001
	(0.100)	(0.224)	(0.157)	(0.202)	(0.039)	(0.228)	(0.243)	(0.103)
Illiquidity	−0.0267**	−0.0777**	−0.0353**	−0.0809**	−0.0500**	−0.0989**	−0.0703*	−0.0772**
	(−1.994)	(−2.088)	(−2.197)	(−1.997)	(−2.055)	(−2.193)	(−1.756)	(−2.052)
Weekly lag return	−0.0094***	−0.0093***	−0.0088***	−0.0098***	−0.0106***	−0.0100***	−0.0097***	−0.0096***
	(−2.733)	(−2.700)	(−2.591)	(−2.893)	(−2.923)	(−2.785)	(−2.686)	(−2.765)
Constant	0.0016	0.0049**	0.0024	0.0057***	0.0006	0.0042**	0.0018	0.0052***
	(0.819)	(2.527)	(1.208)	(2.876)	(0.287)	(2.091)	(0.861)	(2.709)
Adjusted R^2	0.064	0.089	0.063	0.089	0.070	0.096	0.072	0.092
N	768,209	709,216	747,047	692,809	653,847	622,707	709,901	709,216

Table 8: Delta hedged option return predictability

This table reports the results of Fama and MacBeth (1973) regressions of daily delta hedged call and put returns on OTMPC ratio to evaluate the option return predictability of option trading volume. Delta hedged returns of calls and puts are examined for trading days ranging from t to $t+10$, where t is the trading day on which OTMPC ratio is measured. For each call i and put j, the corresponding delta hedged return r^{dh} between trading days t and $t+\tau$ is defined as

$$\frac{(C_{i,t+\tau} - C_{i,t}) - \Delta_{i,t}(S_{t+\tau} - S_t)}{\Delta_{i,t} S_t - C_{i,t}}; \text{ and}$$

$$\frac{(P_{j,t+\tau} - P_{j,t}) - \Delta_{j,t}(S_{t+\tau} - S_t)}{P_{j,t} - \Delta_{j,t} S_t},$$

where $C_{i,t}$ and $\Delta_{i,t}$ are the price and delta of call i on t, respectively, $P_{j,t}$ and $\Delta_{j,t}$ are the price and delta of put j on t, respectively, and S_t is the price of underlying stock on t. Daily delta hedged returns are obtained for trading days from t to $t+10$ by calculating $r^{dh}_{i,t+k-1,t+k}$ for each option type i while setting k as an integer between 0 and 10. The volume-weighted mean delta-hedged returns for ATM and OTM options are calculated separately for calls and puts, and then employed as dependent variables. OTMPC ratio is defined as the daily OTM put trading volume divided by the daily OTM option trading volume. Each regression includes the log size, log book-to-market ratio, momentum, Amihud (2002) illiquidity measure, and lagged weekly return ($r^{dh}_{t-4,t}$) of the corresponding firm or stock as control variables. For trading day t (the "0" row in the table), the lagged weekly return $r^{dh}_{t-4,t}$ is replaced with $r^{dh}_{t-5,t-1}$ to avoid overlapping. The regression results for control variables are not reported in the table. t-statistics are based on Newey and West (1987) adjusted standard errors with four-week lags. ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

	(1)		(2)		(3)		(4)	
	OTM				ATM			
	Call		Put		Call		Put	
k	Coeff.	t	Coeff.	t	Coeff.	t	Coeff.	t
0	−0.0008***	(−14.181)	0.0020***	(28.672)	0.0003	(0.337)	−0.0002***	(−3.251)
+1	0.0006***	(11.616)	−0.0007***	(−13.084)	0.0001**	(2.425)	−0.0003***	(−3.546)
+2	0.0002***	(3.207)	−0.0003***	(−6.467)	−0.0001**	(−1.961)	−0.0001	(−1.386)
+3	0.0001*	(1.946)	−0.0002***	(−4.302)	−0.0002***	(−2.972)	0.0000	(0.469)
+4	0.0000	(0.628)	−0.0002***	(−3.849)	−0.0002***	(−3.558)	−0.0001	(−0.942)
+5	0.0001**	(2.473)	−0.0001	(−1.413)	−0.0001	(−0.947)	0.0001	(1.093)
+6	0.0002***	(2.870)	−0.0001**	(−2.256)	−0.0001	(−0.823)	−0.0000	(−0.662)
+7	0.0000	(0.373)	−0.0001***	(−3.047)	−0.0001	(−0.864)	−0.0000	(−0.390)
+8	0.0000	(0.387)	−0.0001	(−1.081)	-0.0002***	(−2.801)	0.0000	(0.260)
+9	0.0001***	(2.605)	−0.0001**	(−1.973)	−0.0001	(−1.521)	0.0000	(0.189)
+10	0.0001**	(2.345)	−0.0000	(−0.487)	0.0001	(0.863)	0.0001	(1.109)

Table 9: Correlation matrix between predictors

This table summarizes the correlation among option volume and price based predictors. The variables are constructed from weekly observations.

Variables	OTMC ratio	OTMP ratio	OTMPC ratio	PC ratio	OS decile	OTMCS ratio	OTMPS ratio	Short interest	ΔCVOL	ΔPVOL
OTMC ratio	-	-0.193	-0.649	-0.396	0.034	0.343	-0.062	-0.004	0.025	0.018
OTMP ratio		-	0.688	0.578	0.060	-0.034	0.370	0.007	0.002	0.008
OTMPC ratio			-	0.501	0.016	-0.196	0.236	0.001	-0.022	-0.012
PC ratio				-	0.002	-0.137	0.225	0.036	0.039	0.044
OS decile					-	0.499	0.456	0.129	0.043	0.046
OTMCS ratio						-	0.529	0.101	0.032	0.031
OTMPS ratio							-	0.097	0.032	0.037
Short interest								-	0.005	0.010
ΔCVOL									-	0.916
ΔPVOL										-

Table 10: Portfolio Analysis - deciles of OTMPC ratio

This table reports the weekly return on week $t+1$ for OTMPC decile portfolios. Models (1) and (2) show equal- and value-weighted portfolio excess return for each decile. Models (3) and (4) show the CAPM alpha of equal- and value-weighted portfolios for each decile. Models (5) and (6) show the Fama-French three factor alpha of equal- and value-weighted portfolios for each decile. Models (7) and (8) show the Carhart's four factor alpha of equal- and value-weighted portfolios for each decile. OTMPC ratio is defined as the weekly OTM put trading volume divided by the weekly OTM option trading volume on week t. The last row displays the performance of the long-short extreme portfolio, $(10-1)$. ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

	(1)		(2)		(3)		(4)		(5)		(6)		(7)		(8)	
	EW Excess Return		VW Excess Return		EW CAPM Alpha		VW CAPM Alpha		EW Three factor Alpha		VW Three factor Alpha		EW Four factor Alpha		VW Four factor Alpha	
Decile	Coeff.	t	Coeff.	t	Coeff.	t	Coeff.	t	Coeff.	t	Coeff.	t	Coeff.	t	Coeff.	t
1	0.0025***	(2.451)	0.0031***	(3.271)	0.0009*	(1.858)	0.0016***	(3.412)	0.0004	(1.144)	0.0013***	(3.123)	0.0007*	(1.864)	0.0016***	(4.102)
2	0.0028***	(2.689)	0.0031***	(3.457)	0.0011***	(2.421)	0.0017***	(3.849)	0.0008*	(1.941)	0.0016***	(3.866)	0.0010***	(2.366)	0.0018***	(4.339)
3	0.0019*	(1.860)	0.0024***	(2.719)	0.0002	(0.512)	0.0010***	(2.510)	−0.0001	(−0.175)	0.0009***	(2.516)	0.0001	(0.149)	0.0010***	(2.871)
4	0.0020*	(1.949)	0.0022***	(2.454)	0.0003	(0.747)	0.0007**	(1.985)	0.0000	(0.109)	0.0007**	(2.190)	0.0001	(0.313)	0.0009***	(2.545)
5	0.0019*	(1.900)	0.0011	(1.295)	0.0002	(0.616)	−0.0003	(−0.825)	0.0000	(0.012)	−0.0003	(−0.759)	0.0001	(0.407)	−0.0002	(−0.449)
6	0.0012	(1.228)	0.0010	(1.184)	−0.0004	(−1.269)	−0.0004	(−1.280)	−0.0007**	(−2.125)	−0.0004	(−1.302)	−0.0006*	(−1.805)	−0.0003	(−1.033)
7	0.0017*	(1.701)	0.0014	(1.572)	0.0000	(0.090)	0.0000	(−0.124)	−0.0002	(−0.712)	−0.0001	(−0.379)	−0.0001	(−0.396)	0.0000	(0.122)
8	0.0016*	(1.717)	0.0015*	(1.735)	0.0000	(0.125)	0.0001	(0.258)	−0.0003	(−0.903)	−0.0001	(−0.172)	−0.0002	(−0.720)	0.0000	(0.098)
9	0.0011	(1.161)	0.0010	(1.163)	−0.0005	(−1.195)	−0.0004	(−1.018)	−0.0008***	(−2.492)	−0.0006*	(−1.706)	−0.0007**	(−2.244)	−0.0005	(−1.376)
10	0.0012	(1.254)	0.0012	(1.380)	−0.0004	(−0.882)	−0.0002	(−0.468)	−0.0007**	(−2.297)	−0.0004	(−1.322)	−0.0007**	(−2.079)	−0.0004	(−1.144)
10−1	−0.0013***	(−3.315)	−0.0019***	(−3.918)	−0.0012***	(−3.070)	−0.0018***	(−3.723)	−0.0012***	(−2.968)	−0.0018***	(−3.634)	−0.0014***	(−3.489)	−0.0020***	(−4.309)

Table 11: Subsample Analysis - firm size and short interest

This table reports the result of subsample analysis for return predictability of OTMC and OTMP ratio using Fama and MacBeth (1973) regression. Samples of models 1 and 2 consist of the largest size quintile stocks, samples of models 3 and 4 consist of the smallest size quintile stocks, and samples of models 5 and 6 consist of stocks with short interest larger than 10%. t-statistics are shown in parentheses below the coefficient estimates and are based on Newey and West (1987) adjusted standard errors with four-week lags. ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
	Largest size quintile	Largest size quintile	Smallest size quintile	Smallest size quintile	Short interest >10%	Short interest >10%
OTMC ratio	0.0007***	0.0007***	−0.0002	0.0010	−0.0101	0.0104**
	(6.665)	(6.054)	(−0.604)	(0.290)	(−1.114)	(2.076)
OTMP ratio	−0.0008***	−0.0008***	−0.0015***	−0.0111	−0.0094	0.0067
	(−6.624)	(−6.804)	(−3.125)	(−1.109)	(−0.709)	(1.400)
OS decile		−0.0000		−0.0003		0.0002
		(−0.263)		(−0.984)		(0.442)
Short interest		0.0014		−0.0103		−0.0164
		(0.601)		(−0.904)		(−0.687)
Log Size	0.0000	0.0000	−0.0001	−0.0044*	−0.0024	0.0011
	(0.426)	(0.512)	(−0.651)	(−1.860)	(−0.827)	(0.719)
BM	0.0000	0.0000	0.0003***	−0.0013	−0.0017	0.0024**
	(0.321)	(0.185)	(2.623)	(−0.948)	(−0.683)	(1.980)
Momentum	−0.0001	−0.0003	−0.0002	−0.0004	0.0096*	−0.0023
	(−0.376)	(−0.826)	(−0.840)	(−0.123)	(1.827)	(−0.805)
Illiquidity	0.8179*	0.5286	−0.0020	0.0576	−1.6483	−0.4288
	(1.746)	(1.021)	(−0.405)	(1.038)	(−0.860)	(−1.233)
Weekly lag return	−0.0090***	−0.0097***	−0.0046***	−0.0078	−0.0015	−0.0043
	(−7.568)	(−8.232)	(−3.721)	(−0.803)	(−0.065)	(−0.442)
Constant	0.0001	0.0001	0.0026*	0.0284*	0.0236	−0.0057
	(0.208)	(0.188)	(1.909)	(1.959)	(0.800)	(−0.460)
Adjusted R^2	0.130	0.151	0.149	0.444	0.376	0.416
N	756,123	724,023	440,747	369,959	468,146	468,145

Table 12: Subsample Analysis - subperiod

This table reports subperiod analysis for return predictability of OTMC and OTMP ratio. The sample period is 1996–2005 for models 1 and 2, 2006–2010 for models 3 and 4, and 2011–2014 for models 5 and 6. t-statistics are shown in parentheses below the coefficient estimates and are based on Newey and West (1987) adjusted standard errors with four-week lags. ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
	Year (1996, 2005)	Year (1996, 2005)	Year (2006, 2010)	Year (2006, 2010)	Year (2011, 2014)	Year (2011, 2014)
OTMC ratio	0.0007***	0.0004***	0.0002**	0.0003**	0.0003**	0.0003***
	(4.693)	(2.930)	(2.185)	(2.523)	(2.521)	(2.965)
OTMP ratio	−0.0012***	−0.0010***	−0.0007***	−0.0006***	−0.0001	−0.0001
	(−8.079)	(−6.282)	(−5.323)	(−5.051)	(−1.381)	(−0.875)
OS decile		−0.0000		−0.0000*		−0.0001***
		(−0.665)		(−1.658)		(−4.170)
Short interest		−0.0024		−0.0024**		−0.0014*
		(−1.495)		(−2.457)		(−1.752)
Log Size	−0.0001*	−0.0001	−0.0001*	−0.0001**	0.0000	−0.0000
	(−1.752)	(−1.477)	(−1.659)	(−2.479)	(0.097)	(−0.081)
BM	0.0000	0.0001	−0.0000	−0.0001	0.0001	0.0000
	(0.499)	(1.033)	(−0.457)	(−0.909)	(1.031)	(0.330)
Momentum	0.0003	0.0002	−0.0008	−0.0009*	−0.0000	0.0000
	(0.883)	(0.572)	(−1.620)	(−1.739)	(−0.025)	(0.040)
Illiquidity	−0.0029	0.0199*	−0.0015	0.0005	−0.0028	−0.0040
	(−0.742)	(1.739)	(−0.119)	(0.040)	(−0.465)	(−0.645)
Weekly lag return	−0.0086***	−0.0057***	−0.0014	−0.0013	−0.0002	−0.0002
	(−7.549)	(−4.403)	(−0.881)	(−0.855)	(−0.135)	(−0.146)
Constant	0.0018**	0.0015***	0.0010	0.0016**	0.0005	0.0010
	(2.521)	(2.755)	(1.225)	(2.128)	(0.641)	(1.256)
Adjusted R^2	0.080	0.102	0.063	0.070	0.060	0.066
N	989,341	728,402	1,012,663	1,012,661	868,932	868,932

Table 13: Summary statistics - Finer classification of OTM options

This table reports summary statistics of OTM volume ratios that are calculated based on finer OTM option categories. OTM options are categorized into three subgroups using the ratio of strike price to underlying stock price, K/S: An option is specified as 1) OTM(5, 10) if $0.9 \leq K/S < 0.95$ for puts and $1.05 < K/S \leq 1.1$ for calls; 2) OTM(10, 20) if $0.8 \leq K/S < 0.9$ for puts and $1.1 < K/S \leq 1.2$ for calls; and 3) OTM(20, ∞) if $K/S < 0.8$ for puts and $1.2 < K/S$ for calls. After identifying trading volume for each subgroup of OTM subgroup, OTMC and OTMP ratios are calculated separately as

$$\text{OTMC} = (\text{Trading volume of the calls in the OTM subgroup})/(\text{Total options trading volume}),$$
$$\text{OTMP} = (\text{Trading volume of the puts in the OTM subgroup})/(\text{Total options trading volume}).$$

	Number of	OTMC (5,10)		OTMC (10,20)		OTMC (20,∞)		OTMP (5,10)		OTMP (10,20)		OTMP (20,∞)	
Year	firms	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
1996	1,489	0.114	0.238	0.089	0.202	0.032	0.119	0.061	0.163	0.029	0.109	0.007	0.054
1997	1,817	0.116	0.238	0.089	0.201	0.031	0.116	0.061	0.162	0.029	0.110	0.007	0.054
1998	2,038	0.116	0.236	0.095	0.206	0.043	0.141	0.062	0.163	0.033	0.116	0.010	0.064
1999	2,098	0.121	0.235	0.110	0.214	0.054	0.151	0.062	0.158	0.038	0.119	0.015	0.072
2000	2,108	0.114	0.222	0.130	0.218	0.102	0.197	0.058	0.150	0.043	0.122	0.023	0.086
2001	1,869	0.113	0.234	0.110	0.216	0.068	0.169	0.074	0.178	0.048	0.138	0.021	0.089
2002	1,765	0.108	0.230	0.089	0.200	0.036	0.125	0.082	0.187	0.048	0.136	0.016	0.077
2003	1,670	0.105	0.227	0.066	0.173	0.017	0.085	0.084	0.186	0.042	0.124	0.011	0.064
2004	1,837	0.103	0.224	0.063	0.170	0.018	0.088	0.080	0.181	0.033	0.110	0.007	0.051
2005	1,885	0.105	0.220	0.059	0.160	0.015	0.079	0.078	0.176	0.029	0.101	0.006	0.045
2006	2,051	0.108	0.223	0.066	0.168	0.016	0.081	0.078	0.174	0.030	0.102	0.006	0.045
2007	2,160	0.116	0.229	0.076	0.179	0.021	0.092	0.085	0.183	0.034	0.109	0.007	0.047
2008	2,055	0.111	0.222	0.110	0.208	0.060	0.157	0.092	0.191	0.058	0.145	0.024	0.089
2009	1,925	0.115	0.227	0.096	0.201	0.036	0.124	0.101	0.200	0.062	0.152	0.022	0.089
2010	1,966	0.118	0.225	0.072	0.175	0.016	0.083	0.100	0.196	0.044	0.126	0.011	0.060
2011	1,987	0.121	0.216	0.080	0.177	0.022	0.095	0.102	0.188	0.050	0.130	0.014	0.068
2012	1,847	0.110	0.205	0.064	0.158	0.016	0.079	0.099	0.184	0.043	0.120	0.011	0.059
2013	2,014	0.103	0.197	0.053	0.143	0.012	0.067	0.095	0.179	0.037	0.111	0.009	0.057
2014	2,125	0.105	0.201	0.059	0.153	0.018	0.086	0.086	0.172	0.035	0.110	0.011	0.064

Table 14: Fama MacBeth - finer OTM ratios

This table presents return predictability of finely defined OTMC and OTMP ratios. OTM options are categorized into three subgroups using the ratio of strike price to underlying stock price, K/S: An option is specified as 1) OTM(5, 10) if $0.9 \leq K/S < 0.95$ for puts and $1.05 < K/S \leq 1.1$ for calls; 2) OTM(10, 20) if $0.8 \leq K/S < 0.9$ for puts and $1.1 < K/S \leq 1.2$ for calls; and 3) OTM(20, ∞) if $K/S < 0.8$ for puts and $1.2 < K/S$ for calls. After identifying trading volume for each subgroup of OTM subgroup, OTMC and OTMP ratios are calculated separately as

$$\text{OTMC} = (\text{Trading volume of the calls in the OTM subgroup})/(\text{Total options trading volume}),$$
$$\text{OTMP} = (\text{Trading volume of the puts in the OTM subgroup})/(\text{Total options trading volume}).$$

t-statistics are shown in parentheses below the coefficient estimates and are based on Newey and West (1987) adjusted standard errors with four-week lags. ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Return t+1	Return t+1	Return t+1	Return t+1	Return t+2	Return t+2	Return t+2	Return t+2
OTMC ratio (5, 10)	0.0002*			0.0004***	0.0001			0.0002**
	(1.822)			(3.631)	(0.546)			(2.246)
OTMP ratio (5, 10)	−0.0004***			−0.0005***	−0.0004***			−0.0006***
	(−2.820)			(−4.020)	(−3.120)			(−4.241)
OTMC ratio (10, 20)		0.0004**		0.0006***		0.0005***		0.0006***
		(2.536)		(3.723)		(3.075)		(3.627)
OTMP ratio (10, 20)		−0.0006***		−0.0007***		−0.0009***		−0.0010***
		(−2.721)		(−3.221)		(−4.275)		(−4.546)
OTMC ratio (20, ∞)			0.0007	0.0008*			0.0004	0.0006
			(1.594)	(1.951)			(1.088)	(1.427)
OTMP ratio (20, ∞)			−0.0018	−0.0019			−0.0027***	−0.0030***
			(−0.931)	(−1.024)			(−2.595)	(−3.111)
PC ratio	−0.0009***	−0.0008***	−0.0009***	−0.0005***	−0.0001*	−0.0001	−0.0001*	0.0002**
	(−10.274)	(−10.257)	(−11.019)	(−5.082)	(−1.935)	(−1.043)	(−1.891)	(2.447)
Log Size	−0.0001**	−0.0001**	−0.0001**	−0.0001*	−0.0000	−0.0000	−0.0000	−0.0000
	(−2.045)	(−2.045)	(−1.975)	(−1.850)	(−1.118)	(−1.104)	(−1.110)	(−0.995)
BM	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(0.417)	(0.473)	(0.652)	(0.661)	(0.720)	(0.731)	(0.661)	(0.645)
Momentum	−0.0001	−0.0001	−0.0001	−0.0001	0.0000	0.0000	0.0000	0.0000
	(−0.550)	(−0.449)	(−0.372)	(−0.244)	(0.014)	(0.029)	(0.070)	(0.226)
Illiquidity	−0.0025	−0.0026	−0.0027	−0.0027	−0.0040	−0.0039	−0.0037	−0.0035
	(−0.623)	(−0.642)	(−0.662)	(−0.661)	(−0.933)	(−0.925)	(−0.885)	(−0.832)
Weekly lag return	−0.0053***	−0.0053***	−0.0051***	−0.0048***	−0.0036***	−0.0035***	−0.0033***	−0.0031***
	(−6.640)	(−6.669)	(−6.505)	(−6.242)	(−4.645)	(−4.544)	(−4.440)	(−4.120)
Constant	0.0016***	0.0015***	0.0015***	0.0013***	0.0010**	0.0009**	0.0009**	0.0007*
	(3.363)	(3.377)	(3.354)	(2.969)	(2.137)	(2.044)	(2.094)	(1.753)
Adjusted R^2	0.074	0.076	0.079	0.089	0.073	0.075	0.078	0.089
N	2,870,936	2,870,936	2,870,936	2,870,936	2,870,893	2,870,893	2,870,893	2,870,893

Table 15: Correlation matrix among finer OTM ratios

This table summarizes the correlation among finely defined option volume ratios. OTM options are categorized into three subgroups using the ratio of strike price to underlying stock price, K/S: An option is specified as 1) OTM(5, 10) if $0.9 \leq K/S < 0.95$ for puts and $1.05 < K/S \leq 1.1$ for calls; 2) OTM(10, 20) if $0.8 \leq K/S < 0.9$ for puts and $1.1 < K/S \leq 1.2$ for calls; and 3) OTM(20, ∞) if $K/S < 0.8$ for puts and $1.2 < K/S$ for calls. After identifying trading volume for each subgroup of OTM subgroup, OTMC and OTMP ratios are calculated separately as

$$\text{OTMC} = (\text{Trading volume of the calls in the OTM subgroup})/(\text{Total options trading volume}),$$

$$\text{OTMP} = (\text{Trading volume of the puts in the OTM subgroup})/(\text{Total options trading volume}).$$

The variables are constructed from daily observations.

	OTMC (5,10)	OTMC (10,20)	OTMC (20,∞)	OTMP (5,10)	OTMP (10,20)	OTMP (20,∞)	PC	OTMPC
OTMC ratio (5,10)	-	-0.155	-0.046	-0.072	-0.065	-0.036	-0.244	-0.293
OTMC ratio (10,20)		-	-0.011	-0.088	-0.039	-0.012	-0.221	-0.324
OTMC ratio (20,∞)			-	-0.065	-0.021	0.014	-0.143	-0.221
OTMP ratio (5,10)				-	-0.067	-0.016	0.372	0.420
OTMP ratio (10,20)					-	0.023	0.252	0.301
OTMP ratio (20,∞)						-	0.128	0.167
PC ratio							-	0.582
OTMPC ratio								-

Table 16: OTMPC residual - stock return predictability

This table reports the result of Fama and MacBeth (1973) regressions of daily underlying stock returns on OTMPC residual to evaluate the persistence of return predictability. The dependent variables are the daily underlying stock returns on trading days from $t+1$ to $t+10$, where t is the trading day on which OTMPC ratio is measured. OTMPC residual is defined as the daily volume-weighted mean residual of the first-stage OTMPC regression. The first stage regression of OTMPC is designed to eliminate the effect of previous stock returns on OTMPC ratio and is conducted daily. Specifically, we regress the daily OTMPC ratio on daily return on trading days $t-1$ and t, weekly return, and the square of these three returns, and then take the value of the residual. Next, the main regression is conducted while including log firm size, log book-to-market ratio, momentum, Amihud (2002) illiquidity measure, and lagged weekly return of the corresponding firm or stock as control variables. The regression results for control variables and first stage regression results do not appear in the table. t-statistics are estimated based on Newey and West (1987) adjusted standard errors with four-week lags. ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

Day	Coeff.	t
+1	-0.0009^{***}	(-14.361)
+2	-0.0005^{***}	(-7.598)
+3	-0.0002^{***}	(-4.396)
+4	-0.0001^{**}	(-2.248)
+5	-0.0001^{*}	(-1.688)
+6	-0.0001	(-1.000)
+7	-0.0000	(-0.586)
+8	-0.0000	(-0.088)
+9	-0.0001	(-0.890)
+10	0.0000	(0.364)

Table 17: Predictability on M&A target events

This table reports the difference between OTMC and OTMP ratios of target companies and matched companies for 432 M&A cases from 1999 to 2012. Matched stocks are located in the same Fama-French 49 industries and size quintiles. M&A announcement take place in week 0. Each row displays ratio information of different weeks ranging from $t-16$ to $t+4$. OTMC and OTMP ratios are defined as the daily trading volume of out-of-the-money (OTM) calls and puts, respectively, divided by the total option trading volume in each week.

Week	OTMC target	OTMC matched	diff.	t	OTMP target	OTMP matched	diff.	t
−16	0.2395	0.2513	−0.0142	−1.1155	0.1967	0.2014	−0.0006	−0.0537
−15	0.2497	0.2500	0.0011	0.0860	0.1878	0.1952	−0.0083	−0.7518
−14	0.2487	0.2486	−0.0036	−0.2793	0.1904	0.1928	−0.0024	−0.2026
−13	0.2399	0.2385	−0.0001	−0.0110	0.1908	0.1971	−0.0065	−0.5974
−12	0.2481	0.2494	0.0003	0.0230	0.2014	0.1928	0.0062	0.5843
−11	0.2449	0.2503	−0.0051	−0.4297	0.2178	0.1952	0.0247	2.0900
−10	0.2522	0.2417	0.0140	1.1445	0.1874	0.1933	−0.0047	−0.4328
−9	0.2497	0.2461	0.0016	0.1203	0.1805	0.1927	−0.0141	−1.3217
−8	0.2633	0.2426	0.0174	1.3895	0.1850	0.1968	−0.0083	−0.8021
−7	0.2511	0.2508	0.0055	0.4398	0.1961	0.1976	−0.0001	−0.0091
−6	0.2692	0.2434	0.0261	2.1458	0.1876	0.2015	−0.0108	−0.9920
−5	0.2702	0.2489	0.0207	1.6590	0.1842	0.1964	−0.0117	−1.0722
−4	0.2701	0.2433	0.0282	2.3632	0.2040	0.1969	0.0047	0.4282
−3	0.2608	0.2408	0.0196	1.5901	0.1796	0.2025	−0.0190	−1.8259
−2	0.2687	0.2404	0.0278	2.3295	0.1842	0.2010	−0.0148	−1.4120
−1	0.2620	0.2472	0.0156	1.3202	0.1836	0.1990	−0.0164	−1.4796
0	0.2150	0.2388	−0.0214	−1.9989	0.2159	0.1992	0.0181	1.8203
1	0.2199	0.2441	−0.0258	−2.0034	0.2368	0.1991	0.0359	3.0217
2	0.2110	0.2505	−0.0371	−2.9347	0.2576	0.1975	0.0616	4.5299
3	0.2158	0.2558	−0.0355	−2.6073	0.2474	0.2005	0.0491	3.5877
4	0.2333	0.2446	−0.0111	−0.7717	0.2297	0.1970	0.0318	2.4344

Table 18: Predictability on earnings surprise

This table provides regression results of earnings surprise on OTMC and OTMP ratio. The dependent variables are SUE_{AF}, CAR(−1,1) and SUE_{ER} around earnings announcement date. SUE_{AF} is the standard unexplained earnings based on IBES reported analyst forecasts and actual EPS, which is defined as the difference between the actual and the most recent consensus EPSs divided by the stock price. CAR(−1,1) is the cumulative benchmark-adjusted return in the trading day window $(t-1, t+1)$ centered at the earnings announcement date t. SUE_{ER} is the standard unexplained earnings based on last quarters earnings, which is EPS of this quarter minus EPS of last quarter divided by its share price. Benchmark are value-weighted return of size and book-to-market quintile matched stocks. The main independent variables are daily OTMC and OTMP ratios, which are defined as the daily trading volume of out-of-the-money (OTM) calls and puts, respectively, divided by the total option trading volume on trading day t. The control variables include log firm size, log book-to-market ratio, momentum, illiquidity measure of Amihud (2002), and lagged weekly return, all of which are for trading day t. Book-to-market ratio is the book equity for the fiscal year ending in the previous calendar year divided by the market equity at the end of December in the previous calendar year. OS is the O/S ratio in Johnson and So (2012). Momentum is defined as the cumulative underlying stock return during the previous six months. Illiquidity is defined as the ratio of absolute daily stock return to daily dollar trading volume, averaged over the previous six months. Weekly lag return is the weekly raw return of underlying stock, one week lagged to the dependent variable. t-statistics are shown in parentheses below the coefficient estimates and are based on Newey and West (1987) adjusted standard errors with four-week lags. ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

	(1) SUE_{AF}	(2) SUE_{AF}	(3) SUE_{AF}	(4) CAR(−1, 1)	(5) SUE_{ER}
OTMC ratio	0.0717		0.0602	0.0049***	0.0038**
	(1.162)		(0.958)	(2.716)	(2.230)
OTMP ratio		−0.0767	−0.0681	−0.0017	−0.0011
		(−1.444)	(−1.254)	(−0.666)	(−0.618)
Log Size	−0.0096**	−0.0083*	−0.0092**	0.0006	0.0012***
	(−2.059)	(−1.883)	(−2.098)	(1.628)	(4.731)
BM	0.0580**	0.0568**	0.0576**	0.0009	−0.0016
	(2.353)	(2.327)	(2.337)	(1.327)	(−1.081)
Momentum	−0.0245	−0.0211	−0.0225	0.0015	0.0264***
	(−0.508)	(−0.432)	(−0.464)	(0.627)	(7.190)
Illiquidity	−0.7925	−0.8849	−0.7911	−0.4164*	0.3405**
	(−0.457)	(−0.486)	(−0.445)	(−1.915)	(2.465)
Weekly lag return	0.0465	0.0490	0.0425	0.0757***	0.0294**
	(0.148)	(0.157)	(0.136)	(7.133)	(2.582)
Constant	0.1741**	0.1953***	0.1877**	−0.0033	−0.0155***
	(2.571)	(2.693)	(2.624)	(−0.928)	(−4.347)
Adjusted R^2	0.018	0.019	0.021	0.029	0.052
N	49,938	49,938	49,938	51,952	51,866

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Appendix A Variable definitions

Table A1: Variable definitions

This table provides a brief description of the variables used in this study. Variables are sorted in alphabetical order.

Variable name	Description
$CAR(-1,1)$	The cumulative benchmark-adjusted return in $(-1,1)$ trading day window around earnings announcement dates.
Illiquidity	The ratio of absolute daily stock return to daily dollar trading volume, averaged over the prior six months.
Log BM	Natural logarithm of book to market ratio, i.e., book equity for the scal year ending in calendar year $t-1$ divided by the market equity at the end of December of $t-1$. Both book and market equity is calculated based on Fama and French (1993).
Log size	Natural logarithm of firm size, i.e., the number of shares outstanding times the closing price.
Momentum	The previous six month cumulative return.
OS decile	OS is the option volume to stock volume ratio as in Johnson and So (2012). OS decile is collected daily and weekly. 1^{st} (10^{th}) decile contains options with the lowest (highest) OS.
OTMC	(OTM calls trading volume) / (Total options trading volume)
OTMC (10, 20)	(OTM calls trading volume) / (Total options trading volume), for which OTM calls are calls which satisfy $1.1 <$(strike price/stock price)≤ 1.2
OTMC (20, ∞)	(OTM calls trading volume) / (Total options trading volume), for which OTM calls are calls which satisfy $1.2 >$(strike price/stock price)> 1.2
OTMC (5, 10)	(OTM calls trading volume) / (Total options trading volume), for which OTM calls are calls which satisfy $1.05 <$(strike price/stock price)≤ 1.1
OTMCS	(OTM calls trading volume) / (Stock trading volume)
OTMP	(OTM puts trading volume) / (Total options trading volume)
OTMP (10, 20)	(OTM puts trading volume) / (Total options trading volume), for which OTM puts are puts which satisfy $0.8 \leq$(strike price/stock price)< 0.9
OTMP (20, ∞)	(OTM puts trading volume) / (Total options trading volume), for which OTM puts are puts which satisfy (strike price/stock price)< 0.8
OTMP (5, 10)	(OTM puts trading volume) / (Total options trading volume), for which OTM puts are puts which satisfy $0.9 \leq$(strike price/stock price)< 0.95
OTMPS	(OTM puts trading volume) / (Stock trading volume)
PC	(Puts trading volume) / (Total options trading volume)
Weekly lag return	The weekly raw return of underlying stocks, one week lagged to depedent variable.

Table A1: Variable definitions (*cont.*)

This table provides a brief description of the variables used in this study. Variables are sorted in alphabetical order.

Variable name	Description
Short interest	Supplementary Compustat short interest.
SUE_{AF}	The standard unexplained earnings based on IBES reported analyst forecasts and actual EPS, calculated as actual EPS minus most recent consensus EPS divided by its share price.
SUE_{ER}	The standard unexplained earnings based on last quarters earnings, calculated as EPS of this quarter minus EPS of last quarter divided by its share price.
ΔCVOL	Monthly change in the implied volatility of at-the-money call with time to maturity of 30 calendar days.
ΔOTMC	Change in OTMC.
ΔOTMP	Change in OTMP.
ΔPVOL	Monthly change in the implied volatility of at-the-money put with time to maturity of 30 calendar days.