AN INVESTIGATION OF STOCK AND OPTION MARKETS, AND THEIR INTERACTIONS

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A dissertation submitted to the

Graduate School-Newark

Rutgers, The State University of New Jersey

In partial fulfillment of requirements

For the degree of Doctor of Philosophy

Graduate Program in Management

Written under the direction of

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May, 2015

ABSTRACT OF THE DISSERTATION

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My dissertation comprises of three essays: 1) Large price changes and subsequent returns; 2) Using option implied volatilities to predict absolute stock returns: Evidence from earnings announcements and annual shareholders' meetings; and 3) How do short-sale constraints affect options trading? Evidence from Regulation SHO.

The first essay investigates whether large stock price changes are associated with short-term reversals or momentum, conditional on analyst price target or earnings forecast revisions immediately following these price changes. We find momentum when analysts issue revisions after large price shocks, suggesting that the initial price changes were based on new information. In contrast, when price changes are not followed by immediate analyst revisions, we document short-term reversals, indicating that the initial price shocks were caused by liquidity or noise traders. A trading strategy based on the direction of the price change and analyst revisions earns significant abnormal monthly returns (over 1 percent).

The second essay provides evidence that an option implied volatility-based measure predicts future absolute excess returns of the underlying stock around earnings announcements and annual meetings of shareholders. Our results imply that option traders anticipate the change in uncertainty and trade on the expected volatility around these scheduled events. We also show that net straddle returns (after transaction costs) are significantly and negatively related to the predicted volatility of returns around the events, suggesting that the option writers expect to be compensated for the predicted volatility.

The third essay investigates the effect of stock short-sale constraints on options trading by exploiting two SEC rules under Regulation SHO: Rule 203(locate and close-out requirement) and Rule 202T (temporary removal of short-sale price tests for pilot stocks). We find a significant decrease in short interests of stocks after Rule 203, and a significant increase in short-sale volume of pilot stocks after Rule 202T, supporting the validity of Rule 203/Rule 202T as exogenous increase/decrease in short-sale constraints. After Rule 203, options volume increases significantly, especially among firms with low institutional ownership and low option bid-ask spread. However, we find no significant changes in the option trading volume of pilot stocks (relative to control stocks) after Rule 202T.

ACKNOWLEDGEMENTS

This dissertation would not have been possible without the help of my committee members and professors I have worked with. First of all, I would like to give special thanks to my advisor Dr. Suresh Govindaraj. I learn how to be a serious researcher from you. I am very grateful for your continuous trust, support and patience. I also want to thank Dr. Joshua Livnat. You are a mentor to me and give me a lot of confidence in the early stage of my research. Your academic spirits (diligence, modesty, passion etc.) will always inspire me. I would like to thank Dr. Divya Anantharanam. You are one of the best professors I have ever met. You gave me valuable advice on research, teaching and life. Talking and working with you is such a pleasure. I am indebted to Dr. Dan Palmon. As the department chair, you gave me a lot of support, which I truly appreciate. I am also grateful for the patient guidance, encouragement and trust from Dr. Zhaodong Zhong. Your help is vital in my academic career. Finally, I want to give special thanks to Dr. Jianming Ye. Thank you for introducing me to this doctoral program and all the efforts you have made.

The five years it has taken to complete my dissertation has required support that extends beyond research. I am indebted to my parents, grandparents and friends. Your love and care motivate me every day.

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ESSAY 1: Large Price Changes and Subsequent Returns

1. Introduction

A natural question when observing large changes in equity prices is are these changes driven by new information, or whether they are just a temporary aberration caused by noise or liquidity trades. If the latter is true, these large price moves will likely be followed by corrections and price reversals in a relatively short period of time. On the other hand, if these moves are caused by new information, equity prices are unlikely to display the same pattern of corrective price reversals, and may be followed by momentum (if the initial price changes underreact to new information).A related question is whether such large price swings can be used to predict future equity returns, and whether it is possible to construct portfolio strategies that earn abnormal returns based on observing large price shocks. We explore these two questions in this study.

To determine whether large price swings in equity prices are caused by new information, we use the immediate reactions by analysts following these firms. We conjecture that if analysts become aware of new information that is driving the price swings, they will communicate this information by revising either their earnings forecasts or future (one-year ahead) target prices of equity, or both. Otherwise, we would expect to see no analyst revisions. We find that, by and large, the majority of large price changes are not followed by immediate analyst revisions. In instances when revisions occur, they are more likely to be in the same direction as the price swing; that is, positive (negative) large price swings trigger positive (negative) earnings forecast or target price revisions. Furthermore, consistent with prior literature, analyst revisions are more prevalent when trading volumes around the price swings are high. We also find that the direction of the drift in future equity prices is consistent with the direction of analyst revisions. Relying on Dow Jones articles, Key developments database and Forms 8-K to identify information events, we verify that large price changes and associated analyst revisions are indeed caused by new information. Contrary to the typical findings in the extant literature of short-term reversals, we find that, in general, stock returns continue to be negative after large price decreases.

To determine if we can use the combined information in the initial price shocks and immediate analyst revisions to construct a trading strategy, we take long positions in stocks with large daily price increases and immediate positive analyst revisions, and short positions in stocks with large daily price decreases and immediate negative analyst revisions.[1] We find significant positive abnormal returns for this strategy (relative to returns on similar stocks in terms of size, book-to-market ratio, and prior momentum), implying that the initial large price changes and/or the analyst revisions were incomplete.

Our study improves our understanding of the role of information in causing major movements in stock prices. It shows that most large return days are probably not associated with significant new information (at least significant enough to warrant analysts to revise their forecasts). This result contributes to the academic literature which relies on large return days to proxy for the arrival of new information (see, e.g., Jin, Livnat, and Zhang 2012). We also document the crucial impact of new information on post-event performance, confirming and extending some prior studies (Chan 2003; Savor 2012). Our study is very relevant for practitioners and investors. We show how to take advantage of

[1] We also provide results for a similar strategy but with the addition of abnormal volume as a conditioning variable in portfolio construction, as volume is a potential indicator of investor attention. For example, Lee and Swaminathan (2000) show that high volume is associated with positive future returns.

new information contained in large return days when it is confirmed by immediate subsequent earnings forecast or target price revisions, and also point out those large price swings that tend to experience reversals. In addition, we find that short-term reversals are far less likely for large negative-return days than for large positive-return days, especially when not accompanied by analyst forecast revisions.

The next section briefly discusses prior work in this area. Section 3 provides details about our sample and research design. Section 4 shows our results and sensitivity analysis. Section 5 concludes.

2. Prior Literature

Many studies explore the behavior of returns after significant stock price movements. Most find evidence of price reversals following large price changes (Atkins and Dyl 1990; Bremer and Sweeney 1991; Cox and Peterson 1994; Bremer et al. 1997). However, others provide support for return continuation (Schnusenberg and Madura 2001; Lasfer et al. 2003). All of these studies are only focused on shocks of a given magnitude and are not linked to information causing the price shock.

There are also some studies that examine price reversal and momentum after large stock price swings conditional on the existence of public information. One such study by Pritamani and Singhal (2001) shows that it is possible to earn abnormal returns from a strategy based on multiple signals including large price changes, trading volume, and whether there was public information in the news media accompanying the price changes. However, the study does not focus on the magnitude of price changes, and does not use analysts' earnings and target price forecast revisions. Chan (2003)uses news headlines as a proxy for information, and documents drift following price moves accompanied by news, and reversals for moves accompanied by no news (his findings are strongest for negative price events). His research design does not directly incorporate analyst revisions.

The closest study to ours is Savor (2012), which focuses on firms that experience significant price moves and are actively covered by analysts. It then examines subsequent stock returns depending on whether analysts issue (or restate) their recommendations in the period surrounding the large price swing, using these recommendations as a proxy for new information. His findings are very similar to ours, documenting momentum after price shocks accompanied by information, and reversals otherwise. As in this study, momentum occurs only when the direction of the price move and of the change in analyst recommendations have the same sign.

We believe that our research design is potentially more general than Savor (2012), because it uses earnings forecast or price target revisions. As Feldman, Livnat, and Zhang (2012) show, there are about ten times more earnings forecast revisions than recommendation revisions, and over three times more target price revisions than recommendation revisions. Thus, requiring recommendation revisions immediately around significant price changes may omit many cases of significant information that resulted in earnings forecast or target price revisions, but not in recommendation revisions. Second, suppose there was a significant price increase due to new positive information. An analyst with a "buy" or "strong buy" recommendation may have no reason to revise that recommendation. However, this information may be more likely to cause an upward earnings forecast or a target price revision. Similarly, suppose an analyst has a "sell" recommendation on a firm that has just released significant negative information that caused a significant negative price change. The analyst will have little motivation to revise the prior recommendation, but will have a higher likelihood of revising downwards the prior earnings or target price forecasts. Finally, our monthly calendar time tests are more similar to decision making of long-term investors who perform infrequent balancing of their portfolios. Savor's daily rebalancing is more suitable for higher-frequency traders and is likely to incur higher transaction costs.

A focal point of our study, as well as in Savor (2012), is the information provided to the market through equity analysts. There exists a vast literature showing analysts' earnings forecasts to be informative (see, e.g., Feldman et al. 2012 for a short summary). It has also been shown that target price revisions provide information to investors (Brav and Lehavy2003; Feldman et al. 2012;Da and Schaumburg 2011). While Gleason, Johnson, and Li (2012) show a positive association between earnings forecast accuracy and target price target, Feldman, Livnat, and Zhang (2012) find that analysts' target price revisions combined with earnings forecasts jointly provide even more information to investors. Thus, actions of financial analysts, by way of earnings forecast or target price revisions, are perceived by market participants to be driven by new information, and are typically associated with drift returns. Consequently, we use these revisions immediately after large price swing days to highlight potentially new information that market participants can use.

3. Sample and Research Design

The sample period in our study ranges from1982 to 2011 for earnings forecast revisions, and from 1999 to 2011 for target price revisions. We designate Day 0 as a "large return day" when a common stock yields returns of 5% or greater or -5% or less in a single day.[2]These stocks are selected from the *Center for Research in Security Prices* (CRSP) database. In addition, we impose the following additional criteria in selecting our: (1) We select only those firms whose market value exceeds $100 million on the large return day. This ensures that highly volatile small firms are excluded from our sample; (2) To avoid the problem of confounding events, we require that two adjacent large return days for a given firm are not within five days of each other. In some analyses, we separate stocks that experience high trading volume (defined as volume greater than 1.1 times the average trading volume over the prior 45 days) on a large return day from those that had low (normal) volume.

To investigate whether significant price swings are caused by new information, we examine whether analysts revise their earnings forecasts or target prices on or within five days after the price event.[3]We obtain earnings forecast and target price data from the Institutional Brokers' Estimates System (IBES) database. For a firm to be included in our sample, we require that the firm has analyst coverage during the 12 months prior to the large price swing. We compare an analyst's forecast of annual earnings and one-year-ahead stock price target, announced on or within five days after the large price move day, with the same analyst's prior forecast for the same period and the same company. If the forecast following a large price swing is higher (lower) than the prior one, we label it is a positive (negative) revision. A typical firm is usually followed by more than one analyst. Therefore,

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[2] As described in the data robustness sub-section, we also use 7%and 10% as cut-offs for large price changes and obtain similar results. Additionally, we condition the definition of a large price change on prior stock return volatility (computed over a 180-calendar-day window), studying only stock price changes that exceed a two-standard-deviation threshold. Our results hold for this definition as well.

[3] We obtain similar results when we use a longer window of ten days after the initial price change.

if a majority of analysts covering the firm with a large price swing revise upward (downward), we classify the analysts' collective response as a positive (negative) revision.[4]

Next, we investigate the market reaction subsequent to the large price swing. We examine both the short-term excess return[5] for days in the window ([+1, +5]), where Day 0 is the date of the large stock price move, and the longer-term excess returns across different windows following Day +5([+6, +30], [+6, +60] and [+6, +90]). We use the windows from six days onward because we use analyst forecasts during days zero through five as an indication of new information released to the market that caused the significant price swing on Day 0(or lack thereof). Excess return is calculated as the buy-and-hold return over the designated window minus the average buy-and-hold return on a portfolio of stocks with similar size (2 groups), book-to-market ratio (3 groups), and momentum (3 groups).We also cross-tabulate results for short- and long-term post-event returns for firms experiencing large price increases and decreases, and examine how analyst forecast revisions affect the these returns. We then perform regression analysis to ensure that our results are not driven by confounding factors.

Based on the above results, we build various calendar-time monthly trading strategies designed to capture positive abnormal returns. Specifically, at the end of each calendar month, we construct portfolios consisting of long and short positions. We identify firms with large price swings and immediate analyst forecast revisions that occur during the calendar month but prior to the last day of the month. We hold the portfolio for one month

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[4] We also use the average magnitude of analyst revisions to determine whether the revision was positive or negative,and the results were very similar.

[5] Excess returns in this study refer to raw buy and hold returns minus the average buy and hold returns on a portfolio of firms with similar size, Book to Market and momentum characteristics.

and then rebalance. To ensure sufficient diversification, we require at least 15 stocks for both the short and long sides of the portfolio, otherwise that month is excluded from our analyses

4. Results

4.1 How do analysts respond to large price swings?

Table 1 shows the frequency of earnings forecast revisions following large price increases (>=5%) or decreases (<=-5%). We focus on the annual earnings forecast revisions. After observing large price swings, an analyst can either issue a forecast higher or lower than their earlier one, or choose not to issue any new forecasts.

Panel A shows that during the 1982-2011 period there are 722,688 large return days. Only 21.91% of the observations have their earnings forecasts revised on or within five days after the day of the large price swing.[6] This shows that analysts usually do not respond to large price changes with forecast revisions. Additionally, if they do respond, analysts tend to revise in the same direction as the price change; i.e., when there is a large price increase (decrease), analysts tend to revise the earnings forecast upward (downward).

To investigate whether the earnings forecast revision is related to trading volume on the large return day, we next divide the sample into two groups based on trading volume. Panel B shows the frequency analysis for earnings forecast revisions for the group with high trading volume on the large price swing day (defined as above 110% of the average volume in the prior 45 days). Panel C shows similar analysis for the group with low trading

[6]When we extend the window of analyst revisions to ten days after the initial price change, the percentage of price changes followed by earnings forecast revisions increases to 32%. Thus, over two thirds of the large price changes are still not followed by analyst revisions, even over this longer period.

volume. As is evident from Panels B and C, when trading volume is high on a large price swing day, analysts are more likely to revise their earnings forecast (25.89% of the time) relative to low-trading volume days (15.84 % of the time).

[Insert Table 1.1 here]

We conduct similar analysis for target price revisions. Table 2 shows the frequency analysis for target price revisions following large price increases (>=5%) or decreases (<=-5%). During the 1999-2011 period, there are 444,164 high return days.[7] Of these, 18.21% are followed by target price revisions on or within five days after the large price swing. This is lower than the percentage of earnings forecast revisions, and is consistent with Feldman, Livnat, and Zhang (2012), who document significantly more earnings forecast revisions than target price revisions. As is the case with earnings forecast revisions, analysts are more likely to revise the target price when trading volume is high.

[Insert Table 1.2 here]

Overall, we find that only a small proportion of all large return days are associated with analyst earnings forecast or target price revisions, indicating that a majority of these events may not be driven by significant new information about the firm.[8]

[7] IBES began providing target price information in 1999, so the sample reported in Table 2 spans the years 1999 to 2011.

[8] Earnings forecast revisions are more likely to occur immediately after earnings announcements, which, in turn, can also be associated with large price changes. In our sample of large price changes, only 8% of the days coincided either with the day of earnings announcements, or the day after the earnings announcement. Excluding those large price change days does not change our findings.

4.2 Large price swings, analyst forecast revisions, and subsequent returns

Panel A in Table 3 shows short-term and long-term returns after a large price swing during the 1982-2011 period. A breakdown of these post-event returns is provided for price moves that are associated with abnormal volume and those without. Contrary to the typical findings on short-term reversals, we find that after a significant drop in price, there is a short-term bounce-back in the five days immediately afterwards, but then it reverses and price declines continue for the next 30, 60, and even 90 days. Note, however, that when the initial price decline is associated with high volume, the subsequent drift returns are less negative on average than when price declines are associated with normal volume. This is consistent with the hypothesis that lower trading volumes indicate less investor attention, leading to more post-event drift.

In contrast, after a significant increase in price, we document reversals both over the short- and the long-term, irrespective of whether volume at the time of the initial price swing was high or low. Therefore, we show that price reversals are more likely after large positive returns, but not after large negative returns. This result is consistent with the existence of short-selling constraints, which may make it harder for arbitragers to immediately counteract price increases than price decreases.

To check that the return patterns documented in Panel A are not caused by confounding factors, we now estimate the following empirical model:

$$XRET_{m,n} = \alpha + \beta_1 Dret_0 + \beta_2 Down + \beta_3 Dretdown + \beta_4 Dmve + \beta_5 Dbm + \beta_6 Dmom + \beta_7 Dvol + \varepsilon$$

where,

$XRET_{m,n}$: the buy-and-hold return for a stock over a designated window [m,n] minus the average buy-and-hold return on a portfolio of stocks of similar size, book-to-market ratio, and momentum.

$Dret_0$: the decile of raw return on the large price swing day.

Down: a dummy variable, which is equal to 1 if the stock return on large swing day is negative and 0 otherwise.

Dretdown: *$Dret_0$* multiplied by *Down*.

Dmve: the decile of market value of equity.

Dbm: the decile of book to market ratio.

Dmom: the decile of momentum, which is defined as the buy-and-hold return during the previous 12 months (t-12 through t-1).

Dvol: the decile of trading volume on the large price swing day.

We conduct our analysis using deciles to mitigate the influence of outliers on our results. We rank variables within each quarter into deciles (0-9), divide by 9, and subtract 0.5. Thus, each decile variable has a value between -0.5 to 0.5 and the coefficients of decile variables provide an estimate of the return differential between firms that are in the bottom and top deciles. We estimate coefficients and standard errors using quarterly Fama-MacBeth regressions.

In Panel B in Table 3, the negative and significant coefficient on *$Dret_0$* implies large price increases are followed by reversals. In contrast, the coefficient on the interaction term *Dretdown* is significant and positive, which further confirms that price reversals occur after large positive returns, but not after large negative returns. Additionally, the sum of the coefficients on*$Dret_0$* and *Dretdown* is positive, suggesting there is actually a negative drift after large price decreases, rather than reversal, as is the case after large price increases.

[Insert Table 1.3 here]

Next, we explore the impact of earnings forecast revisions on returns after large price swings. As mentioned earlier, analysts may choose to revise their earnings forecasts in the direction of the initial price swing or in the opposite direction. Panel A in Table 4 shows that, consistent with prior findings about the effects of earnings forecast revisions on stock prices (see, e.g., Feldman et al.2012), when analysts revise earnings forecasts upwards the average drift is positive, and the opposite is true for downward revisions. However, the panel reveals an additional interesting phenomenon. When the initial large price swing is negative, and analysts revise their earnings forecasts upwards, the return from that point onwards is positive and significant. This suggests that market participants tend to value analyst pronouncements more than the information, if any, conveyed by the initial price decline. Additionally, when a large price move is not accompanied by immediate earnings forecast revisions, we document reversals after large price increases, and downward drift after large price decreases. This is consistent with the findings in Table 3. Panel B replicates the results in Panel A when we rely on analyst target price revisions instead of earnings forecast revisions, and shows the results are very similar.

[Insert Table 1.4 here]

As discussed earlier, volume may represent a proxy for investor attention, which could impact post-event return patterns. Consequently, we now examine whether trading volume can strengthen our results above. Panel A in Table 5 shows that when analysts revise their earnings forecast upwards (downwards) after an initial large price increase(decrease), stock returns exhibit positive (negative) drift, and this effect is stronger for large price increases (decreases) accompanied by high (low) volume. Panel B in Table 5 documents similar findings for target price revisions. These results confirm that trading volume on the large return day has a significant impact on post-price shock returns.

[Insert Table 1.5 here]

As before, to ensure that the impact of analyst forecast revisions on returns following large price changes is not driven by confounding factors, we estimate the following regression:

$$XRET_{m,n} = \alpha + \beta_1 Dret_0 + \beta_2 confirm + \beta_3 Dretconfirm + \beta_4 conflict + \beta_5 Dretconflict$$
$$+\beta_6 Dmve + \beta_7 Dbm + \beta_8 Dmom + \beta_9 Dvol + \varepsilon$$

where,

$XRET_{m,n}$: the buy-and-hold return for a stock the designated window [m,n] minus the average buy-and-hold return on a portfolio of stocks of similar size, book-to-market ratio, and momentum.

$Dret_0$: the decile of raw return on the large price swing day.

Confirm: a dummy variable that takes the value of 1 if analysts revise earnings forecasts or target prices in a manner consistent with the initial large price change and 0 otherwise.

Dretconfirm: *$Dret_0$* multiplied by *confirm*.

Conflict:a dummy variable that takes the value of 1 if earnings forecast or target price revisions are in the opposite direction to the initial large price change and 0 otherwise.

Dretconflict: $Dret_0$ multiplied by conflict.

Dretdown: $Dret_0$ multiplied by Down.

Dmve: the decile of market value of equity.

Dbm: the decile of book to market ratio.

Dmom: the decile of momentum, which is the buy-and-hold return during the previous 12 months.

Dvol: the decile of trading volume on the large price swing day.

In Panel A in Table 6, the coefficient on $Dret_0$ is negative, which implies that on average there is return reversal after the initial large price change when it is unaccompanied by earnings forecast revisions. However, when initial price shocks are followed by earnings forecast revisions in the same direction, we find evidence of drift, as the sum of coefficients on $Dret_0$ and *Dretconfirm* is positive. If analysts revise earnings forecasts in the opposite direction to initial price changes, we find stronger reversal than in the case with no revisions, as evidenced by the negative and significant coefficient of *Dretconflict*. Panel B in Table 6 documents similar findings for target price revisions, though the impact of target price revisions on future returns is weaker than that of earnings forecast revisions.

[Insert Table 1.6 here]

Overall, we find that we can predict subsequent returns following large price shocks better if we condition on whether analysts revise earnings forecasts or target prices in a manner consistent with the initial price change.

Before proceeding to examine a trading strategy based on the above findings, we verify that large price changes and associated analyst revisions are indeed caused by new information. We follow Chan (2003), who uses media news stories about companies to identify information events.[9]

We rely on three different sources to identify informative events. The first is the Dow Jones (DJ) articles on firms during the years 1997-2011. We use DJ stories that have at least 20 words. Prior to the year 1997, the number of stories captured in the database is significantly smaller, so our analysis spans the years from 1997-2011 period. The second is the Key Developments dataset compiled by Capital IQ, which is available from the year 2002. Key Developments refers to a dataset compiled by Capital IQ. The dataset includes many types of events that affect firms, including earnings announcements, major customer and product announcements, board membership or key executive changes, M&A, dividend changes, etc. The data coverage is spotty prior to 2002, so we use it only for the 2002-2011 period.[10] The third is the original Form 8-K filed by companies since the year 2004.The SEC requires firms to file a Form 8-K whenever they experience a material event that falls into several defined categories. Covered events include material definitive contracts, bankruptcy, earnings announcements, board and key executive changes, auditor changes,

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[9]We thank an anonymous reviewer for suggesting this analysis.

[10]Livnat and Zhang (2012) also use this dataset to claim that over 75% of all earnings forecast revisions are due to public information released by firms prior to the forecast revisions.

restatements, etc. In 2004, the SEC expanded the required categories, and promulgated faster filings after the events. Thus, our data, which is based on the S&P Filing Dates database, is limited to the 2004-2011period.

For each of these sources, we examine whether there is public information released during the period [-1, +5], where Day 0 is the large price change day. Since our analyst revision measures are released during the interval [0, +5], we are attempting to capture public information that was disclosed in the relevant period, causing either the large price change or the analyst revision (or both).

Panel A of Table 7 shows the probability of news releases from Dow Jones, Key Developments, and Form 8-K (in the window [-1, +5] relative to the large price change day, Day 0) conditional on whether there are earnings forecast or target price revisions in the window [0,+5]. As one can easily see, when there are analyst revisions, the probability of public news about the firm being released is roughly twice as high compared to the case with no analyst revisions. For example, at least one Dow Jones story comes out for 70% of large price changes associated with analysts' earnings forecast revisions, but only for 38% of large price changes without earnings revisions. The probability of observing such percentages if forecast revisions were indeed random and equally likely are extremely small (less than 0.0001 according to the Chi-Square statistical test).

Panel B of Table 7 repeats the analysis in Panel A, after excluding large price changes that occur simultaneously with earnings announcements (about 40% of analyst revisions occur after earnings announcement). The percentage of firms with some form of public news when analysts revise their earnings forecasts or price targets drops for this case, but is still above 60%, and almost twice as high as when analysts do not revise. Thus, our results remain intact when we exclude earnings announcements.

[Insert Table 1.7 here]

Given these findings, we conclude that analyst revisions in our sample are indeed much more likely to be associated with new information about the company that is released during the same period.

4.3 Trading strategy and portfolio returns

In this sub-section, we test whether the previous findings can lead to a profitable trading strategy. To make our analysis meaningful for practical applications, we use a calendar-time monthly portfolio approach.

Specifically, at the end of each calendar month we construct our portfolios of long and short positions, which are held for one month until the next rebalancing. We identify firms with large price swings and immediate analyst forecast revisions that occur during the calendar month but prior to the last day of the month.[11] This ensures that on the last day of the month we can actually form our portfolios using available information about daily returns, trading volume, and analyst forecast revision as of that day. We hold long positions in stocks with large daily price increases and immediate positive earnings forecast or target price revisions. We hold short positions in stocks with large daily price decreases and immediate negative target price or earnings forecast revisions (this strategy is referred as Strategy 1 hereafter).The resulting portfolio is held for a month. To ensure sufficient diversification, we require at least 15 stocks for both the short and long sides of the

[11] Since we focus on analyst revisions in days 0 through 5, the large price move must have occurred at least six days prior to month-end.

portfolio. Excess return is calculated as the buy-and-hold return on a portfolio stock minus the average buy-and-hold return on a portfolio of stocks with similar size, book-to-market ratio, and momentum characteristics. Additionally, as Table 5 shows that trading volume can strengthen our results, we analyze excess returns of portfolios constructed on information about large price moves, trading volume, and analyst forecast revisions.

Table 8 provides information on the average monthly excess return for various trading strategies. Panels A and B report the results for earnings forecast and target price revisions, respectively. For the case of earnings forecast revisions (Panel A), the average monthly excess return to Strategy 1 is 1.17% (t-stat=8.06) during the 304 calendar months from 1982 to 2011 with enough securities on each side of the trading strategy. The average number of long and short positions in each monthly portfolio is 141 and 154, respectively. With respect to target price revisions (Panel B), the average monthly excess return to Strategy 1 is 1.09% (t-stat=4.42)during the 148 calendar months from 1999 to 2011, with 191 long and 171 short positions on average.

When we also use trading volume in constructing our portfolios, conditioning on high volume for long positions and low volume for short positions, we obtain higher portfolio returns. As shown in Table 9, the trading strategy based on large price change, trading volume, and earnings forecast revisions in Panel A (target price revisions in Panel B) yields a monthly excess return of 1.52% (1.79%).

The above results show the profitability of trading strategies based on both large price change and subsequent analyst forecast revisions. To test whether analyst forecast revisions provide incremental value in constructing a hedge portfolio beyond the large price move itself, we construct a portfolio composed of stocks with large price change and no immediate analyst revisions, which is used as a benchmark portfolio. Specifically, we take long positions in stocks with initial large price decreases and no subsequent analyst revisions and short positions in stocks with initial large price increases and no subsequent analyst revisions. This strategy is referred to as Strategy 2, and represents a pure reversal strategy.

Next, we next examine the value of analyst forecast revisions in two cases: one when analyst forecast revisions are in the opposite direction to the initial price change, and the other when analyst forecast revisions are in the same direction as the initial price change. In the first case, we take long positions in stocks with large price decreases and no subsequent analyst forecast revisions or positive analyst revisions. We take short positions in stocks with large price increases and no subsequent revisions or negative analyst revisions. This strategy is referred as Strategy 3. It is intended to compare the returns on a pure reversal strategy (with no analyst revisions) to one that combines a pure reversal strategy with cases where analysts revise in the opposite direction of the original large price swing. If there is any value to the conflicting analyst revisions, Strategy 3 should yield significantly larger returns than Strategy 2.

In the second case, we take long positions in stocks with large price increases and subsequent positive analyst forecast revisions and stocks with large price decreases not followed by subsequent revisions. We take short positions in stocks with large price decreases and subsequent negative analyst forecast revisions and stocks with large price increases not followed by subsequent revisions. This strategy is referred as Strategy 4. It is a combination of a pure reversal strategy (Strategy 2) with the information-driven strategy (Strategy 1). Panel A in Table 8clearly shows the value of earnings forecast revisions in constructing portfolios after large price swings. We find that the pure reversal trading strategy (Strategy 2), which does not take into account any analyst forecasts, yields an average monthly excess return of 0.29%, much lower than Strategy 1, where analyst revisions confirm the initial price swing. Similarly, Strategy 2 is inferior to both trading Strategies 3 and 4, which use analyst revisions and yield an average monthly excess return of 0.43%.

If trading volume is also taken into consideration when constructing the portfolio strategies, then, as shown in Panel A in Table 9, Strategy 2 yields an average monthly excess return of 0.21%, while trading Strategies 3 and 4 yield an average monthly excess return of 0.69%and 0.76%, respectively. Similar findings are documented for target price revisions (Panel B).

[Insert Table 1.8 here]

[Insert Table 1.9 here]

In summary, the trading strategies based on both large price swings and analyst forecast revisions are profitable and yield higher excess returns than a pure reversal strategy, especially when analysts confirm the direction of the initial price swing. Also, we can use trading volume to strengthen portfolio results. Thus, analyst revisions immediately after an initial large price shock can help distinguish cases of information-driven price changes, which are expected to be associated with momentum, from no-information price changes, where reversals are more likely to occur.

4.4 Sensitivity and robustness analysis

1. We check whether our main results hold in different time periods, among firms of different sizes, as well as firms with different book-to-market ratios. Overall, we find that our results are indeed robust across all these three dimensions. Specifically, we find for all three dimensions that:

a. In general, price reversals are more likely for initial large positive returns, but not for initial large negative returns;

b. When analysts revise forecasts (target price and/or earnings) upwards immediately after a large price increase, we observe continued positive drift return;

c. When analysts revise forecasts (target price and/or earnings) downwards immediately after a large price decrease, we observe continued negative drift returns;

d. Our calendar time monthly portfolio strategy is profitable and produces positive excess returns. However, it is more profitable in the early periods of our sample, among firms with small size (like most anomalies), and high book-to-market ratios.

2. We repeat the analysis after excluding the years 2001 and 2008, which had potentially more large negative daily returns for many firms. Indeed, these two years had about 12% of our sample observations, about twice the average number of annual observations in our sample. Our results are unchanged for the remaining years, and are essentially unaffected by the recent financial crisis. Also, Strategy 1 returns, which in Panel A in Table 8 yields average monthly returns of 1.17%, shows returns of 1.31% when 2001 and 2008 are omitted.

3. To mitigate concerns about industry-wide (or market-wide) news that may have affected the entire industry rather than a specific company, we have excluded all

observations where there are more than three firms from the same 4-digit SIC industry on the same date. Our main conclusions remain unchanged, and Strategy 1 average monthly returns increase to 1.31%.

4. We exclude from the sample all large price changes on days that coincided either with the day of an earnings announcement or the day after. This excludes about 8% of our sample observations. Implementing Strategy 1 yields average monthly return of 1.13% for the earnings forecast revisions compared with the 1.17% in Panel A in Table 8.

5. We repeat the analysis when we define a large price change as one where the daily return is more than two standard deviations from the firm's normal return in the prior 180 days (with a minimum of 90 trading days). This screen decreases our sample size by7.6%. While for Strategy 1 average monthly return changes slightly from 1.17% to 1.10%for the earnings forecast revisions, the main results remain intact.

6. Given that most anomalies are less powerful for large companies than small companies, we repeat the trading strategies in Section 4.3 by using value-weighted returns. The average monthly portfolio return indeed drops from 1.17% for Strategy 1 to 1.00%, but still economically and statistically significant.

7. Figure 1a and 1b portrays the annual returns of the long positions implied by Strategy 1 (invest in firms that had large price increases and subsequent positive revisions) for the earnings forecasts and the target price revisions. As can clearly be seen in the graphs, for most years the returns are positive, and when they are negative the magnitudes are really small (except for 1987 when earnings forecast revisions are used). We use long positions in the graph to abstract from short constraints and costs.

8. The cumulative returns on the returns of the trading Strategy 1 are provided in Figures 2a and 2b. They show that the hedge returns are driven more strongly by the short side of the strategy, and the long side is much less volatile. The figures portray a pattern of relatively smooth increasing returns for both sides of the strategy in most periods, and do not seem driven by any outlying months.

5. Conclusions

This study investigates whether large daily price moves are indicative of the arrival of new information, and whether subsequent returns exhibit reversals or drift. If large price changes occur due to aggressive trading by liquidity or noise traders, one should expect that subsequent returns will exhibit reversals. In contrast, if a large price move occurs due to new information and if the initial price reaction does not completely reflect this new information, one should expect to observe post-event momentum. To assess whether new information may have caused the initial price shock, we use as proxies analyst earnings forecast or target price revisions immediately after the price event.

We find that only a relatively modest proportion of all large price changes are followed by analyst forecast or target price revisions, and that this proportion increases when the initial price change is associated with a higher than usual volume. We also find that when analysts do revise either their earnings or target price forecasts, the revisions are more likely to be in the same direction as the original price change. Contrary to the short-term reversal literature, we find that reversal typically occurs after initial large price increases, but not after initial large price decreases. We also find that large price moves associated with high volume have subsequent higher excess returns.

The main findings of our study are that, contrary to the short-term reversal literature, when analysts revise immediately after a large price swing in the same direction as the price swing, subsequent excess returns actually show momentum. This suggests that the original price move probably was due to new information that was not completely impounded in prices. We find that a trading strategy based on this information (i.e., the initial direction of the price move and the confirming analyst revisions) can generate significant excess returns of over 100 basis points per month before transaction costs. Our results are stronger for smaller firms and for value firms.

Our work has implications for both academics and practitioners. Academics who want to identify potential days when new information arrives in the market place cannot simply rely on days when stock prices change significantly. Many such price swings may simply be caused by noise or liquidity traders. Investors, who wish to rely on an incomplete market reaction to new information as a basis for a trading strategy, can do so by focusing on large price moves that are followed by analyst revisions in the same direction. Such a strategy yields significant abnormal returns. Value investors who may be attracted to stocks that have recently suffered from large price declines may actually do better if they avoid firms where analysts revised their forecasts downwards after the initial price declines. Similarly, shorting or underweighting securities with large price increases may backfire if analysts revise their forecasts upwards immediately after the initial price increase.

Figure 1.1a:Annual abnormal returns (compounded monthly) for the long position in Strategy 1 using earnings forecast revisions.

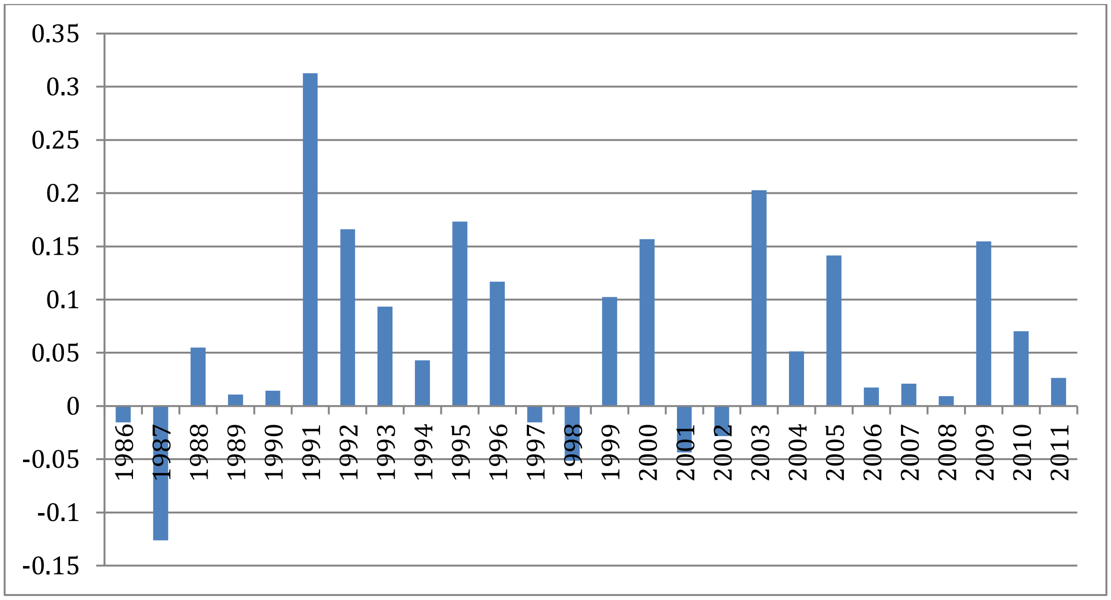

Figure 1.1b: Annual abnormal returns (compounded monthly) for Strategy 1 using target price revisions

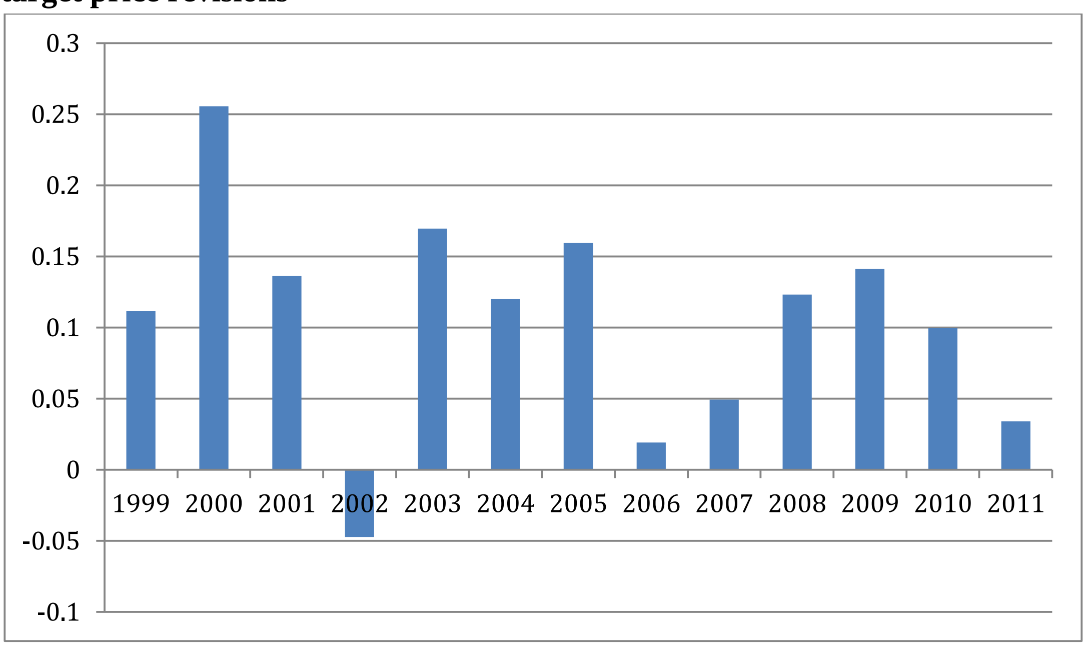

Figure 1.2a: Cumulative abnormal returns (compounded monthly) for the long position in Strategy 1 using earnings forecast revisions

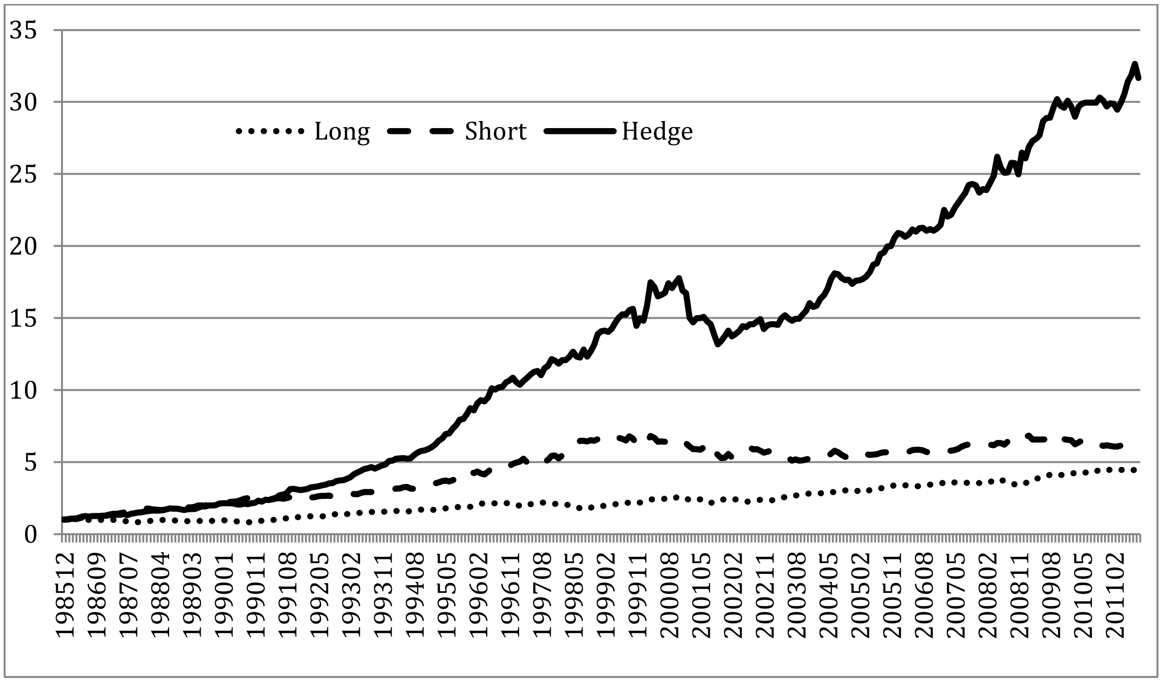

Figure 1.2b: Cumulative abnormal returns (compounded monthly) for Strategy 1 using target price revisions

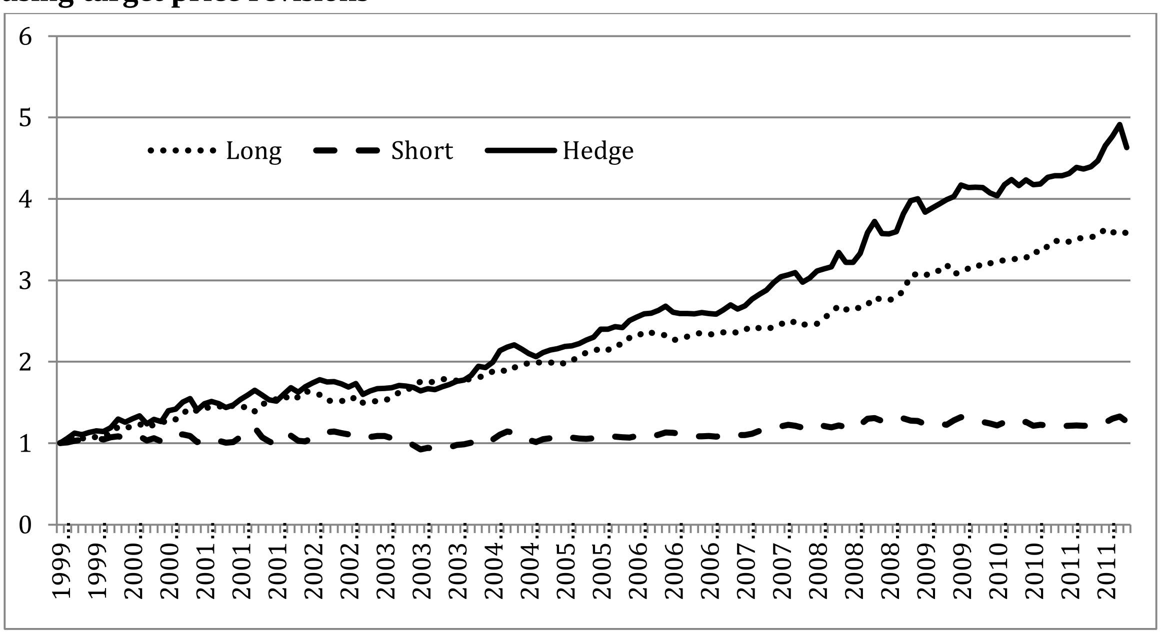

Table 1.1: Frequency analysis of earnings forecast revisions following large price moves

Panel A reports whether and how analysts revise forecasts for annual earnings on or within five days after a large price move day. "No revision" means that analysts do not issue any earnings forecast on or within five days after a large price move day, or that the newly issued earnings forecast is the same as the previous one. "Negative" ("Positive") means that among the analysts following a given firm, the majority makes a downward (upward) revision. Panel B reports frequency analysis for the subsample with high trading volume on the large return day. Panel C reports frequency analysis for the subsample with low trading volume on the large return day. Trading volume is defined as high if it is greater than 1.1 times the average trading volume over prior 45 days and as low otherwise.

Panel A: Large price moves and earnings forecast revisions

Earnings Forecast revision	Daily return		Total
	<=-5%	>=5%	
No revision	236,866 32.78%	327,508 45.31%	564,374 78.09%
Negative	49,983 6.92%	37,483 5.19%	87,466 12.11%
Positive	23,898 3.30%	46,950 6.50%	70,848 9.80%
Total	310,747 43.00%	411,941 57.00%	722,688 100%

Panel B: Large price moves and earnings forecast revisions when trading volume is high

Earnings Forecast revision	Daily return		Total
	<=-5%	>=5%	
No revision	119,289 27.34%	204,062 46.77%	323,351 74.11%
Negative	35,744 8.19%	24,732 5.67%	60,476 13.86%
Positive	15,441 3.54%	37,022 8.49%	52,463 12.03%
Total	170,474 39.07%	265,816 60.93%	436,290 100%

Panel C: Large price swings and earnings forecast revisions when trading volume is low

Earnings Forecast revision	Daily return		Total
	<=-5%	>=5%	
No revision	117,577	123,446	241,023
	41.06%	43.10%	84.16%
Negative	14,239	12,751	26,990
	4.97%	4.45%	9.42%
Positive	8,457	9,928	18,385
	2.95%	3.47%	6.42%
Total	140,273	146,125	286,398
	48.98%	51.02%	100%

Table 1.2: Frequency analysis of target price revisions following large price moves

Panel A reports whether and how analysts revise one-year ahead target prices on or within five days after a large price move day. "No revision" means that analysts do not issue any target price forecast on or within five days after a large price move day, or that the newly issued target price is the same as the previous one. "Negative" ("Positive") means that, among the analysts following the same firm, the majority makes a downward (upward) revision. Panel B reports frequency analysis for the subsample with high trading volume on the large return day. Panel C reports frequency analysis for the subsample with low trading volume on the large return day. Trading volume is high if it is greater than 1.1 times the average trading volume over prior 45 days and as low otherwise.

Panel A: Large price moves and target price revisions

Target price revision	Daily return		Total
	<=-5%	>=5%	
No revision	160,820 36.21%	202,446 45.58%	363,266 81.79%
Negative	26,809 6.04%	12,584 2.83%	39,393 8.87%
Positive	11,058 2.49%	30,447 6.85%	41,505 9.34%
Total	198,687 44.74%	245,477 55.26%	444,164 100%

Panel B: Large price moves and target price revisions when trading volume is high

Target price revision	Daily return		Total
	<=-5%	>=5%	
No revision	80,059 30.57%	118,914 45.40%	198,973 75.97%
Negative	20,996 8.02%	8,096 3.09%	29,092 11.11%
Positive	7,967 3.03%	25,891 9.89%	33,858 12.92%
Total	109,022 41.62%	152,901 58.38%	261,923 100%

Panel C: Large price moves and target price revisions when trading volume is low

Target price revision	Daily return		Total
	<=-5%	>=5%	
No revision	80,761	83,532	164,293
	44.31%	45.84%	90.15%
Negative	5,813	4,488	10,301
	3.19%	2.46%	5.65%
Positive	3,091	4,556	7,647
	1.70%	2.50%	4.20%
Total	89,665	92,576	182,241
	49.20%	50.80%	100%

Table 1.3: Returns following large price moves

Panel A: Cross tabulation

This panel reports both short-term ([+1, +5]) and long-term ([+6, +30], [+6, +60], [+6, +90]) returns after a large return day (Day 0). A large return day is the day on which a firm's stock price increases or decreases by more than 5%. High (low) trading volume means that the trading volume on the high return day is greater (less) than 1.1 times the average trading volume of prior 45 days. xret [m,n] is the buy-and-hold return for a particular stock over the designated window [m,n] minus the average buy-and-hold return on a portfolio of stocks of similar size, book-to-market ratio, and momentum.

Daily return	Trading volume	Variable	Mean	N	Pr> |t|
<-5%	Low	xret[+1,+5]	0.0002	140,273	0.2846
		xret[+6,+30]	-0.0020	140,273	<0.0001
		xret[+6,+60]	-0.0067	140,273	<0.0001
		xret[+6,+90]	-0.0115	140,273	<0.0001
	High	xret[+1,+5]	0.0007	170,474	<0.0001
		xret[+6,+30]	-0.0008	170,474	0.019
		xret[+6,+60]	-0.0037	170,474	<0.0001
		xret[+6,+90]	-0.0061	170,474	<0.0001
>5%	Low	xret[+1,+5]	-0.0026	146,125	<0.0001
		xret[+6,+30]	-0.0073	146,125	<0.0001
		xret[+6,+60]	-0.0094	146,125	<0.0001
		xret[6,90]	-0.0117	146,125	<0.0001
	High	xret[+1,+5]	-0.0014	265,816	<0.0001
		xret[+6,+30]	-0.0016	265,816	<0.0001
		xret[+6,+60]	-0.0029	265,816	<0.0001
		xret[+6,+90]	-0.0043	265,816	<0.0001

Panel B: Regression analysis

This panel reports the average coefficient estimates for the following quarterly cross-sectional regression (Fama - MacBeth regressions):

$$XRET_{m,n} = \alpha + \beta_1 Dret_0 + \beta_2 Down + \beta_3 Dretdown + \beta_4 Dmve + \beta_5 Dbm + \beta_6 Dmom + \beta_7 Dvol + \varepsilon$$

$XRET_{m,n}$ is the buy-and-hold return for a particular stock over the designated window [m,n] minus the average buy-and-hold return on a portfolio of stocks of similar size, book-to-market ratio, and momentum. $Dret_0$ is the decile of raw return on the large price swing day. *Down* is a dummy variable, which is equal to 1 if the stock return on large swing day is negative and 0 otherwise. *Dretdown* is the $Dret_0$multiplied by *Down*. *Dmve* is the decile of market value of equity. *Dbm* is the decile of book to market ratio. *Dmom* is the decile of momentum, which is the buy-and-hold return during the previous 12 months. *Dvol* is the decile of trading volume on the large price swing day. T-statistics are reported in parentheses.

	xret[+1,+5]	xret[+6,+30]	xret[+6,+60]	xret[+6,+90]
Intercept	-0.002	-0.003	-0.004	-0.005
	(-5.00)	(-2.88)	(-1.84)	(-1.53)
$Dret_0$	**-0.003**	**-0.003**	**-0.007**	**-0.010**
	(-3.29)	(-1.63)	(-2.44)	(-2.83)
Down	0.004	0.008	0.007	0.007
	(5.66)	(5.58)	(3.35)	(2.86)
Dretdown	**0.005**	**0.017**	**0.024**	**0.034**
	(2.73)	(4.07)	(4.20)	(4.53)
Dmve	-0.001	-0.001	0.002	0.006
	(-1.16)	(-0.59)	(0.61)	(1.00)
Dbm	0.002	0.005	0.007	0.006
	(3.96)	(3.34)	(2.00)	(1.20)
Dmom	0.003	0.008	0.012	0.013
	(5.35)	(6.07)	(4.68)	(3.66)
Dvol	0.001	0.003	0.000	-0.003
	(1.03)	(1.20)	(0.02)	(-0.32)
N	100	100	100	100
R^2	0.68%	0.87%	1.24%	1.60%

Table 1.4: Returns after large price moves: the impact of analyst forecast revisions

Panel A and Panel B report the impact of earnings forecast and target price revisions, respectively, on returns after large price swings. “No revision” means that analysts do not issue any forecast on or within five days after the large price swing day or the newly issued forecast is the same as the prior forecast. “Negative” (“Positive”) means that among the analysts following the same firm, the majority makes a downward (upward) revision. xret [m,n] is the buy-and-hold return for stocks conditioned on large price changes and analyst forecast revisions over the designated window [m,n] minus the average buy-and-hold return on a portfolio of stocks of similar size, book-to-market ratio, and momentum.

Panel A: Returns after large price moves: the impact of earnings forecast revisions

Daily Return	EF revision	Variable	Mean	N	Pr> |t|
<=-5%	No revision	xret[+1,+5]	0.0012	236,866	<0.0001
		xret[+6,+30]	-0.0013	236,866	0.0001
		xret[+6,+60]	-0.0054	236,866	<0.0001
		xret[+6,+90]	-0.0092	236,866	<0.0001
	Negative	xret[+1,+5]	-0.0074	49,983	<0.0001
		xret[+6,+30]	-0.0042	49,983	<0.0001
		xret[+6,+60]	-0.0059	49,983	<0.0001
		xret[+6,+90]	-0.0108	49,983	<0.0001
	Positive	xret[+1,+5]	0.0094	23,898	<0.0001
		xret[+6,+30]	0.0041	23,898	<0.0001
		xret[+6,+60]	0.0006	23,898	0.6519
		xret[+6,+90]	0.0028	23,898	0.1079
>=5%	No revision	xret[+1,+5]	-0.0019	327,508	<0.0001
		xret[+6,+30]	-0.0047	327,508	<0.0001
		xret[+6,+60]	-0.0066	327,508	<0.0001
		xret[+6,+90]	-0.0088	327,508	<0.0001
	Negative	xret[+1,+5]	-0.0098	37,483	<0.0001
		xret[+6,+30]	-0.0069	37,483	<0.0001
		xret[+6,+60]	-0.0108	37,483	<0.0001
		xret[+6,+90]	-0.0152	37,483	<0.0001
	Positive	xret[+1,+5]	0.0047	46,950	<0.0001
		xret[+6,+30]	0.0066	46,950	<0.0001
		xret[+6,+60]	0.0088	46,950	<0.0001
		xret[+6,+90]	0.0126	46,950	<0.0001

Panel B: Returns after large price moves: the impact of target price revisions

Daily return	TP revision	Variable	Mean	N	Pr> |t|
<=-5%	No revision	xret[+1,+5]	0.0004	160,820	0.0189
		xret[+6,+30]	-0.0004	160,820	0.3791
		xret[+6,+60]	-0.0026	160,820	<0.0001
		xret[+6,+90]	-0.0048	160,820	<0.0001
	Negative	xret[+1,+5]	-0.0107	26,809	<0.0001
		xret[+6,+30]	-0.0019	26,809	0.0283
		xret[+6,+60]	-0.0023	26,809	0.0642
		xret[+6,+90]	-0.0035	26,809	0.0259
	Positive	xret[+1,+5]	0.0120	11,058	<0.0001
		xret[+6,+30]	0.0044	11,058	0.0004
		xret[+6,+60]	0.0069	11,058	0.0003
		xret[+6,+90]	0.0098	11,058	<0.0001
>=5%	No revision	xret[+1,+5]	-0.0013	202,446	<0.0001
		xret[+6,+30]	-0.0028	202,446	<0.0001
		xret[+6,+60]	-0.0024	202,446	<0.0001
		xret[+6,+90]	-0.0020	202,446	0.0039
	Negative	xret[+1,+5]	-0.0132	12,584	<0.0001
		xret[+6,+30]	-0.0030	12,584	0.0225
		xret[+6,+60]	-0.0026	12,584	0.1589
		xret[+6,+90]	-0.0084	12,584	0.0003
	Positive	xret[+1,+5]	0.0069	30,447	<0.0001
		xret[+6,+30]	0.0062	30,447	<0.0001
		xret[+6,+60]	0.0110	30,447	<0.0001
		xret[+6,+90]	0.0146	30,447	<0.0001

Table 1.5: Returns after large price moves: the impact of trading volume and analyst forecast revisions

Panel A and Panel B report the joint impact of trading volume and earnings forecast and target price revisions respectively on returns after large price moves. High (low) trading volume means that the trading volume on the large return day is greater (less) than 1.1 times the average trading volume of prior 45 days. “No revision” means that analysts do not issue any forecast on or within five days after the large price move day, or that the newly issued forecast is the same as the prior forecast. “Negative” (“Positive”) means that among the analysts following the same firm, the majority makes a downward (upward) revision. xret [m,n] is the buy-and-hold return for a particular stock over the designated window [m,n] minus the average buy-and-hold return on a portfolio of stocks of similar size, book-to-market ratio, and momentum.

Panel A: Returns after large price moves: the impact of earnings forecast revisions and trading volume

Daily Return	Trading volume	EF revision	Variable	Mean	N	Pr> |t|
<=-5%	Low	No revision	xret[+1,+5]	0.0006	117,577	0.0113
			xret[+6,+30]	-0.0021	117,577	<0.0001
			xret[+6,+60]	-0.0073	117,577	<0.0001
			xret[+6,+90]	-0.0124	117,577	<0.0001
		Negative	xret[+1,+5]	-0.0097	14,239	<0.0001
			xret[+6,+30]	-0.0061	14,239	<0.0001
			xret[+6,+60]	-0.0088	14,239	<0.0001
			xret[+6,+90]	-0.0151	14,239	<0.0001
		Positive	xret[+1,+5]	0.0122	8,457	<0.0001
			xret[+6,+30]	0.0066	8,457	<0.0001
			xret[+6,+60]	0.0050	8,457	0.0498
			xret[+6,+90]	0.0074	8,457	0.0335
	High	No revision	xret[+1,+5]	0.0019	119,289	<0.0001
			xret[+6,+30]	-0.0005	119,289	0.2566
			xret[+6,+60]	-0.0036	119,289	<0.0001
			xret[+6,+90]	-0.0060	119,289	<0.0001
		Negative	xret[+1,+5]	-0.0065	35,744	<0.0001
			xret[+6,+30]	-0.0034	35,744	<0.0001
			xret[+6,+60]	-0.0048	35,744	<0.0001
			xret[+6,+90]	-0.0091	35,744	<0.0001
		Positive	xret[+1+,5]	0.0078	15,441	<0.0001
			xret[+6,+30]	0.0028	15,441	0.0054
			xret[+6,+60]	-0.0018	15,441	0.2275
			xret[+6,+90]	0.0003	15,441	0.8687

>=5%	Low	No revision	xret[+1,+5]	-0.0024	123,446	<0.0001
			xret[+6,+30]	-0.0077	123,446	<0.0001
			xret[+6,+60]	-0.0099	123,446	<0.0001
			xret[+6,+90]	-0.0125	123,446	<0.0001
		Negative	xret[+1,+5]	-0.0118	12,751	<0.0001
			xret[+6,+30]	-0.0111	12,751	<0.0001
			xret[+6,+60]	-0.0133	12,751	<0.0001
			xret[+6,+90]	-0.0163	12,751	<0.0001
		Positive	xret[+1,+5]	0.0066	9,928	<0.0001
			xret[+6,+30]	0.0023	9,928	0.1038
			xret[+6,+60]	0.0025	9,928	0.2398
			xret[+6,+90]	0.0037	9,928	0.1796
	High	No revision	xret[+1,+5]	-0.0016	204,062	<0.0001
			xret[+6,+30]	-0.0029	204,062	<0.0001
			xret[+6,+60]	-0.0045	204,062	<0.0001
			xret[+6,+90]	-0.0066	204,062	<0.0001
		Negative	xret[+1,+5]	-0.0087	24,732	<0.0001
			xret[+6,+30]	-0.0047	24,732	<0.0001
			xret[+6,+60]	-0.0096	24,732	<0.0001
			xret[+6,+90]	-0.0146	24,732	<0.0001
		Positive	xret[+1,+5]	0.0042	37,022	<0.0001
			xret[+6,+30]	0.0077	37,022	<0.0001
			xret[+6,+60]	0.0105	37,022	<0.0001
			xret[+6,+90]	0.0150	37,022	<0.0001

Panel B: Returns after large price moves: the impact of trading volume and target price revisions

Daily return	Trading volume	TP revision	Variable	Mean	N	Pr> |t|
<=-5%	Low	No revision	xret[+1,+5]	-0.0002	80,761	0.4988
			xret[+6,+30]	-0.0019	80,761	0.0044
			xret[+6,+60]	-0.0057	80,761	<0.0001
			xret[+6,+90]	-0.0095	80,761	<0.0001
		Negative	xret[+1,+5]	-0.0187	5,813	<0.0001
			xret[+6,+30]	-0.0047	5,813	0.0461
			xret[+6,+60]	-0.0064	5,813	0.0525
			xret[+6,+90]	-0.0162	5,813	<0.0001
		Positive	xret[+1,+5]	0.0180	3,091	<0.0001
			xret[+6,+30]	0.0079	3,091	0.0051
			xret[+6,+60]	0.0091	3,091	0.0313

			xret[+6,+90]	0.0088	3,091	0.0934
	High	No revision	xret[+1,+5]	0.0011	80,059	<0.0001
			xret[+6,+30]	0.0011	80,059	0.0392
			xret[+6,+60]	0.0004	80,059	0.5901
			xret[+6,+90]	0.0000	80,059	0.9918
		Negative	xret[+1,+5]	-0.0085	20,996	<0.0001
			xret[+6,+30]	-0.0011	20,996	0.2129
			xret[+6,+60]	-0.0012	20,996	0.3705
			xret[+6,+90]	0.0001	20,996	0.9644
		Positive	xret[+1,+5]	0.0097	7,967	<0.0001
			xret[+6,+30]	0.0031	7,967	0.0222
			xret[+6,+60]	0.0060	7,967	0.0039
			xret[+6,+90]	0.0101	7,967	0.0002
>=5%	Low	No revision	xret[+1,+5]	-0.0018	83,532	<0.0001
			xret[+6,+30]	-0.0051	83,532	<0.0001
			xret[+6,+60]	-0.0055	83,532	<0.0001
			xret[+6,+90]	-0.0057	83,532	<0.0001
		Negative	xret[+1,+5]	-0.0165	4,488	<.0001
			xret[+6,+30]	-0.0063	4,488	0.0102
			xret[+6,+60]	-0.0069	4,488	0.0403
			xret[+6,+90]	-0.0130	4,488	0.0017
		Positive	xret[+1,+5]	0.0120	4,556	<0.0001
			xret[+6,+30]	0.0011	4,556	0.5884
			xret[+6,+60]	0.0072	4,556	0.0214
			xret[+6,+90]	0.0086	4,556	0.0344
	High	No revision	xret[+1,+5]	-0.0010	118,914	<0.0001
			xret[+6,+30]	-0.0012	118,914	0.0106
			xret[+6,+60]	-0.0002	118,914	0.7461
			xret[+6,+90]	0.0005	118,914	0.5504
		Negative	xret[+1,+5]	-0.0113	8,096	<0.0001
			xret[+6,+30]	-0.0011	8,096	0.4528
			xret[+6,+60]	-0.0002	8,096	0.9204
			xret[+6,+90]	-0.0058	8,096	0.0364
		Positive	xret[+1,+5]	0.0060	25,891	<0.0001
			xret[+6,+30]	0.0071	25,891	<0.0001
			xret[+6,+60]	0.0117	25,891	<0.0001
			xret[+6,+90]	0.0157	25,891	<0.0001

Table 1.6: Regression analysis: the effect of analyst forecast revisions on returns after large price moves

This table reports the average coefficient estimates for the following quarterly cross-sectional regression:

$$XRET_{m,n} = \alpha + \beta_1 Dret_0 + \beta_2 confirm + \beta_3 Dretconfirm + \beta_4 conflict + \beta_5 Dretconflict$$
$$+\beta_6 Dmve + \beta_7 Dbm + \beta_8 Dmom + \beta_9 Dvol + \varepsilon$$

$XRET_{m,n}$ is the buy-and-hold return for a stock over the designated window [m,n] minus the average buy-and-hold return on a portfolio of stocks of similar size, book-to-market ratio, and momentum. $Dret_0$is the decile of raw return on the large price swing day. *Confirm* is a dummy variable that takes the value of 1 if analysts revise earnings forecasts or target prices in a manner consistent with the initial price change and zero otherwise. *Dretconfirm* is $Dret_0$multiplied by confirm. *Conflict* is a dummy variable that takes the value of 1 if earnings forecast or target price revisions are in the opposite direction to initial price change and 0 otherwise. *Dretconflict* is $Dret_0$ multiplied by conflict. *Dretdown* is $Dret_0$multiplied by*Down*. *Dmve* is the decile of market value of equity. *Dbm* is the decile of book to market ratio. *Dmom* is the decile of momentum, which is the buy-and-hold return during the previous 12 months. *Dvol* is the decile of trading volume on the large price swing day. T-statistics are reported in parentheses.

Panel A: The effect of earnings forecast revisions on returns after large price moves

	xret[+6,+30]	xret[+6,+60]	xret[+6,+90]
Intercept	-0.003	-0.005	-0.007
	(-2.63)	(-2.38)	(-2.33)
$Dret_0$	**-0.007**	**-0.006**	**-0.006**
	(-4.49)	(-3.30)	(-2.40)
confirm	0.004	0.007	0.008
	(5.84)	(4.59)	(4.42)
Dretconfirm	**0.021**	**0.024**	**0.035**
	(10.07)	(6.68)	(7.88)
conflict	0.000	-0.001	-0.001
	(0.43)	(-1.01)	(-0.72)
Dretconflict	**-0.009**	**-0.013**	**-0.023**
	(-3.13)	(-2.89)	(-4.22)
Dmve	-0.002	0.003	0.006
	(-0.80)	(0.68)	(1.11)
Dbm	0.005	0.007	0.007
	(3.50)	(2.10)	(1.31)
Dmom	0.007	0.010	0.012
	(5.46)	(4.30)	(3.25)
Dvol	0.002	-0.001	-0.004
	(0.94)	(-0.22)	(-0.54)
N	100	100	100
R^2	0.95%	1.36%	1.72%

Panel B: The effect of target price revisions on returns after large price moves

	xret[+6,+30]	xret[+6,+60]	xret[+6,+90]
Intercept	-0.001	-0.001	0.000
	(-0.83)	(-0.31)	(-0.11)
$Dret_0$	**-0.008**	**-0.009**	**-0.009**
	(-4.62)	(-3.92)	(-2.74)
confirm	0.005	0.008	0.009
	(2.78)	(2.70)	(2.47)
Dretconfirm	**0.017**	**0.014**	**0.024**
	(6.74)	(1.72)	(5.39)
conflict	0.001	0.002	0.000
	(0.84)	(0.75)	(0.04)
Dretconflict	**-0.001**	**-0.006**	**-0.021**
	(-0.20)	(-0.77)	(-2.05)
Dmve	-0.004	0.001	0.005
	(-1.33)	(0.21)	(0.53)
Dbm	0.003	0.003	0.000
	(1.40)	(0.50)	(0.02)
Dmom	0.005	0.004	0.003
	(2.34)	(1.11)	(0.55)
Dvol	0.004	0.002	0.000
	(0.89)	(0.17)	(0.01)
N	52	52	52
R^2	0.97%	1.34%	1.70%

Table 1.7: Analyst forecast revisions and public information

The table shows the probability of news releases from Dow Jones, Key Developments, and Form 8-K (in the window [-1, +5] relative to the large price change day, Day 0) conditional on whether there are earnings forecast or target price revisions in the window [0,+5]. Panel A reports results for all large price changes observations with available data from Dow Jones, Key Developments, and SEC Form 8-K. Panel B repeats the analysis in Panel A, after excluding large price changes that occur simultaneously with earnings announcements.

Panel A: All large price changes

Earnings Forecast Revisions	**Dow Jones**	**Key Developments**	**Form 8-K**
Yes	70%	72%	59%
No	38%	38%	21%
Prob of Chi Square statistics	<0.0001	<0.0001	<0.0001
Target Price Revisions			
Yes	78%	75%	77%
No	41%	38%	41%
Prob of Chi Square statistics	<0.0001	<0.0001	<0.0001

Panel B: All large price changes excluding earnings announcements

Earnings Forecast Revisions	**Dow Jones**	**Key Developments**	**Form 8-K**
Yes	63%	61%	43%
No	36%	35%	18%
Prob of Chi Square statistics	<0.0001	<0.0001	<0.0001
Target Price Revisions			
Yes	71%	63%	65%
No	39%	36%	39%
Prob of Chi Square statistics	<0.0001	<0.0001	<0.0001

Table 1.8: Calendar-time monthly portfolio strategy

This table reports the excess returns for hedge portfolios (hedge), long positions (long) and short positions (short), and also gives the number of stocks in the long (nlong) and short (nshort) portfolios. Results for four strategies are presented. All four strategies require holding portfolios for a month. To ensure sufficient diversification, we require at least 15 stocks for both the short and long sides of the portfolio.

Strategy 1: Hold long positions in stocks with large daily price increases and positive earnings forecast or target price revisions on or within the next five days. Hold short positions in stocks with large daily price decreases and negative earnings forecast or target price revisions on or within the next five days.

Strategy 2 (a pure reversal strategy): Hold long positions in stocks with initial large price decreases and no immediate subsequent analyst revisions, and short positions in stocks with initial large price increases and no immediate subsequent analyst revisions.

Strategy 3: Hold long positions in stocks with large price decreases and no immediate subsequent analyst forecast revisions or with immediate subsequent positive revisions. Hold short positions in stocks with large price increases and no immediately subsequent revisions or those with immediate subsequent negative revisions. This is equivalent to the union of Strategy 2 and a strategy where analysts revise in the opposite direction of the initial large price swing.

Strategy 4: Hold long positions in stocks with large price increases and subsequent positive analyst forecast revisions and stocks with large price decreases without immediate subsequent revisions. Hold short positions in stocks with large price decreases and immediate subsequent negative analyst forecast revisions, and stocks with large price increases and no subsequent revisions. Strategy 4 is equivalent to the union of Strategy 2 and Strategy 1.

Panel A: Constructing portfolios based on large price moves and earnings forecast revisions

Daily Return	Variable	N	Mean	StdDev	t	Prob
strategy 1	hedge	304	0.0117	0.0254	8.06	<.0001
	long	304	0.0053	0.0251	3.67	0.0003
	short	304	0.0065	0.0261	4.32	<.0001
	nlong	304	141			
	nshort	304	154			
strategy 2	hedge	309	0.0029	0.0151	3.40	0.0008
	long	309	-0.0015	0.0235	-1.12	0.2643
	short	309	0.0044	0.0198	3.91	0.0001
	nlong	309	374			
	nshort	309	853			
strategy 3	hedge	309	0.0043	0.0149	5.10	<.0001
	long	309	-0.0005	0.0231	-0.34	0.7307
	short	309	0.0048	0.0197	4.27	<.0001
	nlong	309	387			
	nshort	309	935			
strategy 4	hedge	309	0.0043	0.0131	5.80	<.0001
	long	309	0.0002	0.0217	0.13	0.8947
	short	309	0.0042	0.0198	3.71	0.0002
	nlong	309	423			
	nshort	309	963			

Panel B: Constructing portfolios based on large price moves and target price revisions

Daily Return	Variable	N	Mean	StdDev	t	Prob
strategy1	hedge	148	0.0109	0.0299	4.42	<.0001
	long	148	0.0089	0.0211	5.12	<.0001
	short	148	0.0020	0.0283	0.86	0.3933
	nlong	148	191			
	nshort	148	171			
strategy 2	hedge	153	0.0035	0.0148	2.9	0.0043
	long	153	0.0011	0.0209	0.65	0.5158
	short	153	0.0024	0.0179	1.63	0.1044
	nlong	153	479			
	nshort	153	1048			
strategy 3	hedge	153	0.0037	0.0142	3.25	0.0014
	long	153	0.0014	0.0201	0.85	0.398
	short	153	0.0024	0.0180	1.62	0.1083
	nlong	153	493			
	nshort	153	1104			
strategy 4	hedge	153	0.0041	0.0120	4.23	<.0001
	long	153	0.0023	0.0181	1.56	0.1219
	short	153	0.0018	0.0183	1.24	0.2186
	nlong	153	551			
	nshort	153	1167			

Table 1.9: Calendar-time monthly portfolio strategy incorporating trading volumes

This table reports the excess returns for hedge portfolios (hedge), long positions (long) and short positions (short), and also gives the number of stocks in the long (nlong) and short portfolios (nshort). Results for four strategies are presented. All four strategies require holding portfolios for a month. To ensure sufficient diversification, we require at least 15 stocks for both the short and long sides of the portfolio.

Strategy 1: Hold long positions in stocks with large daily price increases, high trading volume, and positive earnings forecast or target price revisions on or within the next five days. Hold short positions in stocks with large daily price decreases, low trading volume, and negative earnings forecast or target price revisions on or within the next five days.

Strategy 2 (a pure reversal strategy): Hold long positions in stocks with initial large price decreases, high trading volume, and no immediate subsequent analyst revisions, and short positions in stocks with initial large price increases, low trading volume, and no immediate subsequent analyst revisions.

Strategy 3: Hold long positions in stocks with large price decreases, high trading volume, and no immediately subsequent analyst forecast revisions or with immediate subsequent positive revisions. Hold short positions in stocks with large price increases, low trading volume, and no immediate subsequent revisions or those with immediate subsequent negative revisions. This is equivalent to the union of Strategy 2 and a strategy where analysts revise in the opposite direction of the initial large price swing.

Strategy 4: Hold long positions in stocks with large price increases, high trading volume, and subsequent positive analyst forecast revisions and stocks with large price decreases, high trading volume, and no immediate subsequent revisions. Take short positions in stocks with large price decreases, low trading volume, and immediate subsequent negative analyst forecast revisions, and stocks with large price increases, low trading volume and no subsequent revisions. Strategy 4 is equivalent to the union of Strategies 1 and 2.

Panel A: Constructing portfolios based on large price moves, trading volume, and earnings forecast revisions

Trading strategy	Variable	N	Mean	StdDev	t	Prob
strategy 1	hedge	225	0.0152	0.0388	5.87	<.0001
	long	225	0.0074	0.0271	4.11	<.0001
	short	225	0.0078	0.0401	2.90	0.0041
	nlong	225	120			
	nshort	225	58			
strategy 2	hedge	309	0.0021	0.0186	1.96	0.0503
	long	309	-0.0021	0.0216	-1.74	0.0836
	short	309	0.0042	0.0290	2.55	0.0111
	nlong	309	300			
	nshort	309	335			
strategy 3	hedge	309	0.0069	0.0162	7.44	<.0001
	long	309	-0.0009	0.0221	-0.69	0.4931
	short	309	0.0077	0.0231	5.87	<.0001
	nlong	309	328			
	nshort	309	390			
strategy 4	hedge	309	0.0076	0.0154	8.62	<.0001
	long	309	0.0008	0.0211	0.65	0.5153
	short	309	0.0068	0.0235	5.08	<.0001
	nlong	309	384			
	nshort	309	393			

Panel B: Constructing portfolios based on large price moves, trading volume, and target price revisions

Trading strategy	Variable	N	Mean	StdDev	t	Prob
strategy 1	hedge	82	0.0179	0.0583	2.79	0.0066
	long	82	0.0105	0.0252	3.77	0.0003
	short	82	0.0075	0.0567	1.19	0.2364
	nlong	82	138			
	nshort	82	60			
strategy 2	hedge	153	0.0036	0.0214	2.08	0.0394
	long	153	0.0013	0.0167	1.00	0.3212
	short	153	0.0022	0.0288	0.96	0.338
	nlong	153	395			
	nshort	153	458			
strategy 3	hedge	153	0.0061	0.0160	4.71	<.0001
	long	153	0.0021	0.0175	1.51	0.1327
	short	153	0.0040	0.0216	2.27	0.0244
	nlong	153	423			
	nshort	153	505			
strategy 4	hedge	153	0.0073	0.0155	5.86	<.0001
	long	153	0.0038	0.0163	2.92	0.004
	short	153	0.0035	0.0220	1.97	0.0506
	nlong	153	514			
	nshort	153	511			

ESSAY 2: Using Option Implied Volatilities to Predict Absolute Stock Returns: Evidence from Earnings Announcements and Annual Shareholders' Meetings

1. Introduction

In recent decades, the capital markets have experienced an impressive proliferation of derivative securities. Prior research argues that informed investors might choose to trade derivatives because of the higher leverage offered by such instruments, and protected downside risk. Consistent with these arguments, a number of studies have shown that investors use options to trade on their directional information about the price of the underlying stock (e.g. Amin and Lee (1997), Cao, Chen and Griffin (2005), Pan and Poteshman (2006), Xing, Zhang and Zhao (2010) and Jin, Livnat and Zhang (2012)). Furthermore, equity options also provide a good venue for traders with information about future volatility. For example, traders with private information about future stock volatility can profit in the option market using a straddle/strangle strategy. While there is a relatively large literature on informed traders exploiting directional information, there is comparatively little written on informed traders exploiting future volatility in the option market. Ni, Pan and Poteshman (2008) is an exception. They construct non-market maker net demand for volatility from the trading volume of individual options, and find that this demand is informative about the future realized volatility of underlying stocks.

The main question in our paper is whether option traders set option prices that incorporate volatility and/or absolute stock returns around firm-specific information events. Specifically, we examine two scheduled information events: (1) quarterly earnings announcements, and (2) annual meetings of shareholders. A well-known fact about earnings announcements is that uncertainty builds up before the earnings releases and declines afterwards (e.g. Patell and Wolfson (1979, 1981)). Additionally, option implied volatility is also very sensitive to the earnings announcement date (see Appendix for an example). Given these facts, we consider earnings announcements to be a particularly interesting venue to study the proper incorporation of uncertainty in the option market. The annual meeting of shareholders is another significant and scheduled information event for a firm. At the annual meeting, the management discusses the company's performance and strategy and shareholders vote on the election of directors and a variety of other governance topics, such as the appointment of outside directors, the issuance of new shares, major mergers and acquisitions etc. Brickley (1986) finds that significant abnormal stock returns around a random sample of annual meetings dates. Consequently, we examine whether option traders anticipate and correctly price the option to incorporate the volatility changes induced by information released in quarterly earnings announcements and annual meetings of shareholders.

First, we estimate the 3-day ([-1, +1]) volatility around the information event from option implied volatilities immediately before the event and investigate its predictive ability for absolute excess stock returns in the 3-day window around the information event. To estimate the 3-day volatility around information events, we decompose option implied volatilities as the weighted average of baseline volatility and volatility associated with the information event (Patell and Wolfson (1979; 1981)), Dubinsky and Johannes (2006), Barth and So (2014)). Note that our estimate of the 3-day volatility around the event is also used to estimate the absolute value of the excess stock return during the short-event period (magnitude, but not direction). Thus, we can examine whether our estimates predict the actual (realized) absolute value of returns around the event.

Next, we examine whether we can take advantage of the increase in volatility around the information event using an option straddle strategy. A straddle consists of a pair of *at-the-money* call option and *at-the-money* put option with the same strike price and time-to-maturity, which allows one to trade on underlying uncertainty without directional exposure to the underlying security. We implement the straddle strategy by buying the straddle contract shortly before the information event and sell the straddle one day after the information event. If the option market correctly forecasts the magnitude of the sharp increase in uncertainty associated with the information event and prices the options correctly, then straddle holders should not earn positive returns around the event.

Our first main finding is that our option implied volatility-based measure does predict future absolute excess returns of the underlying stock around earnings announcements and annual meetings of shareholders, even after controlling for realized stock return volatility shortly before these information events and the volatility of excess stock returns around these two information events in past periods. This suggests that information contained in the option implied volatility complements the historic volatility signals in predicting future uncertainty around information events. The result is consistent with the fact that option traders anticipate the change in uncertainty and trade on volatility information around these two events. We also find that, relative to a randomly selected pseudo-event date, the option implied volatility-based measure has significantly higher predictive ability for short-window absolute excess returns around earnings announcements and annual meetings of shareholders. The higher predictability during information intensive periods suggests that there is informed trading linked to the uncertainty around earnings announcements and annual meetings of shareholders in the option market.

Our second main finding is that a straddle strategy constructed around earnings announcements and annual shareholders meetings yields negative returns (after transaction costs), implying that the option market correctly forecasts the magnitude of the sharp increase in uncertainty associated with the information event and prices options correctly. We also document a negative correlation between net straddle returns and predicted volatility around the two information events based on our implied volatility-based measure. This result suggests that option market makers adjust straddle prices in a way that ensures they get compensated for the predicted higher volatility. This is consistent with Barth and So (2014), which show that earnings announcements pose non-diversifiable volatility risk and investors pay a premium to hedge this non-diversifiable risk. Additionally, we find that the magnitude of the negative impact of our implied volatility-based measure on straddle returns is higher around earnings releases and annual meetings, relative to a random date. This is consistent with the fact that in anticipation of increased information flow into the market and increased uncertainty, market makers increase prices to protect themselves from informed traders.

Our study makes several contributions. First, our paper is related to the literature on the pricing of options around firm-specific information events. For example, Amin and Lee (1997) investigate abnormal trading volume in the option market around the announcement of earnings news, and provide evidence of directional information trading in the option market. Barth and So (2014) find that earnings announcements pose non-diversifiable volatility risks that command a risk premium. Cao, Chen and Griffin (2005) focus on takeovers and find that takeover targets with the largest preannouncement call imbalance increases experience the highest announcement-day returns. Jin, Livnat and Zhang (2012) show that implied volatility spread and skewness immediately before an earnings announcement have significant predictive ability for event signed stock returns, and implied volatility spread and skewness immediately after unscheduled events (such as announcements related to clients and products, executive/board changes) have significant predictability for subsequent (drift) returns. Our study adds to this literature by exploring the predictive ability of the option market for uncertainty around annual meetings of shareholders, another important firm-specific information event which has not been examined in the options literature. Second, our paper extends the literature on the predictability of option implied volatility for future realized volatility. A common finding of such studies is that the implied volatility of an option predicts the ex-post realized volatility over the remaining life of the option (e.g. Jorion (1995), Christensen and Prabhala (1998), and Ederington and Wei (2002)). However, whether the predictability comes from an information advantage of option traders has remained unclear. Our paper makes a twofold contribution to this literature: (1) We focus on the predictability of implied volatility for uncertainty around scheduled information events, and find that the predictability is higher relative to a base case (random date). This provides evidence that option traders indeed utilize information about future volatility in returns around particular information events; (2) Instead of using the implied volatility from option prices (which is a forecast for the volatility of future returns over the entire remaining life of the option), we estimate the implied volatility for the 3-day return around the particular information events of interest, and document its incremental predictive ability for future uncertainty.

The results of our study carry practical implications as well. Market participants alter their investment decisions around significant information events. They track and predict known information events such as earnings announcements. For example, the firm Wall Street Horizon[1]predicts and attempts to verify earnings announcement dates for the coming four quarters. This information can be used by option traders in their pricing of options and their option strategies. Predictions of greater volatility of excess returns around scheduled events can also benefit stock investors. They can invest resources in attempting to predict the direction of these excess returns and take advantage of them, or they can also increase trading of these stocks around the scheduled events to take advantage of the increased market liquidity.

The next section reviews the related literature. Section 3 describes our research design. Section 4 presents the data and descriptive statistics for our sample. Section 5 provides the results of our empirical analysis, and the last section concludes our paper.

2. A Review of Prior Literature

Our paper combines insights from (1) studies of the option market around firm-specific information events (2) studies on the presence of informed trading in the option market (3) studies about the predictive ability of implied volatility for future realized volatility.

2.1 Option market characteristics around firm-specific information events

One of the most frequently investigated information events is the quarterly earnings announcement. Early research examines the impact of earnings announcements on implied volatility, trading volume, open interest and spreads in the stock option market. For example, Patell and Wolfson (1979, 1981) find that implied volatilities increase as earnings announcement dates approach and decline afterwards. They also find that the increase in

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[1]http://www.wallstreethorizon.com/

implied volatilities prior to earnings announcements could predict realized volatilities for the two-day ([0, 1]) or three-day ([-1,+1]) announcement period. Donders, Kouwenberg, and Vorst (2000) document that open interest tends to increase during the days before the earnings announcement but declines to regular levels afterwards, and the effective spread[2] increases on the event day and on the first two days following the earnings announcement. Recent work is focused on the predictive ability of option market for stock returns around earnings announcements. For example, Roll, Schwartz and Subrahmanyam (2012) document that options/stock trading volume ratio (O/S) averaged over the window [-3, -1] prior to the earnings announcement is positively related to post-announcement absolute returns. A follow-up paper on O/S by Johnson and So (2012) find that prior calendar week's O/S decile carries predictive power for future earnings surprises and abnormal returns around earnings announcements. Diavatopoulos et al. (2012) show that changes in skewness and kurtosis stock returns prior to earnings announcements provide information about subsequent stock returns.

In addition to studies on earnings announcements, Cao, Chen and Griffin (2005) focus on takeovers, and find that takeover targets with the largest increases in preannouncement call imbalance experience the highest announcement-day returns. Rogers, Skinner and Van Buskirk (2009) documents that option implied volatilities increase surrounding management earnings forecast, especially forecasts that convey bad news. Jin, Livnat and Zhang (2012) show that implied volatility spread and skewness immediately after unscheduled events (such as firms' clients and products, executive/board changes) have significant predictability for subsequent (drift) returns. In summary, the studies discussed

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[2] The effective spread is calculated as 2 times the difference between the trading price of options and the mid-point price. The mid-point price is the average of the bid quote and the offer quote.

above show that the option market exhibits significant reaction to information events (both *ex ante* and *ex post*). The options market also has predictability for stock returns around firm-specific information events.

2.2 Informed trading in the option market

Earlier studies provide somewhat mixed results about more informed trading in the option market. Consistent with the view that options listing improves the informational efficiency of the market for the underlying stock, Skinner (1990) shows that the information content of firms' accounting earnings releases is lower after exchange-traded options are listed on their stocks. Building on the insight that options offer a leverage advantage over stocks (Black, 1975), Easley, O'Hara and Srinivas (1998) develop an asymmetric information model in which informed traders may trade in both the stock and the option markets. There has been significant effort subsequently to verify the price discovery role of options (e.g.,Chakravarty, Gulen and Mayhew (2004), Cao, Chen and Griffin (2005), Pan and Poteshman (2006), Ni, Pan and Poteshman (2008), Bali and Hovakimian (2009), Xing, Zhang and Zhao (2010), and Jin, Livnat and Zhang (2012)). For example, using a unique data set from the Chicago Board Options Exchange (CBOE) that records purchases and sales of put and call options by non-market makers over the 1990 to 2001 period, Ni, Pan and Poteshman (2008) find that non-market maker net demand for volatility constructed from the trading volume of individual equity options is informative about the future realized volatility of underlying stocks. Van Buskirk (2011) shows that volatility skew identifies which firms are likely to experience stock crashes, but only in the short window around earnings announcements. Jin, Livnat and Zhang (2012) provide evidence on the predictability of option traders before scheduled information events and superior ability of option traders to process less anticipated information.

However, there is also evidence against the price discovery role of option trading. Chan, Chung and Fong (2002) find that stock net trade volume (buyer-initiated volume minus seller-initiated volume) has strong predictive ability for stock and option quote revisions, but option net trade volume has no incremental predictive ability. Using tick-by-tick quote data for 39 liquid US stocks and options on them, Muravyev, Pearson and Broussard (2013) show that option price quotes do not contain economically significant information about future stock prices beyond what is already reflected in current stock prices.

To summarize, although the leveraged nature of option contracts attracts sophisticated investors who wish to exploit public and private information, the option market also has relatively high transaction costs (e.g., high bid-ask spread) that may impede option prices from incorporating all available information (Govindaraj, Li and Zhao, 2014). The existing empirical literature provides mixed evidence on the price discovery role of option trading or the information advantage of option traders over stock traders.

2.3 The predictability of implied volatility for future realized volatility

Our predictive analysis is related to studies that examine the information content of option implied volatility for future realized volatility. These studies show that the implied volatility of an option can predict the ex-post realized volatility over the remaining life of the option. For example, Jorion (1995) reports that implied volatility is an efficient predictor of future return volatility for foreign currency futures. Christensen and Prabhala (1998) document that volatility implied by S&P 100 index option prices outperforms past volatility in forecasting future volatility. Ederington and Wei (2002) show that the implied volatility from S&P500 futures options has strong predictive power and generally subsumes the information in historical volatility. Goodman et al (2013) use information from financial statements to predict future volatilities and show that such information has incremental predictive power beyond both historical realized volatility or option implied volatilities. They use the predicted volatilities to form straddle strategies, but are unable to earn abnormal returns unless transaction costs can be significantly reduced.

3. Methodology

[Insert Figure 2.1 here]

To predict the volatility of 3-day returns around earnings announcements (or other scheduled events), we assume that the *ex ante* stock return volatility is constant (σ_{normal}) over time except for the earnings announcement days ([-1, 1]) on which volatility is higher (σ_{high}) (Patell and Wolfson (1979; 1981), Dubinsky and Johannes (2006), Barth and So (2014))[3]. As illustrated in figure 1, at time t_a, we use two at-the-money (ATM) call options to calculate the predicted volatility of the 3-day returns around earnings announcements. Option 1 expires at t_b and the time to maturity is T1. The implied volatility of option 1 is IV_1. Option 2 expires at t_c and the time to maturity is T2, which is greater than T1. The implied volatility of option 2 is IV_2. T1 and T2 are measured in number of trading days and IV_1 and IV_2 are annualized implied volatility. We identify call options that are at the

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[3] Patell and Wolfson (1979; 1981) express the expected equity return volatility in the Black and Scholes (1974) option pricing formula as the weighted average of the firm's baseline volatility and increases in its volatility associated with an anticipated information event. Dubinsky and Johannes (2006) find that incorporating increases in firms' equity return volatility associated with information events into the option pricing model significantly reduces the option pricing errors. Barth and So (2014) use similar assumptions in estimating the stock return volatility around earnings announcements.

money shortly (5 to 10 days) before the earnings announcement (i.e. -10<= t_a <=-5) and expire at least 10 days after the earnings announcement (i.e. t_b >=10, t_c>=10). We select all call options that have a delta in the range of [0.4, 0.7], and choose the one closest to 0.5. Its implied volatility is the ATM implied volatility. We only include call options with positive (non-zero) open interests. Assuming that the stock return of each day between t_a and t_c is independent and identically distributed, we have the following two equations:

$$\frac{T_1}{252} \cdot IV_1^2 = \frac{3}{252} \cdot \sigma_{high}^2 + \frac{(T_1 - 3)}{252} \cdot \sigma_{normal}^2 \qquad (1)$$

$$\frac{T_2}{252} \cdot IV_2^2 = \frac{3}{252} \cdot \sigma_{high}^2 + \frac{(T_2 - 3)}{252} \cdot \sigma_{normal}^2 \qquad (2)$$

In the above two equations, the only two unknown variables are σ_{normal} and σ_{high}. Thus, the predicted volatility of stock returns around earnings announcements can be calculated as[4]:

$$\sigma_{high} = \sqrt{\frac{IV_2^2 \cdot (3T_2 - T_1T_2) - IV_1^2 \cdot ((3T_1 - T_1T_2)}{3 \cdot (T_2 - T_1)}} \qquad (3)$$

If the formula under the square root is *non-positive*, we estimate σ_{high} as the average of implied volatility of Option 1 and historic volatility, which is the annualized standard deviation of daily stock returns in the 60 calendar days prior to t_a.[5] σ_{high} is the annualized volatility of daily stock returns around earnings announcement. We multiply it by square

[4] By convention, we take the positive square root.

[5] For the earnings announcement sample and the shareholder annual meeting sample, the term under the square root is non-positive for about 15% and 25% of observations, respectively.

root of (3/252) to measure the predicted 3-day volatility around earnings announcements (IVOL3).

We present one example to illustrate the above methodology. Amazon was scheduled to release its earnings for the first quarter of 2013 on April 25, 2013. On April 19, 2013 (a week before the anticipated earnings announcement), we identify two ATM call options: Option 1 expires on May 11, 2013 (T1=15 trading days), with delta at 0.526 and implied volatility (IV1) at 0.459. Option 2 expires on May 18, 2013 (T2=20 trading days), with delta at 0.527 and implied volatility (IV2) at 0.404. Plugging these numbers into the equation (3), we get σ_{high} equal to 0.985. σ_{high} is the annualized volatility. To get the 3-day expected volatility, we multiply 0.985 with the square root of 3/252 and get 0.107. Thus, the 3-day expected volatility is 0.107.

We now describe another example to show the usefulness of our method. We conducted an *ex ante* analysis for Children's Place (PLCE), a retail store on November 8, 2013. The stock returns for retail companies are generally not very volatile. Using a similar methodology as above, we estimated the expected volatility on the next scheduled earnings announcement day (November 26, 2013) to be about 8%. On November 26, 2013, the company released its earnings and stock price jumped by 5%. In fact, in the last three years (756 daily returns), it had only 19 days (or roughly 2.5% of the days) of absolute returns in excess of 5%. Thus, we were able to correctly predict the significant large abnormal volatility or absolute value of abnormal return around the earnings announcement.

To show the incremental predictive ability of our implied volatility measure beyond realized volatility, we calculate two additional measures that are based on realized volatility: HIST and STDXRET. HIST is the standard deviation of daily stock returns in the 60 calendar days prior to t_a multiplied by $\sqrt{3}$ (to make it comparable with IVOL3). STDXRET is the standard deviation of 3-day excess returns around prior earnings announcements using all available quarters since the year 1986. In our regression analysis, within each quarter, we rank the three volatility measures into deciles (0-9), divide by 9 and subtract 0.5. Thus, each decile variable has a value between -0.5 and +0.5 and the coefficients of decile variables provide an estimate of the return differential between firms that are in the bottom and top deciles. We measure abnormal (or excess) returns as the buy-and-hold return over the 3-day window ([-1, 1]) around earnings announcement minus the buy-and-hold return on a portfolio of stocks with similar size (market value of equity, two groups), book-to-market ratio (three groups), and 12-month momentum (three groups). Our tests are based on the absolute value of abnormal returns around the earnings announcements, since the predicted volatility around earnings announcement does not predict the sign of the return, only its magnitude.

To examine whether we can take advantage of the increase in volatility around earnings announcements, we investigate a straddle strategy. Specifically, for every earnings announcement of a firm, we buy a straddle contract (i.e., purchasing an ATM call option and a put option with the same strike price and expiration date) at t_a, the time we calculate IVOL3. We then sell the straddle one day after the earnings announcement. To conservatively adjust for transaction costs, the purchase price of the straddle is calculated as the sum of ask prices of the ATM call and ATM put options on day t_a. The selling price of the straddle is the sum of bid prices of the same ATM call and ATM put options one day after the earnings announcements. Net straddle returns are estimated as the selling price of the straddle minus its purchase price divided by its purchase price. A straddle strategy is likely to generate positive returns if the implied volatility increases, because both the option call and put will become more valuable with an increased implied volatility. If option market makers do not fully adjust for the increase in volatility around earnings announcements, we expect to see a positive correlation between our predicted volatility and straddle returns.

In addition to earnings announcements, we also examine the predictability of our option implied volatility-based measure for absolute abnormal returns around annual meetings of shareholders. We use the same methodology described above to calculate the 3-day absolute excess returns around annual meetings of shareholders, estimate the three volatility measures shortly before annual meetings and construct the straddle trading strategy.

One potential concern about the research design is that our option implied volatility-based measure may have predictive ability for future absolute excess returns around any random day. To more directly gauge the information advantage option traders have immediately before earnings announcements or annual shareholders meetings, we provide a robustness test to benchmark our results against a randomly selected pseudo-event date. For each earnings announcement or annual meeting (treatment sample), we randomly select a trading date in the window of [30, 60] relative to the earnings announcement date or annual meeting date (day 0) and treat it as our pseudo-event date (control sample). We calculate absolute abnormal returns, the three volatility measures and straddle returns in the same fashion as for the scheduled information event date. For each information event (earnings announcements or annual meetings), the treatment sample has the same number of observations as the control sample. In the regression analysis, we pool the treatment sample with its corresponding control sample and use dummy variables RDQ or AMS to indicate observations of earnings announcements or annual meetings. We then interact RDQ or AMS with the three volatility measures to capture the incremental predictive ability of volatility measures before earnings announcements and annual meetings of shareholders relative to those before the pseudo-event dates.

4. Data and Sample

4.1 Data

The sample period in our study ranges from the first quarter of 1996 to the fourth quarter of 2011. We obtain earnings announcement dates from Compustat and return information from CRSP. We obtain annual meeting dates from the S&P Filing Dates database. Our option data is from Option Metrics, which provides end of day bid and ask quotes, open interest, volume, implied volatilities and option Greeks for all put and call options listed in the U.S. option market. In particular, Option Metrics calculates the underlying implied volatilities of individual options based on binomial trees that account for early exercise of individual stock options and the dividends expected to be paid over the lives of the options.

4.2 Descriptive statistics of the sample

[Insert Table 2.1 here]

Panel A in Table 1 reports summary statistics for the earnings announcement sample. It has 101,241 firm-quarter observations. The mean and median of 3-day absolute excess returns (AXRET) are 6.23% and 4.20%, respectively. The mean of net straddle returns

(STRADDLE) is -11.8%. This is consistent with Coval and Shumway (2001), which documents negative returns of straddles on the S&P500 index. The volatility of returns in the 60 days prior to the event (HIST) is on average 0.0517, smaller than the volatility of excess returns around past events (STDXRET). The predicted volatility in the 3-day window (-1, +1) of earnings announcements (IVOL3) is on average 0.0825. It is higher than the other two past realized volatility measures, which is consistent with option prices reflecting greater future uncertainty around earnings announcements. Panel B reports similar summary statistics for the annual meetings sample. Compared to the sample of earnings announcements, the 3-day absolute excess returns, straddle returns and three volatility measures are all lower in the annual meetings sample. The standard deviations of these variables are also smaller.

Panel C in Table 1 compares means of key variables between treatment sample and control sample for both earnings announcements and annual meetings. Columns (1) and (2) are based on earnings announcement sample and its corresponding pseudo-event date (a random day in the window of [30, 60] relative to the date of earnings announcement) sample, respectively. For each earnings announcement observation in the treatment group, we identify one random event observation for the control group. This results in 87,088 observations with all available data for each group. Similarly, we get treatment group and control group for annual meetings of shareholders, each with 17,108 observations[6].

As shown in Panel C, the absolute excess returns (AXRET) are significantly higher around earnings announcements and annual meetings than the random event days. This is intuitively reasonable, as earnings announcements and annual meetings are important

[6] There is typically only one shareholders meeting per year, but four earnings announcements.

information events for firms. Net straddle returns (STRADDLE) around earnings announcements and annual meetings are higher than those around a random day, which is due to the increased volatility around these information events. However, they are still significantly negative, which implies that option market makers protect themselves against the increase in uncertainty associated with earnings announcements and annual meetings. The volatility of returns in the 60 days prior to the event (HIST) in the random day sample is higher than that in the earnings announcement sample. This is probably due to the fact that the random day is a day between day 30 to day 60 after earnings announcements and the calculation of HIST covers the volatile earnings release period. As expected, both the volatility of excess returns around past events (STDXRET) and our option based volatility measure are significantly higher around earnings announcements and annual meetings. In addition, the magnitude of the differences for all these variables is higher for earnings announcement than annual meetings, suggesting that the earnings announcement is a more important information event, at least as evidenced by the associated market reaction.

[Insert Table 2.2 here]

Panel A and B in Table 2 shows the correlation matrix of key variables in the earnings announcement sample and the annual meetings sample, respectively. Pearson correlations are reported above the main diagonal and Spearman correlations are reported below the main diagonal. The three volatility measures are significantly and positively correlated with each other, which suggests that the realized volatility measures (HIST and STDXRET) and option predicted volatility measure (IVOL3) contain some overlapping information. In the earnings announcement sample, the Pearson (Spearman) correlation coefficient for HIST and STDXRET is 0.309 (0.366), similar to the correlation between IVOL3 and

STDXRET at 0.309 (0.410). The correlation between HIST and IVOL3 is the highest at 0.594 (0.643). In the annual meetings of shareholders sample, the direction of the correlations among the three volatility measures is the same as that in the earnings announcement sample but the magnitude is smaller, especially for the correlation between IVOL3 and STDXRET, which is only 0.181 (Pearson) and 0.233 (Spearman). The positive correlation between IVOL3 and HIST is still as high as 0.60. This may potentially reduce the significance of IVOL3 in predicting future volatility and straddle returns when HIST is controlled for in the regression.

The three volatility measures are also positively and significantly associated with absolute excess returns. In the earnings announcement sample, the correlation coefficients between each volatility measure and absolute excess returns are of similar magnitude (about 0.30), with the correlation between AXRET and STDXRET as the highest at 0.335 (0.365). However, in the annual meetings sample, the correlation coefficient between AXRET and STDXRET is the lowest among the three correlation coefficients, only at 0.140 (0.140).

Then we turn to the correlation between the three volatility measures and straddle returns. The negative correlation between IVOL3 and STRADDLE is significant and robust in both the earnings announcement and annual meetings samples. This suggests that option market makers do price-protect against the anticipated volatility. The correlation between STDXRET and STRADDLE is significantly positive in the earnings announcement sample but significantly negative in the annual meetings sample. The negative correlation between HIST and STRADDLE is not robust in both the earnings announcement sample and the annual meetings sample.

5. Results

5.1 Predictive analysis

We argue that our option implied volatility based measure (IVOL3) reflects investors' expectation about the future uncertainty around earnings announcements and annual meetings of shareholders. In this section, we illustrate the predictability of IVOL3 for future absolute excess returns around earnings announcements and annual meetings of shareholders. Firstly, we show the absolute excess returns in portfolios double sorted by IVOL3 and one of the two realized volatility measures (HIST and STDXRET). Then, we conduct Fama-Macbeth regressions to examine whether our option implied volatility-based measure can predict absolute excess returns after controlling for other factors, and whether this predictability is higher around information events (i.e. earnings announcements and annual meetings of shareholders) than the predictability around a randomly chosen day.

[Insert Table 2.3 here]

Table 3 displays absolute excess returns in portfolios double sorted by IVOL3 and one of the two realized volatility measures (HIST and STDXRET). Each quarter, firms are sorted into quartile based on HIST, STDXRET or IVOL3. The first (fourth) quartile includes firms with lowest (highest) value of HIST, STDXRET or IVOL3, respectively. In the earnings announcement sample (Panels A and B), absolute excess returns increase monotonically with the quartile of IVOL3. Specifically, absolute excess returns increase from 4.2% to 8.5% going from the first quartile to the fourth quartile of IVOL3. More importantly, within each quartile of HIST or STDXRET, absolute excess returns still increase monotonically with the quartile of IVOL3. This implies that IVOL3 has incremental predictive ability beyond the realized volatility measures. We document similar findings for the sample of annual meetings of shareholders (Panel C and Panel D). These results provide preliminary support for option traders incorporating new information about future absolute returns into option prices beyond what is captured by stock market historic volatilities either in the immediate 60-day period before the event or around the same event in prior quarters or years.

[Insert Table 2.4 here]

In Table 4, we present Fama-Macbeth regression analyses of the predictive ability of our option implied volatility-based measure. The dependent variable is AXRET, which is the absolute excess return in the short window around the event (earnings announcements, annual meetings of shareholders or pseudo-event dates). Each volatility measure is sorted quarterly into deciles (0-9), then divided by 9 and subtracting 0.5. Thus, each decile variable has a value between -0.5 and +0.5 and the coefficients of decile variables provide an estimate of the return differential between firms that are in the bottom and top deciles. T-statistics reported in parentheses are based on Newey-West adjusted standard errors.

Panel A shows the regressions results for earnings announcements. Results in regressions (1) and (2) are based on earnings announcement sample alone, which has 101,241 observations (as described in Panel A of Table 1). Due to the high correlation between HIST and IVOL3, HIST is not controlled for in regression (1). In regression (2), both STDXRET and HIST are included. The coefficients of RIVOL are significant in both regressions (1) and (2). This implies that our option implied volatility-based measure has incremental predictability for future absolute abnormal returns beyond that captured by stock market historic volatilities. This is consistent with results in Panels A and B of Table 3. As to the magnitude of the predictability, the difference in the 3-day absolute abnormal returns around earnings announcement between decile 9 and decile 0 of IVOL3 is 1.9%, after controlling for HIST and STDXRET.

To more directly gauge the information advantage option traders have immediately before an earnings announcement, we run regressions (3) and (4). Results in regressions (3) and (4) are based on both earnings announcements sample (treatment sample) and its corresponding pseudo-event dates sample (control sample), which includes 174,716 observations in total and 87,358 observations for each sample. HIST is controlled for in regression (4), but not in regression (3). The baseline in regressions (3) and (4) is the pseudo-event date. The fact that RIVOL is positive and significant on a random date in regressions (3) and (4) is not surprising as RIVOL is a predictor of realized volatility, which is positively correlated with absolute returns. The positive and significant interacted coefficients (RIVOL3_RDQ) measure the incremental association of the predictions based on the implied volatilities around the earnings announcements beyond the random event dates. This suggests that option traders have information advantage before earnings announcements in setting up the option prices after properly predicting future volatilities.

Panel B shows the regression results for annual meetings of shareholders. Results in regressions (1) and (2) are based on annual meetings sample alone, which has 19,551 firm-year observations (as described in Panel B of Table 1). Results in regressions (3) and (4) are based on annual meetings sample (treatment sample) and its corresponding pseudo-event dates sample (control sample), which includes 34,216 observations in total and 17,108 observations for each. The findings are similar to what we document for earnings announcements. The positive and significant interacted coefficients (RIVOL3_AMS) indicate that option traders also have information advantage in predicting volatilities around future annual meetings of shareholders. It should be noted that the interacted variables of the realized historical volatility (i.e., RSTDXRET_AMS and RHIST_AMS) are not significantly associated with the absolute excess returns, suggesting that the incremental realized volatilities do not add much beyond the “normal” or base (random date) case.

5.2 Straddle returns and predicted volatility

[Insert Table 2.5 here]

Table 5 examines the relation between net straddle returns and volatility measures. Panel A shows the Fama-Macbeth regression results for earnings announcements. As in Table 4, results in regressions (1) and (2) are based on earnings announcement sample alone. Results in regressions (3) and (4) are based on both earnings announcements sample (treatment sample) and its corresponding pseudo-event dates sample (control sample). Due to the high correlation between RHIST and RIVOL3, which may potentially reduce the significance of RIVOL3, RHIST is not controlled for in regressions (1) and (3). In regressions (2) and (4), both RSTDXRET and RHIST are included.

The coefficients of RIVOL3 are significantly negative in both regressions (1) and (2) of Panel A. This implies that option market makers adjust straddle prices in a way that they get compensated for the predicted volatility. Specifically, when RIVOL3 increases from the bottom decile (i.e. decile 0) to the top decile (i.e. decile 9), the net straddle returns decrease by 6.9%, after controlling for RHIST and RSTDXRET. Additionally, the net straddle returns are significantly and positively related to RSTDXRET, implying that a straddle strategy can potentially be used to take advantage of the expected increase in volatility around earnings announcements. In regression (3) of Panel A, RIVOL3_RDQ is significantly negative, implying that option market makers will require even higher compensation for the expected increase in volatility around earnings announcements relative to random days. This is consistent with the notion that market makers are more concerned about and price-protect against informed traders during information events relative to a random day. After adding RHIST and RHIST_RDQ in regression (4), the coefficient of RIVOL3_RDQ is still positive but becomes insignificant.

Panel B reports similar analysis for the sample of annual meetings of shareholders. As in Table 4, results in regressions (1) and (2) are based on annual meetings sample alone. Results in regressions (3) and (4) are based on both annual meetings sample (treatment sample) and its corresponding pseudo-event dates sample (control sample). In regressions (1) and (2), only our option implied volatility-based measure is significant and past realized volatility measure remain insignificant. This implies that the option implied volatilities are more important than realized volatilities when option's market makers set prices for straddles around annual meetings. The coefficient of RIVOL3_AMS in regression (3) is negative and marginally significant, suggesting a higher compensation required by option market makers during annual meetings relative to a random day. After adding RHIST and RHIST_AMS in regression (4), the coefficient of RIVOL3_AMS remains negative but is insignificant.

6. Conclusions

Equity options are particularly suited to investors with information about future volatility. In this study, we investigate whether option prices anticipate and correctly incorporate the magnitude of uncertainty associated with quarterly earnings announcements and annual meetings of shareholders. We find that our option implied volatility-based measure predicts future absolute excess returns of the underlying stock around earnings announcements and annual meetings of shareholders, even after controlling for realized stock return volatility shortly before the information events and volatility of excess stock returns around these prior information events. The predictability of our option implied volatility-based measure is higher around these information events than a random selected date, implying that option traders anticipate the change in uncertainty and trade on volatility information around these two information events. In addition, our analysis of the straddle strategy shows that option market makers adjust straddle prices in a way that they get compensated for the predicted volatility and require higher volatility risk premium around information events than a random selected day.

Figure 2.1: Timeline of events and estimation windows

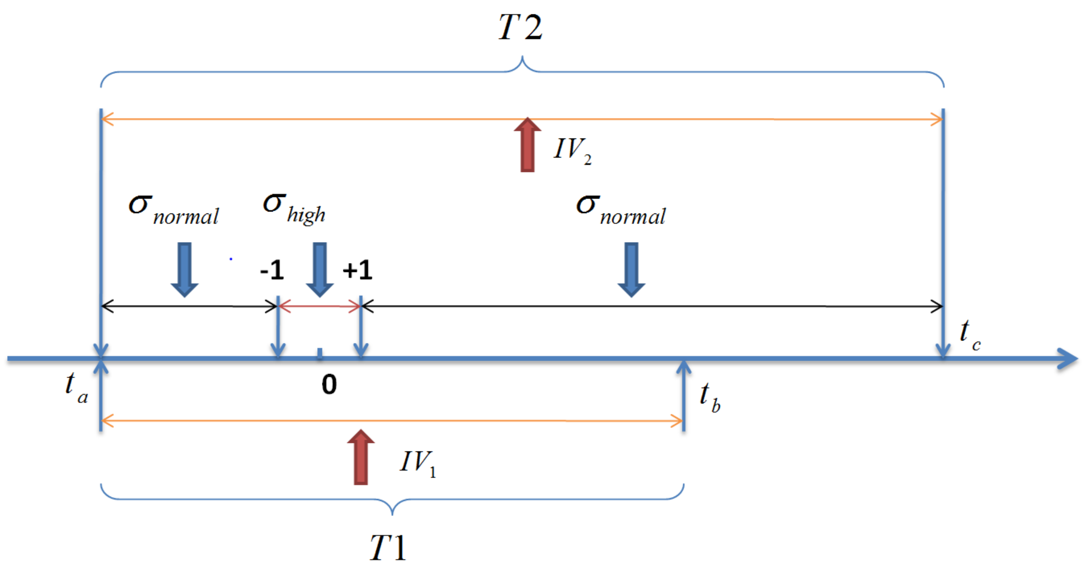

Table 2.1: Summary statistics

Panel A and Panel B reports summary statistics for variables in the earnings announcements sample and annual meetings of shareholders sample, respectively. Panel C shows the difference of sample means and its significance. ***, **, and * denote significance at 1%, 5%, and 10% levels, based on one-sided t-test. In the column of earnings announcement, "treatment" refers to the earnings announcement sample and "control" refers to the sample of pseudo-event, which is a random day between Day 30 to Day 60 relative to the day of earnings announcements. Similarly, in the column of annual meetings of shareholders, "treatment" refers to the sample of shareholders annual meetings and "control" refers to the sample of pseudo-event, which is a random day between Day 30 to Day 60 relative to the day of annual meetings of shareholders. See the appendix for variable definitions.

Panel A: Earnings announcements

Variable	N	Mean	StdDev	5th	25th	Median	75th	95th
AXRET	101,241	0.0623	0.0666	0.0035	0.0184	0.0420	0.0834	0.1881
STRADDLE	101,241	-0.1180	0.3813	-0.5275	-0.3250	-0.2000	-0.0137	0.5854
HIST	101,241	0.0517	0.0321	0.0185	0.0301	0.0434	0.0638	0.1130
STDXRET	101,241	0.0778	0.0417	0.0293	0.0479	0.0704	0.0970	0.1524
IVOL3	101,241	0.0825	0.0599	0.0225	0.0486	0.0712	0.1032	0.1895

Panel B: Annual meetings of shareholders

Variable	N	Mean	StdDev	5th	25th	Median	75th	95th
AXRET	19,551	0.0332	0.0390	0.0019	0.0096	0.0218	0.0422	0.1028
STRADDLE	19,551	-0.1762	0.2845	-0.5185	-0.3250	-0.2143	-0.0833	0.3089
HIST	19,551	0.0517	0.0313	0.0191	0.0305	0.0434	0.0639	0.1131
STDXRET	19,551	0.0467	0.0339	0.0112	0.0256	0.0388	0.0586	0.1073
IVOL3	19,551	0.0679	0.0518	0.0187	0.0357	0.0549	0.0840	0.1614

Panel C: Comparison of sample means

	Earnings Announcements			**Annual Meetings of Shareholders**		
Variable	**(1) Treatment**	**(2) Control**	**(1)-(2)**	**(3) Treatment**	**(4) Control**	**(3)-(4)**
AXRET	0.0627	0.0306	0.0322***	0.0333	0.0288	0.0045***
STRADDLE	-0.1042	-0.1772	0.0730***	-0.1633	-0.1762	0.0129***
HIST	0.0518	0.0543	-0.0025***	0.0519	0.0502	0.0017***
STDXRET	0.0780	0.0481	0.0309***	0.0467	0.0422	0.0045***
IVOL3	0.0818	0.0651	0.0167***	0.0675	0.0625	0.0045***
N of obs	87,088	87,088		17,108	17,108	

Table 2.2: Correlation analysis

Panel A and Panel B show the correlation matrix of key variables in earnings announcements sample and annual meetings of shareholders sample, respectively. Pearson correlations are reported above the main diagonal and Spearman correlations are reported below the main diagonal. In each cell, the first row shows the correlation coefficient and the second row shows the p-value. See appendix for variable definitions.

Panel A: Earnings announcements

	AXRET	STRADDLE	HIST	STDXRET	IVOL3
AXRET	1.000	0.463	0.282	0.335	0.273
		<.0001	<.0001	<.0001	<.0001
STRADDLE	0.276	1.000	-0.007	0.054	-0.058
	<.0001		0.0038	<.0001	<.0001
HIST	0.287	-0.002	1.000	0.309	0.594
	<.0001	0.4935		<.0001	<.0001
STDXRET	0.365	0.015	0.366	1.000	0.309
	<.0001	<.0001	<.0001		<.0001
IVOL3	0.283	-0.047	0.643	0.410	1.000
	<.0001	<0.0001	<.0001	<.0001	

Panel B: Annual meetings of shareholders

	AXRET	STRADDLE	HIST	STDXRET	IVOL3
AXRET	1.000	0.337	0.322	0.140	0.278
		<.0001	<.0001	<.0001	<.0001
STRADDLE	0.168	1.000	-0.005	-0.017	-0.067
	<.0001		0.443	0.0178	<.0001
HIST	0.326	-0.023	1.000	0.222	0.566
	<.0001	0.0014		<.0001	<.0001
STDXRET	0.140	-0.031	0.272	1.000	0.181
	<.0001	<.0001	<.0001		<.0001
IVOL3	0.287	-0.069	0.632	0.233	1.000
	<.0001	<.0001	<.0001	<.0001	

Table 2.3: Cross tabulation of volatility measures and absolute excess returns

This table shows the absolute excess stock returns in the 3-day ([-1, +1]) window around earnings announcements and annual meetings of shareholders. Each quarter, firms are sorted into quartile based on HIST, STDXRET or IVOL3. The first (fourth) quartile includes firms with lowest (highest) value of HIST, STDXRET or IVOL3, respectively. Panels A and B report absolute excess returns for the sample of earnings announcements. Panel C and D report absolute excess returns for the sample of annual meetings of shareholders. See appendix for variable definitions.

Panel A: Absolute excess returns around earnings announcements, sorted by HIST and IVOL3

	AXRET				
	Rank for IVOL3				
Rank for HIST	1	2	3	4	All
1	0.034	0.042	0.048	0.055	0.039
2	0.047	0.053	0.059	0.068	0.055
3	0.059	0.062	0.070	0.080	0.070
4	0.070	0.074	0.078	0.094	0.086
All	0.042	0.055	0.067	0.085	0.062

Panel B: Absolute excess returns around earnings announcements, sorted by STDXRET and IVOL3

	AXRET				
	Rank for IVOL3				
Rank for STDXRET	1	2	3	4	All
1	0.032	0.039	0.047	0.068	0.039
2	0.045	0.051	0.058	0.073	0.055
3	0.057	0.064	0.069	0.079	0.069
4	0.070	0.075	0.084	0.097	0.087
All	0.042	0.055	0.067	0.085	0.062

Panel C: Absolute excess returns around annual meetings of shareholders, sorted by HIST and IVOL3

	AXRET				
	Rank for IVOL3				
Rank for HIST	**1**	**2**	**3**	**4**	**All**
1	0.020	0.023	0.028	0.029	0.022
2	0.025	0.028	0.031	0.036	0.029
3	0.029	0.030	0.036	0.041	0.035
4	0.038	0.038	0.040	0.054	0.047
All	0.023	0.029	0.035	0.046	0.033

Panel D: Absolute excess returns around annual meetings of shareholders, sorted by STDXRET and IVOL3

	AXRET				
	Rank for IVOL3				
Rank for STDXRET	**1**	**2**	**3**	**4**	**All**
1	0.020	0.025	0.031	0.044	0.027
2	0.022	0.027	0.031	0.043	0.030
3	0.027	0.030	0.036	0.045	0.035
4	0.031	0.034	0.041	0.049	0.041
All	0.023	0.029	0.035	0.046	0.033

Table 2.4: The predictability of option implied volatility-based measure for future absolute excess returns

This table reports Fama–MacBeth statistics based on 64 quarterly regressions. The dependent variable is the 3-day ([-1, +1]) absolute excess return. Panels A and B show the regression results for earnings announcements and annual meetings of shareholders, respectively. Variables indicated by *R* are the underlying variables sorted quarterly into deciles (0-9), then divided by 9 and subtracting 0.5. Thus, each decile variable has a value between -0.5 to 0.5. T-statistics reported in parentheses are based on Newey-West adjusted standard errors. ***, **, and * indicate that the mean is significant at 1%, 5%, and 10% levels, respectively. See appendix for variable definitions.

Panel A: Earnings announcements

Variable	**(1)**	**(2)**	**(3)**	**(4)**
Intercept	0.062***	0.062***	0.031***	0.031***
	(24.73)	(24.73)	(12.94)	(12.94)
RDQ			0.032***	0.032***
			(17.9)	(17.9)
RIVOL3	**0.032*** **	**0.019*** **	**0.018*** **	**0.008*** **
	(14.22)	(12.97)	(10.89)	(8.45)
RIVOL3_RDQ			**0.013*** **	**0.011*** **
			(9.30)	(9.67)
RSTDXRET	0.043***	0.034***	0.017***	0.008***
	(23.34)	(23.14)	(9.26)	(9.75)
RSTDXRET_RDQ			0.027***	0.027***
			(17.36)	(16.49)
RHIST		0.028***		0.022***
		(11.47)		(11.02)
RHIST_RDQ				0.004***
				(2.41)
N	101,241	101,241	174,716	174,716
R square	0.107	0.118	0.189	0.200

Panel B: Annual meetings of shareholders

Variable	**(1)**	**(2)**	**(3)**	**(4)**
Intercept	0.036***	0.036***	0.031***	0.031***
	(17.28)	(17.28)	(12.18)	(12.17)
AMS			0.005***	0.005***
			(8.40)	(8.43)
RIVOL3	**0.026*** **	**0.016*** **	**0.022*** **	**0.008*** **
	(12.02)	(4.58)	(7.06)	(4.65)
RIVOL3_AMS			**0.006*** **	**0.009*** **
			(2.43)	(3.60)
RSTDXRET	0.012***	0.010***	0.010***	0.004***
	(5.93)	(4.30)	(7.47)	(3.52)
RSTDXRET_AMS			0.002	0.004
			(0.59)	(1.32)
RHIST		0.020***		0.025***
		(5.72)		(7.36)
RHIST_AMS				-0.006
				(-1.64)
N	19,551	19,551	34,216	34,216
R square	0.088	0.114	0.099	0.132

Table 2.5: Straddle returns regressions

This table reports Fama–MacBeth statistics based on 64 quarterly regressions. The dependent variable is the straddle return. Panels A and B show the regression results for earnings announcements and annual meetings of shareholders, respectively. Variables indicated by *R* are the underlying variables sorted quarterly into deciles (0-9), then divided by 9 and subtracting 0.5. Thus, each decile variable has a value between -0.5 to 0.5. T-statistics reported in parentheses are based on Newey-West adjusted standard errors. ***, **, and * indicate that the mean is significant at 1%, 5%, and 10% levels, respectively. See appendix for variable definitions.

Panel A: Earnings announcements

Variable	**(1)**	**(2)**	**(3)**	**(4)**
Intercept	-0.117***	-0.117***	-0.176***	-0.176***
	(-14.05)	(-14.05)	(-23.09)	(-23.09)
RDQ			0.073***	0.073***
			(11.40)	(11.40)
RIVOL3	**-0.080*** **	**-0.069*** **	**-0.046*** **	**-0.062*** **
	(-10.15)	(-7.73)	(-7.14)	(-8.05)
RIVOL3_RDQ			**-0.033*** **	**-0.004**
			(-4.24)	(-0.44)
RSTDXRET	0.059***	0.067***	-0.003	-0.016***
	(6.39)	(6.69)	(-0.45)	(-3.11)
RSTDXRET_RDQ			0.063***	0.085***
			(6.57)	(7.88)
RHIST		-0.027***		0.035***
		(-1.85)		(3.18)
RHIST_RDQ				-0.064***
				(-7.13)
N	101,241	101,241	174,716	174,716
R square	0.007	0.010	0.023	0.025

Panel B: Annual meetings of shareholders

Variable	**(1)**	**(2)**	**(3)**	**(4)**
Intercept	-0.169***	-0.169***	-0.175***	-0.175***
	(-20.88)	(-20.89)	(-25.27)	(-25.29)
AMS			0.017***	0.017***
			(3.64)	(3.68)
RIVOL3	**-0.055*** **	**-0.063*** **	**-0.015**	**-0.026**
	(-3.83)	(-2.61)	(-1.01)	(-1.66)
RIVOL3_AMS			**-0.022***	**-0.010**
			(-1.73)	(-0.71)
RSTDXRET	0.003	0.012	0.005	-0.002
	(0.35)	(1.27)	(0.41)	(-0.13)
RSTDXRET_AMS			-0.012	0.003
			(-0.73)	(0.20)
RHIST		-0.007		0.020
		(-0.28)		(1.16)
RHIST_AMS				-0.040**
				(-2.19)
N	19,551	19,551	34,216	34,216
R square	0.022	0.038	0.034	0.048

ESSAY 3: How do Short-sale Constraints Affect Options Trading? Evidence from Regulation SHO

1. Introduction

A short-sale is the sale of a stock that an investor does not own or a sale which is consummated by the delivery of a stock borrowed by, or for the account of, the investor. Short sale constraints include various costs and risks, such as the expense and difficulty of borrowing stocks, legal and institutional restrictions, and the risk that the short position will have to be involuntarily closed due to recall of the stock loan (Lamont 2004). The existing literature provides mixed evidence on how short-sale constraints affect options trading. For example, Diamond and Verrecchia (1987) and Easley, O'Hara, and Srinivas (1998) hypothesize that when short selling is expensive, establishing short positions in the options market can be an alternative choice for informed investors. Consistent with this hypothesis, Lin and Lu (2014) show that stock lending fee is positively associated with put options trading volume, supporting a substitute relationship between equity short-sale and options trading. However, focusing on the most binding form of short-sale constraints−2008 short-sale ban of financial stocks, Grundy, Lim, and Verwijmeren (2012) find sizeable decreases in options trading volume for banned stocks. They conjecture that this inability to circumvent the ban through options trading is due to the increased hedging costs faced by options market makers and thus higher option bid-ask spreads during the ban. Their results suggest a complementary relation between equity-short sale and options trading when short-sale is prohibited.

In this paper, I examine the impact of short sale constraints on options trading by exploiting an exogenous shock to short-sale constraints-Regulation SHO. Regulation SHO provides a regulatory framework governing short selling of securities in the U.S. equity market. Regulation SHO is intended to establish uniform locate and delivery requirements (Rule 203), create uniform marking requirements for sales of all equity securities (Rule 200), and establish a procedure to temporarily suspend the short-sale price test of any exchange or national securities association for short sales of certain securities for certain time periods" in order to "evaluate the overall effectiveness and necessity of such restrictions (Rule 202T or pilot program). In this study, I investigate the impact of Rule 203 and Rule 202T on options trading separately.

The advantage of focusing on Regulation SHO is twofold: Firstly, it provides an opportunity to investigate two different forms of short-sale constraints: locate and close-out requirement of Rule 203, and short-sale price tests of Rule 202T. The locate and close-out requirement aims to reduce naked short selling and extended fail-to-deliver of outstanding short positions. Short-sale price tests were initially introduced to the U.S. equity markets in the 1930s, ostensibly to avoid bear raids by short sellers in declining markets. Both rules are important in governing the short selling activity and received great public attention when SEC proposed and later on amended these rules.[1] Consequently, it is

[1] Subsequent to the pilot program of Rule 202T, on July 6, 2007, the SEC eliminated short-sale price tests for all exchange-listed stocks. The decision to eliminate all short-sale price tests prompted a huge backlash from managers and politicians. In response to this pressure, the SEC partially reversed course and restored a modified uptick rule on February 24, 2010. Under the new rule, price tests are triggered when a security's price declines by 10% or more from the previous day's closing price. This policy reversal drew sharp criticism itself, this time from hedge funds and short sellers. As initially adopted, Rule 203 included two major exceptions to the close-out requirement: the "grandfather" provision and the "options market maker" exception. Due to continued concerns about failures to deliver, and the fact that the Commission continued to observe certain securities with failure to deliver positions that were not being closed out under then existing requirements, in 2007 the Commission eliminated the "grandfather" provision and in 2008 the Commission eliminated the "options market maker" exception. In addition, the Commission adopted temporary Rule 204T in 2008 and final Rule 204 in 2009, which strengthened further the close-out requirements of Regulation SHO by applying close-out requirements to failures to deliver resulting from sales of all equity securities and reducing the time-frame within which failures to deliver must be closed out.

interesting to test the impact of these rules on the option market and compare the results with prior studies of other short-sale regulations. Secondly, unlike other proxies for short-sale constraints (e.g. short interests, stock lending fees) that are endogenously determined, Regulation SHO represents exogenous shocks to short-sale constraints. This enables me to provide direct evidence on the substitutability/complementarity between equity short-sale and options trading by examining both the change of short-sale activities and the change of options trading volume given the exogenous increase/decrease of short-sale constraints.

Rule 203 (locate and close-out requirement) went into effect on January 3, 2005. The rule addresses the potentially manipulative effects of "naked" short selling and extended "fails to deliver" of outstanding short positions. Naked short selling is selling short without borrowing the necessary securities to make delivery, thus potentially resulting in a "fail to deliver" securities to the buyer. The fail to deliver typically occurs three business days after the naked short sale due to the "T+3" settlement used in the U.S. Boni (2006) finds that prior to Regulation SHO, a substantial fraction of issues (42% of listed stocks and 47% of unlisted stocks) had persistent fails to deliver of 5 days or more and these long-lived fails to delivers were more likely to occur when stocks were expensive to borrow. This is consistent with the fact that equity and options market makers strategically fail to deliver shares that are expensive or impossible to borrow (Evans et al. 2009).

Rule 203 of Regulation SHO creates a uniform rule requiring all broker-dealers to "locate" or borrow securities before executing short sales and to deliver upon and close-out short positions in which short sellers have prolonged fails to deliver. Rule 203 supplants existing overlapping Self-Regulatory Organizations (SRO) rules.[2] These requirements in

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[2] See appendix for a detailed comparison of locate and delivery requirement before and after Rule 203.

Rule 203 differ from SRO rules in several important aspects. For example, the mandatory close-out provision in NASD Rule 11830 only applies to Nasdaq securities. Rule 203 extends the close-out requirement to any equity security of an issuer that is registered under Section 12, or that is required to file reports pursuant to Section 15(d) of the Exchange Act (e.g. stocks listed on NYSE, AMEX, Nasdaq; OTCBB stocks; and stocks of Pink Sheet filers). Rule 203 also provides narrower exceptions from locate and close-out requirement for market participants (See appendix for detailed comparison of locate and close-out requirement before and after Regulation SHO). In addition, adopting uniform rules will further the goals of regulatory simplification and avoidance of regulatory arbitrage, as well as assist the Commission in its enforcement efforts regarding naked short selling activity (SEC Release No. 34-50103).[3]

Rule 203 increases the cost of taking short positions in the stock market. It would affect both the naked short sellers and covered short sellers. If the would-be naked short sellers continue to take short positions in the stock market after Rule 203 became effective, they have to bear search costs with locating and negotiating securities for lending, post margins and pay lending fees to the lender. They also face the risk of a short squeeze due to an involuntary closure of the stock loan (the short seller is unable to find an alternative supply of stock in the event that the loan is closed). As the additional demand for stock lending from the would-be naked short sellers will boost the stock lending fee, the short selling cost of existing covered short sellers is also likely to increase (Stratmann and Welborn 2013). If Rule 203 indeed represents an exogenous increase in short-sale costs, the short interests of optionable stocks are expected to decrease because some short sellers

[3] Examples of enforcement actions towards naked short selling can be found at: http://en.wikipedia.org/wiki/Naked_short_selling#Regulatory_enforcement_actions.

would leave the stock market and take short positions in the option market by buying put options or selling call options. However, if a stock has no exchange traded options, the above result is expected to be less pronounced because short sellers have no alternative trading venue but to remain in the stock market and bear higher short-sale costs (unless the short-sale cost is so high that the trading profit is negative). Consistent with my expectations, I find a significant decrease in the short interests of stocks with exchange traded options in the three months after the effective date of Rule 203, but no significant change for stocks without exchange traded options[4].

After verifying the validity of Rule 203 as an exogenous increase in short-sale costs, I examine the impact of Rule 203 on options trading volume. Consistent with the substitute relationship between equity short-sale and options trading, I find a significant increase in the trading volume of call options and put options after the implementation of Rule 203. Specifically, I find a 13.2% (21.8%) increase in call (put) options volume after controlling for firm characteristics, market conditions and industry fixed effects. Furthermore, I document that the positive impact of Rule 203 on options trading volume is more pronounced among firms with low institutional ownership and low option bid-ask spread. Institutional ownership is associated with the availability of shares that makes short selling feasible (e.g., see Nagel, 2005). These results suggest that short sellers are more likely to migrate to the option market when short selling in the stock market is less feasible and more costly, and when the option transaction costs are low.

The above results are in contrast with Grundy, Lim, and Verwijmeren (2012), which documents a complementary relation between equity short-sale and option trading during

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[4] Insignificant change in the short interest of stocks without exchange traded options does not imply no change in the short-sale cost of these stocks. The stock lending fee might increase.

2008 short sale ban. One important driver for the complementary relation is the substantial increase in the option bid-ask spread, which reduces investors' incentive to trade options when short-sale is prohibited. However, in the setting of Rule 203, I find no significant change in the option bid-ask spread. This explains and reconciles our findings.

Rule 202T of Regulation SHO is a temporary rule that allows the SEC to establish a pilot program to examine the efficacy of short-sale price tests, including the tick test for exchange-listed stocks and the bid test for Nasdaq National Market Stocks. The tick test mandates that a short-sale can only occur at a price above the most recently traded price (plus tick) or at the most recently traded price if that price exceeds the last different price (zero-plus tick). The bid test requires a short sale to occur at a price one penny above the bid price if the bid is a downtick from the previous bid. Previous research shows that short sellers can receive better prices as a result of the short-sale price test (Albert, Smaby, and Robison 1997). However, the tick test and bid test restrict the ability of short sellers to demand liquidity even in rising markets. This results in execution delays and lower fill rates (Alexander and Peterson 1999).

Under the pilot program, roughly 1,000 U.S. stocks—so called pilot stocks—were exempted from short-sale price tests from May 2, 2005 to August 6, 2007. The pilot stocks were drawn from the Russell 3000 index, comprising every third stock ranked by volume. The remaining Russell 3000 index securities were control stocks. Prior studies show that exemption from short-sale price tests decreased the cost of short selling in the pilot stocks relative to the control stocks (see the SEC's Office of Economic Analysis, 2007; Diether, Lee, and Werner, 2009). I confirm the above finding in my sample. Specifically, I document a significant increase in the short-sale volume of pilot stocks relative to that of control stock during the pilot program. In addition, the short trade frequency increases and short trade size decreases, suggesting that short sellers engage more heavily in order-splitting.

Next, I investigate the impact of removing short-sale price tests on options trading volume. When a short sale order is executed without price restrictions, will option traders be attracted to the stock market to take short position? I find no evidence that removing short-sale price tests have significant impact on option volume. There is also no significant change in the option bid-ask spread. Overall, although the exemption of short-sale price tests has significant impact on short selling activities in the stock market, it has little influence on the option market.

This paper is related to the literature on the impact of short-sale regulations on options market. Focusing on the most binding form of short-sale constraints-2008 short-sale ban of financial stocks, Grundy, Lim, and Verwijmeren (2012) find sizeable decreases in options trading volume and significant increases in options bid-ask spread for banned stocks. Their results suggest a complementary relation between equity-short sale and options trading when short-sale is prohibited. Stratmann and Welborn (2013) study the elimination of option market maker exception to Regulation SHO close-out requirement in September 2008, a follow-up amendment to the close-out requirement in Rule 203. They find that eliminating the exception leads to higher stock borrow rates for optionable stocks as compared to non-optionable stocks, and lower options trading volume. I contribute to this literature by studying two distinct rules of Regulation SHO: Rule 203 and Rule 202T. Both rules significantly affect short selling activities, as evidenced in the validity tests. However, their impact on options trading differs from each other and also from prior studies of other short-sale regulations. Specifically, I find a significant increase in options trading volume after the locate and close-out requirement was in place, but no significant change in options trading volume for stocks that were temporarily exempted from short-sale price tests. These results imply that short-sale constraints may not necessarily harm the transactional efficiency of the option market as documented in studies of 2008 short-sale ban (Battalio and Schulz (2011) and Grundy Lim, and Verwijmeren (2012)). Taken together with prior literature, these findings highlight the fact that the impact of short-sale regulations on options market varies with the type of short-sale constraints affected, the stringency of the regulation and its influence on option market makers.

This study also contributes to the literature on Regulation SHO. Evans et al. (2009, p. 1975) describes the locate and delivery requirement of Regulation SHO as "it has the potential to alter the cost of short exposure, so its impact is an important new empirical question". However, prior research of Regulation SHO mainly focuses on the pilot program of Rule 202T (e.g. Diether, Lee and Werner 2009; Alexander and Peterson 2008; SEC 2007), the effect of Rule 203 is largely ignored. To the best of my knowledge, this is the first study that examines the consequence of Rule 203. I contribute to this literature by documenting that Rule 203 indeed increases short-sale constraints, and it also has significant impact on the options market.

A contemporaneous paper by Lin and Lu (2014) also investigates the effect of short-sale constraints on options trading. Whereas I use exogenous shocks to short-sale constraints arising from Regulation SHO to identify the tests, Lin and Lu (2014) use stock lending fees as a proxy for short-sale costs. They find that the stock lending fee is positively associated with put options trading volume in general, and interpret the result as higher short-sale costs shift investors from the stock lending market to the option market. Although the stock lending fee is recently used by researchers as a proxy for short-sale costs (e.g. Saffi and Sturgess 2011; Johnson and So 2012), it is endogenously determined and thus may affect the interpretation of results. For example, a high stock lending fee may be driven by high demand for stock loans. The demand for stock loans is usually high when investors have negative view for future stock price. Investors with negative expectation may either short sell stocks or buy put options, leading to increase in stock lending fee and put options trading volume at the same. Therefore, a positive contemporaneous association between stock lending fees and put option trading volume may not necessarily reflects a shift from the stock lending market to the option market when facing high short-sale costs, but merely investors' negative expectation for the future stock price. By exploiting two short-sale rules that are exogenous, my study provides more direct evidence on how short-sale constraints affect options trading.

The paper is organized as follows. Section 2 is a brief introduction to short selling, and Rule 203 and Rule 202T of Regulation SHO. Section 3 describes the data and sample. Section 4 tests the validity of Rule 203 and Rule 202T as exogenous shocks to equity short-sale constraints. Section 5 examines the impact of Rule 203 and Rule 202T on options trading activity separately. Section 6 provides additional analysis, and Section 7 concludes.

2. Short Selling and Regulation SHO

2.1 Short selling

A short sale is the sale of a security that the seller does not own or any sale that is consummated by the delivery of a security borrowed by, or for the account of, the seller.

In general, short selling is used to profit from an expected downward price movement, to provide liquidity in response to unanticipated demand, or to hedge the risk of a long position in the same security or in a related security. Short selling is an important fraction of the stock trading activity. For example, Diether, Lee, and Werner (2008) find that short sales represent 31% of share volume for Nasdaq-listed stocks and 24% of share volume for NYSE-listed stocks in 2005.

The procedures of covered short selling are as follows. In order to deliver the security to the purchaser, the short seller will borrow the security, typically from a broker-dealer or an institutional investor and then sell it. While the short position is open, the lender requires collateral. This collateral (usually the proceeds from the sale) earns interest payable to the borrower at less than a normal market rate (rebate rate).The spread between the normal market rate and the rebate rate is the "lending fee" that the lender earns and the borrower pays. When closing a position, the short seller buys back equivalent shares in the market and returns them to the stock lender. The collateral is then returned to the borrower plus interest earned at the rebate rate. There is no set time frame on how long a covered short position can be held, provided the lender does not recall the stock and the trader can meet the margin requirements.

Naked short selling is selling short without first borrowing the necessary security or ensuring that the security can be borrowed to make delivery. In U.S. equity markets, sellers are required to deliver shares in return for payment by the third day following the transaction (‘‘T+3’’). Shares that are not delivered by T+3 are called failures-to-deliver. If the short-seller fails to deliver the shares to the buyer three days after the naked short sale, the clearing corporation intermediating the trade takes margin and marks it to market, thereby defending buyers against their sellers' nonperformance. In such cases naked short selling, then failing to deliver is economically equivalent to borrowing shares at a zero-fee zero-rebate equity loan plus the expected cost of being forced to buy back the stock and deliver it (a process called "buying-in"). As shown in Evans et al. (2009) and Boni (2006), the probability of buying-in is quite low. Therefore, if equity loans are expensive, unavailable or unreliable, as research shows they can be (e.g., D'Avolio, 2002; Geczy, Musto, and Reed, 2002; Jones and Lamont, 2002; Lamont, 2004) naked short selling and then failing to deliver is less costly than covered short selling. Evans et al. (2009) document that when borrowing costs are high, market makers sometimes choose not to borrow and instead naked short sell.

2.2 Regulation SHO

Regulation SHO provides a new regulatory framework governing short-selling of securities in U.S. equity markets. The rules were passed on September 7, 2004 and became effective on January 3, 2005. Regulation SHO was adopted to update short sale regulation in light of numerous market developments since short sale regulation was first adopted in 1938. Some of the goals of Regulation SHO includes: 1) establishing uniform locate and delivery requirements in order to address problems associated with failures to deliver, including potentially abusive "naked" short selling (Rule 203) temporarily suspending short sale price tests in a group of securities to evaluate the overall effectiveness and necessity of such restrictions (Rule 202T), and 3) creating uniform order marking requirements for sales of all equity securities. In this study, I focus on the impact of locate and delivery requirement and eliminating short sale price tests on options trading activity respectively.

2.2.1 Rule 203-"locate" and "delivery" requirement

Effective on January 3, 2005, Rule 203 imposes two key requirements: (1) the "locate" requirement prior to executing short sales; and (2) the delivery requirement for closing out short positions in "threshold securities" that are the subject of extended fails to deliver[5]. The locate requirement of Rule 203 prohibits a broker-dealer from executing a short sale order for its own account or the account of another person, unless the broker-dealer, or the person for whose account the short sale is executed (1) borrowed the security, or entered into an arrangement for the borrowing of the security, or (2) had reasonable grounds to believe that it could borrow the security so that it would be capable of delivering the securities on the date delivery is due. The delivery (or close-out) requirement of Rule 203 mandates any participant of a registered clearing agency (*e.g.*, clearing brokers) to close-out any fail-to-deliver in "threshold securities"[6] by purchasing securities of like kind and quantity 10 days after the normal settlement date, *i.e.*, 13 consecutive days after the transaction.

Short sales executed by market makers, including specialists and options market makers, are exempt from the locate requirement. They are not exempt from the close-out provisions, however. Nor are they exempt from the prior-borrowing requirement for additional short sales by those with extended fails in threshold securities. There is a limited

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[5] Prior to the implementation of Regulation SHO, Self-Regulatory Organizations ("SRO") had enacted several rules designed to prevent abusive naked short-selling practices and fails to deliver. However, the SEC considered existing SRO rules as inadequate to prevent abusive short selling and extended fails to deliver.

[6] Rule 203(c)(6) defines “threshold securities” as the securities of publicly traded and reporting issuers in which: (1) For five consecutive settlement days have aggregate fails to deliver at a registered clearing agency of 10,000 shares or more; (2) The volume of fails in a security is equal to at least one-half of one percent of the reported total shares outstanding in the security; and (3) The security is included on a SRO list identifying securities that exceed specified fail levels.

exemption from close-out requirement for options market makers that hedge options positions ("bona-fide market making") established prior to the security's achieving threshold status.[7] According to the SEC, the options market maker exception was created to address concerns regarding liquidity and the pricing of options. When option market makers sell put options or buy call options they are in a long position. They can hedge their long options position by selling short the underlying equity. The exception allowed option market makers to hedge the risk of long options positions for the duration of an options contract if unable to borrow, which allowed them to delay short sale close-out until options expiration if necessary.

2.2.2 Rule 202T- eliminating short sale price tests

Short-sale price tests were initially introduced to the U.S. equity markets in 1930s, ostensibly to avoid bear raids by short sellers in declining markets. The NYSE adopted an uptick rule in 1935, which was replaced in 1938 by a stricter SEC rule, Rule 10a-1, also known as the "tick test". The rule mandates that a short-sale can only occur at a price above the most recently traded price (plus tick) or at the most recently traded price if that price exceeds the last different price (zero-plus tick). In 1994, the NASD also adopted its own price test ("bid test") under Rule 3350. Rule 3350 requires a short sale to occur at a price one penny above the bid price if the bid is a downtick from the previous bid.

[7] Bona-fide market making does not include activity that is related to speculative selling strategies or investment purposes of the broker-dealer and is disproportionate to the usual market making patterns or practices of the broker-dealer in that security. In addition, where a market maker posts continually at or near the best offer, but does not also post at or near the best bid, the market maker's activities would not generally qualify as bona-fide market making for purposes of the exception. Further, bona-fide market making does not include transactions whereby a market maker enters into an arrangement with another broker-dealer or customer in an attempt to use the market maker's exception for the purpose of avoiding compliance with Rule 203 by the other broker-dealer or customer.

Rule 202T of Regulation SHO is a temporary rule that allows the SEC to establish, through separate orders, a pilot program to examine the efficacy of price restrictions. On May 2, 2005, roughly 1,000 U.S. stocks—so called pilot stocks—began to trade without short-sale price tests (tick test for the NYSE and bid price test for Nasdaq). These stocks were selected by the SEC to represent a broad cross-section of the U.S. equity market. The pilot stocks were drawn from the Russell 3000 index, comprising every third stock ranked by volume. The remaining Russell 3000 index securities were control stocks. The experiment was designed by the SEC to investigate whether Rule 10a-1, NYSE's Uptick rule, and Nasdaq's bid price test affect market quality, and to develop uniform price tests if such rules were deemed necessary going forward. The temporary suspension was originally set to expire on April 28, 2006, but was extended to August 6, 2007.

Most evidence indicates that the price tests work to constrain short selling. For example, Angel (1997) and Alexander and Peterson (1999) show that Rule 10a-1 impedes short selling by delaying order execution and lowering fill rates, even in rising markets. McCormick and Reilly (1996) find that Rule 3350 curtails short selling for Nasdaq NMS stocks during declining markets. Diether, Lee, and Werner (2009) show that pilot stocks listed on both the NYSE and Nasdaq experienced a significant increase in short selling activity during the pilot program. These stocks had more frequent short-sale trades and a greater short sales-to-share volume ratio during the term of the pilot program. Moreover, NYSE-listed pilot stocks experienced a higher level of order-splitting (i.e., short-sale trades with smaller trade size), suggesting that short sellers applied more active trading strategies.

In summary, previous research shows that short sellers can receive better prices as a result of the tick test and that the tick test does not impede profit opportunities. However, the tick test and bid test restrict the ability of short sellers to demand liquidity even in rising markets.

3. Data and Sample

3.1 Data

Options data is from OptionMetrics, which provides end of day bid and ask quotes, open interest, volume, implied volatilities and option Greeks for all put and call options listed in the U.S. option market. OptionMetrics calculates the underlying implied volatilities of individual options based on binomial trees that account for early exercise of individual stock options and the dividends expected to be paid over the lives of the options. To alleviate the influence of illiquid options, I require the following criteria (Grundy, Lim, and Verwijmeren (2012)): 1) the open interest is positive; 2) the time to expiration is between 7 and 365 calendar days; 3) the option relative bid-ask spread is no greater than 0.5; and 4) the option's best closing ask is no less than the best closing bid.

The stock trading data are from the Center for Research in Security Prices (CRSP). The general accounting data and monthly short interests data are provided by Compustat. I also download intraday data from all self-regulatory organizations (SROs) that report short sales for NYSE- and Nasdaq-listed securities and compute the daily number of shares sold short (both in absolute terms and as a fraction of stock trading volume), short trade size and number of short trades each day.

3.2 Sample and descriptive statistics

3.2.1 Rule 203 sample

The Rule 203 became effective on Jan 3, 2005. The Rule 203 sample covers the period from October 1, 2004 through March 31, 2005, including 125 trading days around the effective date. The sample consists of stocks in the 2004 Russell 3000 index with listed options. After merging with necessary option, stock and firm related data, the resulting sample contains 1040 firms.

[Insert Table 3.1 here]

Panel A of Table 1 reports firm characteristics. There are 127,411 firm-day observations. The mean firm size (market capitalization) is 9.06 billion dollars. The mean daily stock trading volume is 1.68 million. The mean institutional ownership is 75%. Panel B reports the option characteristics. There are 1,435,480 (1,284,064) call (put) option-day observations. The mean and standard deviation of call (put) option relative bid-ask spread are 0.115 and 0.110 (0.136 and 0.121). The mean implied volatility of call (put) options is 0.351 (0.363). The mean time-to-maturity of call (put) options is 129 calendar days. The daily trading volume per option is highly skewed, with mean of 92 (63) and median of 0 (0) for call (put) options. The daily aggregated option trading volume at stock level is on average 1,044 for call options and 645 for put options.

3.2.2 Rule 202T sample

The pilot program started from May 2, 2005 and ended on August 6, 2007. Consistent with the Rule 203 sample, I choose the 6 months around the effective date as the sample period, i.e. February 1, 2005 through July 31, 2005.The initial sample includes all pilot stocks as defined by the Securities Exchange Act Release No. 50104 (July 28, 2004), 69 FR 48032 (August 6, 2004). The remaining Russell 3000 securities are included as control stocks. To eliminate the potential confounding influence of index inclusion or index exclusion, I require that sample stocks be members of the Russell 3000 index after the June 2004 reconstitution and remain members of the Russell 3000 index after the June 2005 reconstitution. After merging with necessary option, stock and firm related data, the resulting sample contains 1049 firms, with 362 pilot firms and 687 control firms.

[Insert Table 3.2 here]

Panel A of Table 2 reports firm characteristics for both pilot stocks and control stocks. There are 44,424 pilot firm-day observations and 84,325 control firm-day observations. The two groups exhibit similar mean and median values of firm size, stock price, book-to-market ratio, daily stock trading volume, stock return volatility, stock return skew and institutional ownership. Panel B shows option characteristics. I find that pilot firms and control firms are quite comparable in terms of the option relative bid-ask spread, implied volatility, time-to-maturity and option trading volume. Summary statistics from Panels A and B support the contention that Regulation SHO's pilot program is a well-controlled experiment that is suitable for examining the effects of short-sale constraints.

4. The Validity of Regulation SHO as Exogenous Shocks to Short-sale Constraints

Before investigating the impact of Rule 203 and Rule 202T on options market, I first examine whether these rules do affect short-sale constraints by testing the change of short interests or short-sale volume before and after the implementation of the rules. Section 4.1 examines the validity of Rule 203 as an exogenous increase in short-sale constraints. Section 4.2 examines the validity of Rule 202T as an exogenous decrease in short-sale constraints.

4.1 Does short selling decrease after Rule 203?

To examine the validity of Rule 203 as exogenous increase to short-sale constraints, I test the change of relative short interests[8] before and after the effective date of Rule 203 (Jan 3, 2005). If locate and close-out requirement increases short-sale constraints, then there will be a decrease in short interests after the implementation of Rule 203. In addition, the decrease in short interests is expected to be larger for stocks with exchange traded options than those without. The rationale is that the would-be naked short sellers of stocks with exchange traded options could stay in the stock market and do covered short selling, or move to the options market, or do not trade at all, but the naked short sellers of stocks without exchange traded options could only stay in the stock market or quit trading.

[Insert Table 3.3 here]

Table 3 shows the impact of Rule 203 on relative short interests for optionable and non-optionable stocks in 2004 Russell 3000 index. The dependent variable is the short interest scaled by shares outstanding (in percentage). The control variables include firm size, book-to-market ratio, stock bid-ask spread, stock turnover, last month stock return, stock return volatility, stock return skew, institutional ownership and Fama-French 12-industry fixed effects. The standard errors are two-way clustered by firm and date. The first column shows how short interests change after Rule 203 for stocks with exchange traded options. I find a negative and significant coefficient on Rule203, suggesting a significant decrease in short interests under the locate and delivery requirement. This result supports

[8] Short interest data is on a monthly basis. Daily short sale volume data is not available before year 2005.

the argument that the locate and delivery requirement of Rule 203 increases short sale costs and therefore reduces short selling activities.

There are two possible explanations for the decrease in short interests: first, in face of higher short sale costs, the would-be naked short sellers will migrate to the options market and take short positions by buying put options or selling call options; second, the would-be naked short sellers quit the market and do not trade at all. To differentiate these two explanations, I further test how short interests of non-optionable stocks change after Rule 203. A significant decrease in the short interests of non-optionable stocks would lend support to the second explanation while no significant change would be in favor of the first explanation. Results from the second column shows a positive but insignificant coefficient on Rule203, suggesting no significant change in short interests of non-optionable stocks after Rule 203. This supports the first explanation and provides preliminary evidence for the substitution relation between short-sale and option trading.

4.2 Does short selling increase after Rule 202T?

To examine the validity of Rule 202T as exogenous decrease to short-sale constraints of pilot stocks, I test the change of the short-sale activity of pilot stocks (relative to control stocks) before and during the pilot program. If the removal of short-sale price tests relaxes short-sale constraints, then there will be an increase in short-sale volume of pilot stocks (relative to that of control stocks) after the effective date of the pilot program (May 2, 2005).

[Insert Table 3.4 here]

I first show the univariate comparison of short selling activities of pilot stocks and control stocks before and during the pilot program. Panel A of Table 4 shows the mean and median of the daily short sale volume, short sale volume as a fraction of stock trading volume and short trade size for pilot stocks and control stocks during the 3 months before and 3 months after the start of the pilot program. For pilot stocks, the mean and median of the number of shares sold are similar before and during the pilot program. However, there is a slight decrease in the number of shares sold short of control firms. As to the relative short sales (short sale volume divided by stock trading volume), I find a slight increase in the both the mean and median values for pilot stocks, but not for control stocks. In addition, I find there is about 15% decrease in the short trade size for pilot stocks and only 4% decrease for control stocks. Therefore, the univariate comparison suggests that after removing short sale price tests, short sale volume increases and short sellers engage more heavily in order-splitting.

Next, I test the statistical significance of the change of short sale volume in regression analysis. Results are reported in Panel B of Table 4. The dependent variable is the number of shares sold short (in thousands). The variable of interest is *PilotStock**Post*, which is the interaction between pilot stock dummy and Post dummy. As shown in Column 1, without adding any control variables, the coefficient of *PilotStock**Post* is positive and significant (t-statistic=6.96). This suggests that the short sale volume of pilot stocks increases significantly (relative to that of control stocks) after removing short sale price tests. As to the economic magnitude, the relative increase in short sale volume of pilot stocks is about 4.4% of the mean short sale volume during the 3-months before the pilot program. Then I add control variables to the above regression to test whether the result still holds. The control variables include firm size, market-to-book ratio, stock bid-ask spread, stock trading volume, last month stock return, stock return volatility, stock return skew and institutional ownership. As shown in Column 2, the coefficient of *PilotStock**Post* is still positive and significant (t-statistic=2.31). The coefficient is even larger after adding control variables, increasing from 12.55 to 20.87. After controlling for firm and stock related characteristics, the relative increase in the short sale volume of pilot stocks is about 7.2% of the mean short sale volume during the 3-months before the pilot program. Overall, the significant increase in the short-sale volume of pilot stocks supports the use of the pilot program as an exogenous decrease to the cost of selling short in pilot firms.

5. How does Regulation SHO Affect Options Trading Volume?

5.1 The impact of Rule 203 on the options trading volume

5.1.1 Multivariate analysis

Rule 203 of Regulation SHO requires all broker-dealers to "locate" or borrow securities before executing short sales and to deliver upon and close-out short positions in which short sellers have prolonged fails to deliver. Consequently, naked short selling is expected to decrease under Rule 203. If the would-be naked short sellers continue to take short positions in the stock market, they have to bear search costs with locating and negotiating securities for lending, post margins and pay lending fees to the lender. They also face risk of a short squeeze due to an involuntary closure of the stock loan (the short seller is unable to find an alternative supply of stock in the event that the loan is closed). Given the exogenous increase in short-sale costs due to the locate and close-out requirement, some of the would-be naked short sellers will migrate to the options market to take short positions by either buying put options or selling call options. My first hypothesis is that there will be an increase in the options trading volume after the implementation of Rule 203. To test this hypothesis, I perform the following pooled OLS regressions:

$$\begin{aligned} OptionVolume = {} & \beta_0 + \beta_1 Rule203b + \beta_2 Ln(Size) + \beta_3 BM + \beta_4 Stockbasp + \beta_5 Stockvolume \\ & + \beta_6 Lagreturn + \beta_7 Volatility + \beta_8 Skewness + \beta_9 IO + \beta_{10} VIX + \beta_{11} Marketret \\ & + \beta_{12} Stockret + IndustryFixedEffects + \varepsilon \end{aligned} \tag{1}$$

In model (1), I regress the daily aggregated option trading volume (in thousands) on the dummy variable for Rule 203. The control variables include a series of firm-level characteristics and market-level conditions, i.e., the natural logarithm of firm size at the end of the last calendar month; the book-to-market ratio at the end of the last calendar year; the stock bid-ask spread, defined as the closing ask less the closing bid and divided by the midpoint; the daily stock trading volume; the daily stock return; the cumulative stock return over the previous month; stock return volatility in the previous month; the skewness of daily stock returns in the previous month; the institutional ownership ratio, which is defined as institutional holdings divided by the total number of shares outstanding at the last quarter end; the market uncertainty proxied by the VIX, and the market return measured by the return on the S&P 500 Index. Fama-French 12 industry fixed effects are also included. The estimated standard errors are two-way clustered by firm and date.

I expect a significant and positive coefficient on Rule203 in the option volume regression. Such a finding would suggest that an increase in short-sale costs after Rule 203 is accompanied by an increase in option trading volume, supporting the substitution relationship between short-sale and option trading.

[Insert Table 3.5 here]

Table 5 presents the estimated coefficients for option volume regressions (at stock-level). The dependent variable is the daily aggregated option trading volume (in thousands). The results for calls and puts are reported separately. For call options, the coefficient of Rule203 is significantly positive (Coef=0.131, t-statistic=2.09). This indicates that the daily call option trading volume on average is increased by 131 or 13.2%[9] after Rule 203. For put options, the coefficient of Rule203 is also significantly positive (Coef=0.128, t-statistic=3.10). This indicates that the daily put option trading volume on average is increased by 128 or 21.8%[10]. Overall, I find that as short-sale costs increase after Rule 203, investors would shift their demand from stock market to the option market. In addition, the larger proportionate increase in put options volume relative to call options volume implies that buying put options is preferred to selling call options as substitute for shorting stocks.

5.1.2 Multivariate analysis partitioned by institutional ownership

In this section, I investigate whether the positive effect of Rule 203 on option trading volume is related to the level of institutional ownership in the firm. Institutional ownership is associated with the availability of shares that makes short selling feasible. When institutional ownership is low, stock loan supply tends to be sparse and stock lending is more expensive (e.g., see Nagel, 2005; Chen, Hong, and Stein, 2002; Hirshleifer, Teoh, and Yu, 2011). This will affect the positive effect of Rule 203 on option trading volume in two possible ways (that are not exclusive to each other): first, the scarcity and expensiveness of stock loan in firms with low institutional ownership will lead to a higher

[9] 131/998=13.2%, where 998 is the mean value of daily call option trading volume in the 3-month period before the implementation of Rule 203.

[10] 128/588=21.8%, where 588 is the mean value of daily put option trading volume in the 3-month period before the implementation of Rule 203.

level of naked short selling before the locate and delivery requirement is in place (Boni 2006)[11]. Rule 203, which intends to curb naked short selling, is expected to have more pronounced effect on firms with higher level of naked short selling before the rule takes effect. Thus, I expect the positive impact of Rule 203 on option trading volume to be higher among firms with low institutional ownership. Second, the decision of would-be naked short sellers to migrate to the option market depends on the incremental costs related to covered short selling (such as searching costs, stock lending fees etc.). For stocks that are easy to borrow, the increase in options trading volume will be smaller because the incremental cost associated with covered short selling is small and short sellers are more likely to stay in stock market and do covered short selling. Stated differently, the positive impact of Rule 203 on options trading volume is expected to be greater for firms with low institutional ownership since the incremental cost associated with covered short selling is larger and this may drive investors to the option market.

To test this conjecture, I partition the sample into two subsamples based on whether a firm's institutional ownership is above the sample median. Institutional ownership is retrieved from Thomson's CDA/Spectrum database (form 13F) and aggregated on the firm level. I define institutional ownership as the shares held by all institutions divided by the total shares outstanding at the end of the quarter from CRSP monthly files.

[Insert Table 3.6 here]

Table 6 reports the results from re-estimating model (1) using these two subsamples. Results for call options and put options are displayed separately. Consistent with my

[11] Boni (2006) documents that likelihood of persistent fails-to-deliver (a proxy for naked short selling) decreases with institutional ownership.

conjecture, the impact of Rule 203 on options trading volume is more pronounced among firms with low levels of institutional ownership. In fact, the evidence in Columns (2) and (4) indicates that there is no significant effect among firms with above median levels of institutional ownership. The results hold for both call options and put options, and are stronger for put options. Among firms with low levels of institutional ownership, the magnitude of the effect is about 36% (74%) higher than that reported in Table 5 for the overall call (put) option sample.

5.1.3 Multivariate analysis partitioned by option transaction costs

As widely documented in the literature, the transaction cost (bid-ask spread) in options market is much higher than that in the stock market. For example, Li, Gonvindaraj and Zhao (2015) show that the relative bid-ask spread of liquid at-the-money options is on average as high as 20%; in contrast, the average relative bid-ask spread of the underlying stocks is only 0.6%. As option transaction costs directly reduce the profit of trading options, it will affect whether investors will trade in stock market or option market (e.g. Easely and Srinivas 1998; Chakravarty, Gulen and Mayhew 2004). The larger the bid-ask spread in the option market, the less likely that investors will choose options market. Consequently, I expect the positive impact of Rule 203 on options trading volume to be more pronounced for firms with low option bid-ask spread.

To test this conjecture, I partition the sample of into two subsamples based on whether a firm's daily equal-weighted option bid-ask spread is above the sample median. For each option contract, the bid-ask spread is calculated as the end-of-day ask price minus the bid price then divided by the mid-point. It is then aggregated at stock-day level by taking the equal-weighted average across all call (put) options with the same underlying stock.

[Insert Table 3.7 here]

Table 7 reports the results from re-estimating model (1) using these two subsamples. Results for call options and put options are displayed separately. Consistent with my conjecture, the impact of Rule 203 on options trading volume is more pronounced among firms with lower option bid-ask spread. In fact, the evidence in Columns (2) and (4) indicates that there is no significant effect among firms with above median value of option bid-ask spread. The results hold for both call options and put options, but are much stronger for put options. Among firms with low option bid-ask spread, the magnitude of the effect is about 19% (108%) higher than that reported in Table 5 for the overall call (put) option sample.

5.2 The impact of Rule 202T on the options trading volume

Under the pilot program of Rule 202T, pilot stocks are traded without short-sale price tests. The increase in short-sale volume of pilot stocks provides evidence that removing price tests reduces short sale constraints. In this subsection, I investigate whether investors would migrate from options market to stock market when they are faced with lower short-sale constraints due to the removal of price tests. To test this, I perform the following pooled OLS regression:

$$\begin{aligned} OptionVolume = {} & \beta_0 + \beta_1 PilotStock * Post + \beta_2 PilotStock + \beta_3 Post + \beta_4 Ln(Size) + \beta_5 BM \\ & + \beta_6 Stockbasp + \beta_7 Stockvolume + \beta_8 Lagreturn + \beta_9 Volatility + \beta_{10} Skewness \\ & + \beta_9 IO + \beta_{10} VIX + \beta_{11} Marketret + \beta_{12} Stockret + IndustryFixedEffects + \varepsilon \qquad (2) \end{aligned}$$

In Model (2), the dependent variable is the option trading volume aggregated over all classes of options for each underlying stock on a daily basis (in thousands). PilotStock is an indicator variable, which is equal to 1 for pilot firms and 0 for control firms. Post is an indicator variable, which is equal to 1 for the 3-months immediately after the effective date of the pilot program and 0 for the 3-months before the effective date. The variable of interest is *PilotStock*Post,* which is the interaction between *PilotStock* and *Post*. A negative and significant coefficient on *PilotStock*Post* indicates that the removal of price tests drives investors from the option market to the stock market. The control variables are the same as those in regression (1). The coefficients are estimated using daily stock-level data. The estimated standard errors are two-way clustered by firm and date.

[Insert Table 3.8 Here]

Table 8 presents the estimated coefficients for Model (2). The dependent variable is the daily aggregated option trading volume (in thousands). The results for calls and puts are reported separately. Without adding any control variables, the coefficient of *PilotStock***Post* is negative but insignificant for both call options and put options, as shown in Columns 1 and 3. After controlling for firms characteristics, market conditions and Fama-French 12-industry fixed effects, the coefficients on *PilotStock***Post* are still negative and insignificant (as shown in Columns 2 and 4). Overall, the option trading volume results provide no statistical evidence that decrease in short sale constraints as a result of the removal of price tests would drive investors away from option market and to the equity market to trade.

6. Additional Analysis

6.1 The impact of Rule 203 on options bid-ask spread

During the 2008 short sale ban, researchers find a substantial increase in the option bid-ask spread resulting from the higher hedging cost of option market makers (Battalio and Schultz 2011; Grundy, Lim, and Verwijmeren 2012). The significant increase in option bid-ask spread further discourages option trading volume and leads to a complementary relation between short-sale and options trading.

In this section, I examine whether there is a significant change of option bid-ask spread after the implementation of Rule 203. As option market makers are exempted from the locate and certain close-out requirement when doing bona-fide market making, the hedging cost of market makers will not change significantly. Consequently, I expect no significant change in the option bid-ask spread after the implementation of Rule 203. To test this conjecture, I perform the following pooled OLS regression at the option-day level:

$$\begin{aligned} Basp = {} & \beta_0 + \beta_1 Rule203 + \beta_2 D \times Moneyness + \beta_3 [D \times Moneyness]^2 \\ & + \beta_4 (1-D) \times Moneyness + \beta_5 [(1-D) \times Moneyness]^2 + \beta_6 (Maturity)^{-1} \\ & + \beta_7 Ln(Size) + \beta_8 BM + \beta_9 Stockbasp + \beta_{10} Stockvolume + \beta_{11} Lagreturn \\ & + \beta_{12} Volatility + \beta_{13} Skewness + \beta_{14} IO + \beta_{15} VIX + \beta_{16} Marketret \\ & + \beta_{17} Stockret + IndustryFixedEffects + \varepsilon \end{aligned} \tag{3}$$

In model (3), the option relative bid-ask spread is regressed on the dummy variable for Rule 203. Option relative bid-ask spread is defined as the closing ask price minus the closing bid price and then divided by the midpoint. Following Grundy, Lim, and Verwijmeren (2012), I control for various option-level characteristics. D is a dummy variable that equals 1 if the option strike price is no greater than the underlying stock price and 0 otherwise. Moneyness is defined as $Ln(StockPrice / StrikePrice) / (IV_{ATM} * \sqrt{Maturity})$, where IV_{ATM} is the implied volatility of the at-the-money options on the same stock with an identical observation date, strike price and expiration date. This variable describes how much an option is in or out of the money. Maturity is the number of days to the option's expiration date. In addition, I control for the same firm-level and market-level explanatory variables that I use in regression (1). In both regressions, Fama-French 12 industry fixed effects are also included. The estimated standard errors are two-way clustered by firm and date.

[Insert Table 3.9 here]

Table 9 presents the estimated coefficients for option relative bid-ask spread regressions (at option-level). The results for call options and put options are reported separately. In contrast to the significant increase in options bid-ask spread during 2008 short sale ban, I find no significant change of the relative bid-ask spread after Rule 203 for both call options and put options. This reconciles my finding that short-sale and options trading are substitutes in the setting of Rule 203, with studies that show complements in the setting of 2008 short sale ban.

6.2 The impact of Rule 202T on options bid-ask spread

In this section, I examine whether there is a significant change of option bid-ask spread of pilot stocks (relative to that of control stocks) during the pilot program. To test this, I perform the following pooled OLS regression:

$$\begin{aligned}Basp = \beta_0 + \beta_1 PilotStock*Post + \beta_2 PilotStock + \beta_3 Post + \beta_4 D\times Moneyness \\ + \beta_5[D\times Moneyness]^2 + \beta_6(1-D)\times Moneyness + \beta_7[(1-D)\times Moneyness]^2 \\ + \beta_8(Maturity)^{-1} + \beta_9 Ln(Size) + \beta_{10}BM + \beta_{11}Stockbasp + \beta_{12}Stockvolume \\ + \beta_{13}Lagreturn + \beta_{14}Volatility + \beta_{15}Skewness + \beta_{16}IO + \beta_{17}VIX + \beta_{18}Marketret \\ + \beta_{19}Stockret + IndustryFixedEffects + \varepsilon\end{aligned} \quad (4)$$

In regression (4), the dependent variable is the option relative bid-ask spread, defined as the closing ask price minus the closing bid price and then divided by the midpoint. The variable of interest is *PilotStock**Post*. A negative coefficient on *PilotStock**Post* suggests that market makers decreases the option bid-ask spread after the lifting of short-sale price restrictions. The control variables are the same as those in Model (3). The coefficients are estimated using daily option-level data. The estimated standard errors are two-way clustered by firm and date.

[Insert Table 3.10 here]

Table 10 presents the estimated coefficients for option relative bid-ask spread regressions. The results for call (put) options are reported in the first (last) two columns. Without adding any control variables, the coefficient of *PilotStock**Post* is positive but insignificant for both call options and put options, as shown in Columns1 and 3. After controlling for option characteristics, firms characteristics, market conditions and Fama-French 12 industry fixed effects, the coefficients on *PilotStock**Post* are still positive but insignificant (as shown in Columns 2 and 4). Thus, I find no evidence that pilot firms experience significant change in option bid-ask spread during the first 3-months of the pilot program (relative to control firms).

7. Conclusion

This study investigates the effect of stock short-sale constraints on options trading by exploiting two SEC rules under Regulation SHO: Rule 203 and Rule 202T. Rule 203 creates a uniform rule requiring all broker-dealers to “locate” or borrow securities before executing short sales and to deliver upon and close-out short positions in which short sellers have prolonged fails to deliver. Consistent with the conjecture that Rule 203 tightens short-sale constraints, I find a significant decrease in short interests of optionable stocks after Rule 203 became effective. The trading volume of call options and put options increases significantly after the implementation of Rule 203. This results is more pronounced among firms with low levels of institutional ownership and smaller option bid-ask spread. Rule 202T of Regulation SHO is a temporary rule that allows the SEC to establish, through separate orders, a pilot program to examine the efficacy of short-sale price tests. During the pilot program, pilot stocks are traded without short-sale price tests and control stocks are traded with price restrictions. I find a significant increase in the short-sale volume of pilot stocks relative to that of control stocks, supporting the validity of Rule 202T as exogenous decrease in short-sale constraints of pilot stocks. Although exemption of short-sale price tests relaxes short sale constraints, I find no significant change in the options trading volume of pilot stocks (relative to control stocks) during the pilot program of Rule 202T.

Table 3.1: Summary statistics of Rule 203 sample

This table reports the summary statistics of Rule 203 sample. Panel A displays firm characteristics and Panel B shows characteristics for call options and put options. Size is the market value of equity, expressed in billion dollars. Stock price is the end-of-day stock price. BM ratio is the book-to-market ratio at the end of the last calendar year. Stock volume is the daily stock trading volume, expressed in millions. Stock return volatility is the standard deviation of daily returns in the previous month multiplied by square root of 252/30 (annualized). Stock return skew is the skewness of daily stock returns over the previous month. Institutional ownership is defined as institutional holdings divided by the total number of outstanding at the last quarter end. Relative bid-ask spread is defined as the closing option ask price minus the closing bid price and then divided by the midpoint. Implied volatility is the implied volatility of at-the-money options on the same stock with an identical observation date, strike price and expiration date. Time-to-maturity is the number of days to expiration. Trading volume per option is the daily option trading volume for each option contract. Trading volume per stock is the daily aggregated option trading volume for the same underlying stock.

Panel A: Firm characteristics

Variable	N	Mean	SD	5th	25th	Median	75th	95th
Size (in billions $)	127,411	9.06	27.08	0.28	0.82	2.11	6.32	32.21
Stock Price	127,411	33.59	20.28	6.85	17.9	30.59	44.75	71.2
BM Ratio	127,411	0.40	0.26	0.09	0.23	0.36	0.54	0.83
Stock Volume (in millions)	127,411	1.68	5.49	0.08	0.24	0.54	1.34	5.55
Stock Return Volatility	127,411	0.33	0.15	0.16	0.22	0.30	0.42	0.62
Stock Return Skew	127,411	0.14	1.01	-1.43	-0.36	0.12	0.61	1.84
Institutional Ownership	127,411	0.75	0.20	0.38	0.63	0.78	0.89	1.00

Panel B: Option characteristics

	Call Options				Put Options			
	N	Mean	Median	SD	N	Mean	Median	SD
Relative Bid-ask Spread	1,435,480	0.115	0.074	0.110	1,284,064	0.136	0.092	0.121
Implied Volatility	1,435,480	0.351	0.323	0.153	1,284,064	0.363	0.329	0.166
Time-to-maturity	1,435,480	129	116	87	1,284,064	131	117	88
Trading volume per option	1,435,480	92	0	767	1,284,064	63	0	469
Trading volume per stock	126,637	1,044	41	5,027	124,571	645	11	2,860

Table 3.2: Summary statistics of Rule 202T sample

This table reports the summary statistics of Rule 203T sample. Panel A displays firm characteristics and Panel B shows characteristics for call options and put options. Size is the market value of equity, expressed in billion dollars. Stock price is the end-of-day stock price. BM ratio is the book-to-market ratio at the end of the last calendar year. Stock volume is the daily stock trading volume, expressed in millions. Stock return volatility is the standard deviation of daily returns in the previous month multiplied by square root of 252/30 (annualized). Stock return skew is the skewness of daily stock returns over the previous month. Institutional ownership is defined as institutional holdings divided by the total number of outstanding at the last quarter end. Relative bid-ask spread is defined as the closing option ask price minus the closing bid price and then divided by the midpoint. Implied volatility is the implied volatility of at-the-money options on the same stock with an identical observation date, strike price and expiration date. Time-to-maturity is the number of days to expiration. Trading volume per option is the daily option trading volume for each option contract. Trading volume per stock is the daily aggregated option trading volume for the same underlying stock.

Panel A: Firm characteristics

Variable	N	Mean	SD	5th	25th	Median	75th	95th
					Pilot Firms			
Size (in billions $)	44,424	9.01	23.91	0.26	0.81	2.06	6.84	42.07
Stock Price	44,424	32.93	20.32	6.52	17.5	29.69	44.13	71.92
BM Ratio	44,424	0.40	0.25	0.10	0.23	0.37	0.55	0.86
Stock Volume (in millions)	44,424	1.69	5.09	0.09	0.26	0.56	1.33	5.82
Stock Return Volatility	44,424	0.34	0.14	0.16	0.22	0.31	0.42	0.59
Stock Return Skew	44,424	0.17	0.99	-1.35	-0.3	0.16	0.64	1.8
Institutional Ownership	44,424	0.75	0.22	0.34	0.62	0.78	0.90	1.00
					Control Firms			
Size (in billions $)	84,325	9.30	28.8	0.28	0.88	2.23	6.27	32.13
Stock Price	84,325	34.59	20.81	6.30	18.62	31.97	46.36	73.53
BM Ratio	84,325	0.41	0.28	0.09	0.24	0.36	0.55	0.87
Stock Volume (in millions)	84,325	1.65	4.87	0.09	0.25	0.56	1.38	5.47
Stock Return Volatility	84,325	0.32	0.14	0.16	0.21	0.29	0.39	0.6
Stock Return Skew	84,325	0.18	0.99	-1.35	-0.31	0.15	0.64	1.86
Institutional Ownership	84,325	0.77	0.2	0.41	0.66	0.80	0.91	1.00

Panel B: Option characteristics

	Call Options				Put Options			
	N	Mean	Median	SD	N	Mean	Median	SD
				Pilot Firms				
Bid-ask Spread	529,702	0.118	0.075	0.112	483,460	0.133	0.088	0.120
Implied Volatility	529,702	0.343	0.318	0.141	483,460	0.36	0.327	0.166
Time-to-maturity	529,702	145	141	89	483,460	144	138	90
Trading Volume per Option	529,702	91	0	883	483,460	64	0	453
Trading Volume per Stock	43,933	1098	43	5002	43,521	710	13	2884
				Control Firms				
Bid-ask Spread	986,897	0.116	0.074	0.112	889,972	0.137	0.092	0.121
Implied Volatility	986,897	0.327	0.302	0.133	889,972	0.34	0.309	0.153
Time-to-maturity	986,897	143	137	88	889,972	144	138	89
Trading Volume per Option	986,897	85	0	675	889,972	61	0	478
Trading Volume per Stock	83,466	1009	43	4555	82,333	661	15	3051

Table 3.3: How does Rule 203 influence the short selling activity?

In this table, I show the impact of Regulation SHO-Rule 203 on short interests. The dependent variable is the short interest as of the midmonth reporting date scaled by shares outstanding, expressed in percentage. Rule203 is a dummy variable, which is equal to 1 if the observation date is between Jan 1, 2005 and March 31, 2005, and equal to 0 if the observation date is between Oct 1, 2004 and Dec 31, 2005. Ln (Size) is the natural logarithm of firm size at the end of the last calendar month. BM ratio is the book-to-market ratio at the end of the last calendar year. Stock bid-ask spread is defined as the closing ask less the closing bid and divided by the midpoint (expressed in percentage), averaged over the prior month. Stock turnover is the daily stock volume divided by shares outstanding (expressed in percentage), averaged over the prior month. Last month stock return is the cumulative stock return over the last month. Stock return volatility is calculated using the daily return in the previous month (expressed in percentage). Historical return skewness is the skewness of daily stock returns over the previous month. Institutional holding ratio is defined as institutional holdings divided by the total number of outstanding at the last quarter end. Industry FE refers to controls for Fama-French 12-industry fixed effects. Estimated standard errors are two-way clustered by firm and month. ***, **, and * indicate that the estimated coefficient is significant at the 1%, 5%, and 10% level, respectively.

	Optionable Stocks	Non-optionable Stocks
Rule203	**-0.200****	**0.048**
	(-2.18)	(0.23)
Ln(Size)	-1.266***	-0.658***
	(-7.27)	(-3.11)
BM Ratio	-1.347***	-1.968***
	(-2.93)	(-4.98)
Stock Bid-ask Spread	0.035	-0.027
	(0.11)	(-0.24)
Stock Turnover	3.924***	3.238***
	(6.71)	(5.94)
Last Month Stock Return	3.592***	1.610*
	(4.71)	(1.91)
Stock Return Volatility	-0.681	-0.310
	(-1.20)	(-0.96)
Stock Return Skew	0.028	-0.033
	(0.29)	(-0.41)
Institutional Ownership	8.242***	4.744***
	(6.25)	(6.05)
Intercept	40.791***	12.902***
	(2.87)	(2.94)
Industry FE	Yes	Yes
R^2	0.25	0.55
N	10,336	4,806

Table 3.4: How does Rule 202T influence the short selling activity?

In this table, I show the impact of Regulation SHO-Rule 202T on the short selling activity in the stock market. Panel A shows the summary statistics for short selling activity before and after the pilot program. Shares sold short is the daily short sale volume, expressed in thousands. Relative short sales is daily short sale volume divided by daily stock trading volume, expressed in percentage. Trade size is the number of shares sold short in each trade. Panel B reports Pooled OLS regression results. The dependent variable is the daily short sale volume, expressed in thousands. Pilot stock is a dummy variable, equals one if a firm's stock is designated as pilot stock in the Regulation SHO's pilot program and zero otherwise. Post is a dummy variable, which is equal to 1 if the observation date is between May 1, 2005 and July 31, 2005, and equal to 0 if the observation date is between Feb 1, 2005 and April 30, 2005. Ln (Size) is the natural logarithm of firm size at the end of the last calendar month. B/M ratio is the book-to-market ratio at the end of the last calendar year. Stock bid-ask spread is defined as the closing ask less the closing bid and divided by the midpoint, expressed in percentage. Stock volume is the daily stock trading volume, expressed in millions. Last month stock return is the cumulative stock return over the last month. Stock return volatility is calculated using the daily return in the previous month. Historical return skew is the skewness of daily stock returns over the previous month. Institutional holding ratio is defined as institutional holdings divided by the total number of outstanding at the last quarter end. Industry FE refers to controls for Fama-French 12 industry fixed effects. Estimated standard errors are two-way clustered by firm and date. ***, **, and * indicate that the estimated coefficient is significant at the 1%, 5%, and 10% level, respectively.

Panel A: Short selling activities before and during the pilot program

		Pilot stocks				Control Stocks			
		Before		During		Before		During	
		Mean	Median	Mean	Median	Mean	Median	Mean	Median
Shares Sold Short	1,000 shares	288.1	104.8	285.5	104.9	286.5	106.5	270.6	97.0
Relative Short Sales	%	19.5	18.0	20.9	19.4	19.8	18.2	19.5	18.1
Trade Size	shares	452.1	366.8	387.1	307	452.3	365.8	439.4	346.6
N. Obs.		22,140		22,619		42,211		42,998	

Panel B: Regression analysis

	(1)	(2)
Pilot Stock* Post	**12.55*****	**20.87****
	(6.96)	(2.31)
Pilot Stock	9.19	-6.78
	(0.22)	(-0.77)
Post	-16.06**	-7.46
	(-2.50)	(-1.57)
Ln(Size)		13.95
		(1.44)
BM Ratio		8.06
		(0.41)
Stock Bid-ask Spread		-29.53***
		(-2.68)
Stock Volume		145.85***
		(20.75)
Last Month Stock Return		239.51***
		(9.27)
Stock Return Volatility		123.65**
		(2.51)
Stock Return Skew		-14.46***
		(-5.92)
Institutional ownership		51.53***
		(3.05)
Intercept	182.76***	-343.09
	(7.10)	(-1.51)
Industry FE	Yes	Yes
R^2	0.03	0.89
N	129,968	129,968

Table 3.5: How does Rule 203 influence option volume?

In this table, I show the impact of Regulation SHO-Rule 203 on the option trading volume. Pooled OLS results are reported for call and put options separately. The dependent variable is the daily aggregated option trading volume (in thousands). Rule203 is a dummy variable. Ln (Size) is the natural logarithm of firm size at the end of the last calendar month. B/M ratio is the book-to-market ratio at the end of the last calendar year. Stock bid-ask spread is defined as the closing ask less the closing bid and divided by the midpoint, expressed in percentage. Stock volume is the daily stock trading volume, expressed in millions. Last month stock return is the cumulative stock return over the last month. Stock return volatility is calculated using the daily return in the previous month. Stock return skew is the skewness of daily stock returns over the previous month. Institutional holding ratio is defined as institutional holdings divided by the total number of outstanding at the last quarter end. VIX is the daily VIX index value. S&P 500 index return is the daily return of the S&P 500 index. Stock return is the daily stock return. Industry FE refer to controls for Fama-French 12 industry fixed effects. Estimated standard errors are two-way clustered by firm and date. ***, **, and * indicate that the estimated coefficient is significant at the 1%, 5%, and 10% level.

	Call Options	Put Options
Rule203	**0.132****	**0.128*****
	(2.09)	(3.10)
Ln(Size)	0.596***	0.460***
	(5.57)	(6.69)
BM Ratio	0.192	0.183
	(0.87)	(1.22)
Stock Bid-ask Spread	-0.172	-0.100
	(-1.49)	(-1.33)
Stock Volume	0.505***	0.255***
	(7.30)	(5.45)
Last Month Stock Return	1.224**	0.065
	(2.10)	(0.18)
Stock Return Volatility	4.448***	3.143***
	(4.44)	(4.58)
Stock Return Skew	-0.040	-0.027
	(-1.30)	(-1.34)
Institutional Ownership	-0.247	-0.053
	(-1.15)	(-0.34)
VIX	0.016	0.029***
	(0.81)	(2.61)
SP 500 Index Return	-0.360	1.897
	(-0.12)	(1.12)
Stock Return	5.870***	-2.590***
	(4.65)	(-3.69)
Intercept	-14.253***	-11.238***
	(-5.45)	(-6.62)
Industry FE	Yes	Yes
R^2	0.39	0.36
N	126,637	124,571

Table 3.6: The change of option volume after Rule 203, partitioned by institutional ownership

In this table, I show the impact of Rule 203 on options trading volume for subsamples of firms with institutional ownership above or equal to (High), or below (Low) the sample median. Pooled OLS results are reported for call and put options separately. The dependent variable is the daily aggregated option trading volume (in thousands). Rule203 is a dummy variable, which is equal to 1 if the observation date is between Jan 1, 2005 and March 31, 2005, and equal to 0 if the observation date is between Oct 1, 2004 and Dec 31, 2005. Institutional Ownership is defined as institutional holdings divided by the total number of outstanding at the last quarter end. Ln (Size) is the natural logarithm of firm size at the end of the last calendar month. B/M ratio is the book-to-market ratio at the end of the last calendar year. Stock bid-ask spread is defined as the closing ask less the closing bid and divided by the midpoint, expressed in percentage. Stock volume is the daily stock trading volume, expressed in millions. Last month stock return is the cumulative stock return over the last month. Stock return volatility is calculated using the daily return in the previous month. Historical return skewness is the skewness of daily stock returns over the previous month. VIX is the daily VIX index value. S&P 500 index return is the daily return of the S&P 500 index. Stock return is the daily stock return. Industry FE refer to controls for Fama-French 12 industry fixed effects. Estimated standard errors are two-way clustered by firm and date. ***, **, and * indicate that the estimated coefficient is significant at the 1%, 5%, and 10% level.

	Call Options		Put Options	
	Institutional Ownership		Institutional Ownership	
	Low	High	Low	High
Rule203	**0.179***	**0.074**	**0.223*****	**0.021**
	(1.68)	(1.52)	(2.91)	(1.02)
Ln(Size)	0.813***	0.070	0.586***	0.127***
	(5.69)	(1.43)	(6.36)	(2.63)
BM Ratio	0.174	-0.035	0.188	0.063
	(0.46)	(-0.23)	(0.69)	(0.76)
Stock Bid-ask	-0.285	-0.041	-0.155	-0.039
	(-1.27)	(-0.84)	(-1.06)	(-1.18)
Stock Volume	0.481***	0.742***	0.239***	0.430***
	(6.99)	(12.91)	(5.17)	(8.39)
Last Month	1.749*	0.750**	0.196	0.094
	(1.74)	(2.37)	(0.30)	(0.47)
Stock Return	6.165***	1.267***	4.052***	1.161***
	(3.58)	(2.91)	(3.39)	(3.18)
Stock Return	-0.061	-0.011	-0.057	0.006
	(-1.08)	(-0.58)	(-1.55)	(0.64)
Institutional	0.173	0.041	0.133	0.396*
	(0.30)	(0.16)	(0.34)	(1.77)
VIX	0.010	0.005	0.035**	0.014**
	(0.30)	(0.57)	(2.02)	(2.10)
SP 500 Index	0.508	-3.329	1.447	0.327
	(0.11)	(-1.39)	(0.53)	(0.23)
Stock Return	7.789***	5.019***	-3.042***	-0.915
	(3.53)	(4.46)	(-3.37)	(-1.09)
Intercept	-19.562***	-2.241*	-14.442***	-3.736***
	(-5.33)	(-1.80)	(-6.01)	(-3.07)
Industry FE	Yes	Yes	Yes	Yes
R^2	0.40	0.38	0.37	0.34
N	63,558	63,079	62,372	62,199

Table 3.7: The change of option volume after Rule 203, partitioned by option bid-ask spread

In this table, I show the impact of Rule 203 on options trading volume for subsamples of firms with daily equal-weighted options bid-ask spread above or equal to (High), or below (Low) the sample median. Pooled OLS results are reported for call and put options separately. The dependent variable is the daily aggregated option trading volume (in thousands). Rule203 is a dummy variable, which is equal to 1 if the observation date is between Jan 1, 2005 and March 31, 2005, and equal to 0 if the observation date is between Oct 1, 2004 and Dec 31, 2005. Institutional Ownership is defined as institutional holdings divided by the total number of outstanding at the last quarter end. Ln (Size) is the natural logarithm of firm size at the end of the last calendar month. B/M ratio is the book-to-market ratio at the end of the last calendar year. Stock bid-ask spread is defined as the closing ask less the closing bid and divided by the midpoint, expressed in percentage. Stock volume is the daily stock trading volume, expressed in millions. Last month stock return is the cumulative stock return over the last month. Stock return volatility is calculated using the daily return in the previous month. Historical return skewness is the skewness of daily stock returns over the previous month. VIX is the daily VIX index value. S&P 500 index return is the daily return of the S&P 500 index. Stock return is the daily stock return. Industry FE refer to controls for Fama-French 12 industry fixed effects. Estimated standard errors are two-way clustered by firm and date. ***, **, and * indicate that the estimated coefficient is significant at the 1%, 5%, and 10% level.

	Call Options		Put Options	
	Option Bid-ask Spread		Option Bid-ask Spread	
	Low	High	Low	High
Rule203	**0.157***	**0.037**	**0.266*****	**0.009**
	(1.72)	(1.44)	(3.40)	(0.96)
Ln(Size)	0.878***	0.112*	0.668***	0.125***
	(5.95)	(1.67)	(7.39)	(4.53)
BM Ratio	-0.044	0.083	0.202	0.060*
	(-0.13)	(0.97)	(0.75)	(1.67)
Stock Bid-ask Spread	-0.230	-0.097*	-0.226	0.012
	(-1.09)	(-1.95)	(-1.44)	(1.60)
Stock Volume	0.537***	0.279***	0.258***	0.086**
	(7.47)	(3.15)	(5.61)	(2.56)
Last Month Stock Return	2.391**	-0.408	0.360	0.151
	(2.20)	(-1.38)	(0.54)	(1.38)
Stock Return Volatility	7.787***	1.401**	5.144***	0.539***
	(5.06)	(2.37)	(4.75)	(4.16)
Stock Return Skew	-0.043	-0.011	-0.046	-0.004
	(-0.82)	(-0.80)	(-1.32)	(-0.76)
Institutional Ownership	-0.522	0.020	-0.091	0.015
	(-1.31)	(0.27)	(-0.31)	(0.41)
VIX	0.037	-0.002	0.059***	0.004
	(1.01)	(-0.26)	(2.80)	(1.13)
SP 500 Index Return	0.518	-0.864	3.625	-0.446
	(0.10)	(-0.53)	(1.10)	(-0.66)
Stock Return	10.866***	1.053	-4.422***	0.405*
	(5.12)	(1.33)	(-3.46)	(1.66)
Intercept	-21.564***	-2.888*	-16.844***	-2.906***
	(-5.72)	(-1.88)	(-7.21)	(-4.67)
R^2	0.41	0.29	0.37	0.14
Industry FE	Yes	Yes	Yes	Yes
N	63,290	63,347	62,079	62,492

Table 3.8: How does Rule 202T influence option volume?

In this table, I show the impact of Regulation SHO-Rule 202T on the option trading volume. Pooled OLS results are reported for call and put options separately. The dependent variable is the daily aggregated option trading volume (in thousands). Pilot stock is a dummy variable, equals one if a firm's stock is designated as pilot stock in the Regulation SHO's pilot program and zero otherwise. Post is a dummy variable, which is equal to 1 if the observation date is between May 1, 2005 and July 31, 2005, and equal to 0 if the observation date is between Feb 1, 2005 and April 30, 2005. Ln (Size) is the natural logarithm of firm size at the end of the last calendar month. B/M ratio is the book-to-market ratio at the end of the last calendar year. Stock bid-ask spread is defined as the closing ask less the closing bid and divided by the midpoint, expressed in percentage. Stock volume is the daily stock trading volume, expressed in millions. Last month stock return is the cumulative stock return over the last month. Stock return volatility is calculated using the daily return in the previous month. Historical return skewness is the skewness of daily stock returns over the previous month. Institutional holding ratio is defined as institutional holdings divided by the total number of outstanding at the last quarter end. VIX is the daily VIX index value. S&P 500 index return is the daily return of the S&P 500 index. Stock return is the daily stock return. Industry FE refer to controls for Fama-French 12 industry fixed effects. Estimated standard errors are two-way clustered by firm and date. ***, **, and * indicate that the estimated coefficient is significant at the 1%, 5%, and 10% level, respectively.

	Call Options		Put Options	
Pilot Stock* Post	**-0.077**	**-0.025**	**-0.079**	**-0.050**
	(-1.27)	(-0.40)	(-1.55)	(-1.01)
Pilot Stock	0.136	0.021	0.089	0.021
	(0.60)	(0.15)	(0.61)	(0.22)
Post	-0.060	-0.036	-0.051	-0.007
	(-1.20)	(-0.77)	(-1.15)	(-0.17)
Ln(Size)		0.555***		0.467***
		(5.31)		(6.36)
B/M Ratio		0.282		0.297
		(1.42)		(2.12)**
Stock Bid-ask Spread		-0.175*		-0.134*
		(-1.67)		(-1.87)
Stock Volume		0.531***		0.282***
		(7.43)		(5.31)
Last Month Stock Return		0.654*		-0.184
		(1.74)		(-0.66)
Stock Return Volatility		4.127***		3.169***
		(5.66)		(5.69)
Stock Return Skewness		-0.026		-0.032
		(-0.74)		(-1.12)
Institutional Ownership		-0.127		-0.120
		(-0.69)		(-0.80)
VIX		-0.007		0.004
		(-0.50)		(0.39)
S&P 500 Index Return		-5.814**		-1.932
		(-2.27)		(-1.14)
Stock Return		5.926***		-1.400**
		(5.26)		(-2.08)
Intercept	0.625***	-13.067***	0.491***	-10.936***
	(3.68)	(-5.17)	(3.97)	(-6.21)
Industry FE	Yes	Yes	Yes	Yes
R^2	0.02	0.41	0.01	0.34
N	127,399	127,399	125,854	125,854

Table 3.9: How does Rule 203 influence the option bid-ask spread?

In this table, I show the impact of Regulation SHO-Rule 203 on the option bid-ask spread. Pooled OLS results are reported for call and put options separately. The dependent variable is the option relative bid-ask spread, defined as the closing ask price minus the closing bid price and then divided by the midpoint. Rule203 is a dummy variable, which is equal to 1 if the observation date is between Jan 1, 2005 and March 31, 2005, and equal to 0 if the observation date is between Oct 1, 2004 and Dec 31, 2005. Dummy is a dummy variable that that equals 1 if the option strike price is no greater than the underlying stock price and 0 otherwise. Moneyness describes how much an option is in or out of the money. Time to maturity is the number of days to the option's expiration date. Ln (Size) is the natural logarithm of firm size at the end of the last calendar month. B/M ratio is the book-to-market ratio at the end of the last calendar year. Stock bid-ask spread is defined as the closing ask less the closing bid and divided by the midpoint, expressed in percentage. Stock volume is the daily stock trading volume, expressed in millions. Last month stock return is the cumulative stock return over the last month. Stock return volatility is calculated using the daily return in the previous month. Historical return skewness is the skewness of daily stock returns over the previous month. Institutional holding ratio is defined as institutional holdings divided by the total number of outstanding at the last quarter end. VIX is the daily VIX index value. S&P 500 index return is the daily return of the S&P 500 index. Stock return is the daily stock return. Industry FE refer to controls for Fama-French 12 industry fixed effects. Estimated standard errors are two-way clustered by firm and date. ***, **, and * indicate that the estimated coefficient is significant at the 1%, 5%, and 10% level, respectively.

	Call options	Put options
Rule203	**0.001**	**0.001**
	(1.54)	(1.09)
Dummy*Moneyness	-0.352***	3.179***
	(-13.79)	(48.39)
$(\text{Dummy*Moneyness})^2$	0.291***	-5.537***
	(3.83)	(-10.95)
(1-Dummy)*Moneyness	-3.403***	0.660***
	(-17.49)	(18.63)
$[(1\text{-Dummy})\text{*Moneyness}]^2$	1.743	1.206***
	(0.54)	(8.28)
1/(Time to Maturity)	1.161***	1.293***
	(29.66)	(28.49)
Ln(Size)	-0.030***	-0.033***
	(-28.27)	(-28.25)
B/M Ratio	0.031***	0.024***
	(5.63)	(3.99)
Stock Bid-ask Spread	0.023***	0.022***
	(9.09)	(8.16)
Stock Volume	0.001***	0.001***
	(7.26)	(9.19)
Last Month Stock Return	-0.032***	-0.036***
	(-5.06)	(-4.81)
Stock Return Volatility	-0.178***	-0.188***
	(-13.68)	(-14.62)
Stock Return Skewness	0.001	0.001**
	(1.46)	(2.33)
Institutional Ownership	-0.056***	-0.065***
	(-8.44)	(-9.08)
VIX	0.001***	0.001*
	(4.08)	(1.74)
S&P 500 Index Return	0.048	0.063
	(1.20)	(1.29)
Stock Return	0.006	0.035***
	(0.59)	(2.60)
Intercept	0.793***	0.880***
	(27.90)	(27.95)
Industry FE	Yes	Yes
R^2	0.63	0.63
N	1,435,480	1,284,064

Table 3.10: How does Rule 202T influence option bid-ask spread?

In this table, I show the impact of Regulation SHO-Rule 202T on the option bid-ask spread. Pooled OLS results are reported for call and put options separately. The dependent variable is the option relative bid-ask spread, defined as the closing ask price minus the closing bid price and then divided by the midpoint. Pilot stock is a dummy variable, equals one if a firm's stock is designated as pilot stock in the Regulation SHO's pilot program and zero otherwise. Post is a dummy variable, which is equal to 1 if the observation date is between May 1, 2005 and July 31, 2005, and equal to 0 if the observation date is between Feb 1, 2005 and April 30, 2005. Dummy is a dummy variable that that equals 1 if the option strike price is no greater than the underlying stock price and 0 otherwise. Moneyness describes how much an option is in or out of the money. Time to maturity is the number of days to the option's expiration date. Ln (Size) is the natural logarithm of firm size at the end of the last calendar month. B/M ratio is the book-to-market ratio at the end of the last calendar year. Stock bid-ask spread is defined as the closing ask less the closing bid and divided by the midpoint, expressed in percentage. Stock volume is the daily stock trading volume, expressed in millions. Last month stock return is the cumulative stock return over the last month. Stock return volatility is calculated using the daily return in the previous month. Historical return skewness is the skewness of daily stock returns over the previous month. Institutional holding ratio is defined as institutional holdings divided by the total number of outstanding at the last quarter end. VIX is the daily VIX index value. S&P 500 index return is the daily return of the S&P 500 index. Stock return is the daily stock return. Industry FE refer to controls for Fama-French 12 industry fixed effects. Estimated standard errors are two-way clustered by firm and date. ***, **, and * indicate that the estimated coefficient is significant at the 1%, 5%, and 10% level, respectively.

	Call Options		Put Options	
	Model 1	Model 2	Model 3	Model 4
Pilot Stock* Post	**0.002**	**0.001**	**0.001**	**0.001**
	(1.45)	(0.68)	(0.79)	(0.68)
Pilot Stock	0.001	-0.002	-0.004	-0.001
	(0.30)	(-0.90)	(-1.31)	(-0.36)
Post	-0.001	0.002***	0.006***	0.004***
	(-0.76)	(2.75)	(4.36)	(4.35)
Dummy*Moneyness		-0.276***		3.048***
		(-6.85)		(46.73)
$(\text{Dummy*Moneyness})^2$		0.059***		-4.741***
		(5.61)		(-9.12)
(1-Dummy)*Moneyness		-3.085***		0.754***
		(-20.83)		(22.13)
$[(1\text{-Dummy})\text{*Moneyness}]^2$		6.991***		1.456***
		(3.15)		(12.00)
1/(Time to Maturity)		1.187***		1.326***
		(29.22)		(29.08)
Ln(Size)		-0.033***		-0.035***
		(-27.26)		(-28.99)
B/M Ratio		0.026***		0.018***
		(4.71)		(3.03)
Stock Bid-ask Spread		0.023***		0.022***
		(10.67)		(8.56)
Stock Volume		0.001***		0.002***
		(6.42)		(8.53)
Last Month Stock Return		-0.014*		-0.022**
		(-1.90)		(-2.48)
Stock Return Volatility		-0.190***		-0.203***
		(-12.73)		(-13.10)
Stock Return Skewness		0.002***		0.003***
		(2.74)		(3.98)
Institutional Ownership		-0.057***		-0.058***
		(-8.38)		(-7.50)
VIX		0.000		-0.001***
		(0.45)		(-2.89)
S&P 500 Index Return		-0.091***		-0.134***
		(-3.08)		(-3.61)
Stock Return		-0.005		0.039***
		(-0.38)		(2.76)
Intercept	0.114***	0.877***	0.130	0.951***
	(18.84)	(27.68)	(27.30)***	(28.34)
Industry FE	Yes	Yes	Yes	Yes
R^2	0.01	0.63	0.01	0.63
N	1,516,599	1,516,599	1,373,432	1,373,432

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APPENDIX

A1. The sensitivity of option implied volatility to earnings announcement date

On August 4, 2014, JinkoSolar Holdings Co. Ltd. (JKS) announced that it will release earnings for the second quarter of 2014 on August 18, 2014. Wall Street Horizon, a company that tracks upcoming events for publicly listed companies, has forecasted that JKS will announce earnings on August 12, 2014. Although this announcement delayed the earnings release date by just six days, it had a subtle effect on outstanding options. The August 2014 options expired on August 16, 2014. Thus, if option traders followed the expectations of the Wall Street Horizon, they would have priced the August option to include the higher volatility around the earnings announcement date. When the date was finalized for August 18, 2014, i.e. after the expiration of the August options, the option prices should have reflected just normal volatility, and the option implied volatility (IV) should have dropped. The actual option implied volatilities observed were:

	8/4/2014	8/5/2014	8/6/2014	8/7/2014
IV of call options expiring at 8/16/2014 and strike price at $23	83%	76%	77%	70%
IV of call options expiring at 8/16/2014 and strike price at $24	78%	72%	77%	73%
IV of call options expiring at 9/20/2014 and strike price at $23	78%	74%	74%	77%
IV of call options expiring at 9/20/2014 and strike price at $24	77%	72%	73%	75%
Stock Price (in dollars)	23.40	25.37	25.42	25.48

As can be seen, the implied volatility of the 8/16/2014 call options dropped after the company's announcement that earnings will be released after the option expiration date. In addition, the decrease of implied volatility of the 8/16/2014 call options is larger than that of call options expiring at 9/20/2014, which was not or less affected by the announcement on August 4, 2014.

A2. Variable definitions

AXRET	Absolute excess return, calculated as the absolute value of buy-and-hold return over the 3-day window ([-1, 1]) around a firm specific event (earnings announcements, annual meetings of shareholders or random events) minus the buy-and-hold return on a portfolio of stocks with similar size (market value of equity, two groups), book-to-market ratio (three groups), and momentum (three groups).
STRADDLE	Net straddle return. A straddle contract is bought shortly (5 to 10 days) before the firm specific event and sold one day after the event. The purchase (selling) price of the straddle is calculated as the sum of ask (bid) prices of the ATM call and ATM put options. Net straddle returns are estimated as the selling price of the straddle minus its purchase price divided by its purchase price.
HIST	Standard deviation of daily stock returns in the 60 calendar days prior to the firm specific event (earnings announcements, annual meetings of shareholders or random events) multiplied by square root of 3.
STDXRET	Standard deviation of 3-day ([-1, +1]) excess returns around prior earnings announcements, annual meetings of shareholders or random events using all available data since the year 1986.
IVOL3	Predicted 3-day volatility around earnings announcements, annual meetings of shareholders or random events. It is calculated as σ_{high} multiplied by $\sqrt{3/252}$. σ_{high} is obtained from formula (3).
RHIST	HIST sorted quarterly into deciles (0-9), then divided by 9 and subtracting 0.5.
RSTDXRET	STDXRET sorted quarterly into deciles (0-9), then divided by 9 and subtracting 0.5.
RIVOL3	IVOL3 sorted quarterly into deciles (0-9), then divided by 9 and subtracting 0.5.
RDQ	A dummy variable, which is equal to 1 when the information event is the earnings announcement and 0 otherwise.
AMS	A dummy variable, which is equal to 1 when the information event is the annual meeting of shareholders and 0 otherwise.
RHIST_RDQ	RHIST multiplied by RDQ.
RHIST_AMS	RHIST multiplied by AMS.
RSTDXRET_RDQ	RSTDXRET multiplied by RDQ.
RSTDXRET_AMS	RSTDXRET multiplied by AMS.
RIVOL3_RDQ	RIVOL3 multiplied by RDQ.
RIVOL3_AMS	RIVOL3 multiplied by AMS.

A3. Comparison of locate and close-out requirements before and after Rule 203

	Before Rule 203	**After Rule 203**
Locate requirement	Prior to short selling, there must be arrangements or acceptable assurances that the stock can be borrowed and delivered on the settlement date. Exempt: Equity market makers Option market makers Hedgers Arbitragers	Prior to short selling, there must be arrangements or acceptable assurances that the stock can be borrowed and delivered on the settlement date. Exempt: Equity market makers Option market makers (but only in connection with bona-fide market making activities)
Close-out requirement	For Nasdaq stocks with fails of at least 0.5% of shares outstanding and 10,000 shares, positions that have failed for at least 10 days must be closed out. Exempt: Equity market makers Option market makers Hedgers Arbitragers	For stocks issued by Section 12 and Section 15(d) filers (i.e., stocks listed on NYSE, AMEX, Nasdaq; OTCBB stocks; and stocks of Pink Sheet filers) with total fails of at least 0.5% of shares outstanding and 10,000 shares for 5 consecutive days (i.e., ‘‘threshold’’ stocks), positions that have failed for at least 10 days must be closed out. Exempt: Pre-existing fail positions; New short sales that are options market makers’ hedges for preexisting option positions.
Others	NASD rules prohibit further short selling by those with fails-to-deliver of that security for at least 60 days.	Those with fails of at least 10 days in the above ‘‘threshold’’ stocks cannot make further short sales until fail position is closed out unless stock has been already borrowed (or arranged to borrow).

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