

Informed Trading and Option Prices: Theory and Evidence from Activist Trading[☆]

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Abstract

Using a comprehensive sample of trades from Schedule 13D filings by activist investors, we study how option prices respond to informed trading in the stock market. We show that this class of informed traders chooses to trade stocks and to not trade derivatives in more than 97% of cases, suggesting that most of informed trading by activist shareholders takes place in the stock market. We find that on days when activists accumulate shares, option implied volatility decreases and volatility skew increases. These changes are consistent with the drop in realized volatility we observe around the filing date. We also find that measures of adverse selection increase for options but decrease for stocks on days when Schedule 13D filers trade in stocks. Option markets seem to reflect valuable volatility specific information. We develop a simple model of stock and option pricing where informed trading takes place in the stock market in anticipation of a random announcement date. In the model, even though informed are not trading options, option implied volatilities reflect information pertaining to the announcement jump that cannot be inferred or traded via the underlying.

It has long been argued that derivative markets should provide an interesting trading avenue for investors to exploit an informational advantage. Options may provide valuable embedded leverage for example (Black (1975)). They may also allow investors to achieve better liquidity or to hide their information better (Back (1993), Easley et al. (1998)). Indirect empirical evidence that informed trading does occur in option markets based on the predictability of stock returns by option to stock volume or other option market statistics has been documented (Vijh (1990); Chakravarty et al. (2004); Chan et al. (2002)). On the other hand, Muravyev et al. (2013) conclude that no economically significant price discovery occurs in the option market. Thus, whether informed investors actually use derivatives and what informational linkages there are between option and stock markets remain open questions.

In this paper we use new data on informed investors' trading behavior to revisit the following questions. How do investors who possess valuable private information trade in stocks and derivatives? How does private information flow into stock and option prices? Do measures of adverse selection in option and stock markets respond to the presence of informed trading?

Addressing these questions is challenging because the identity of informed investors is typically unobservable to econometricians. Standard approaches in the literature to overcome this challenge include studying periods of time when informed trading is likely (e.g., M&A announcements) or assuming that a class of investors is informed (e.g., corporate insiders or institutional investors).¹

In this paper we use a novel data set of trades by investors who we can identify as having substantial private information to study how private information flows into stock and option prices. More specifically, we follow Collin-Dufresne and Fos (2015) and exploit

¹For example, Cao et al. (2005) and Augustin et al. (2014) study informed trading prior to M&A announcements. For the analysis of the option market around analyst revisions see Hayunga and Lung (2014).

a disclosure requirement Rule 13d-1(a) of the 1934 Securities Exchange Act to identify trades that rely on valuable private information. Rule 13d-1(a) requires investors to file with the SEC within 10 days of acquiring more than 5% of any class of securities of a publicly traded company if they have an interest in influencing the management of the company. In addition to having to report their actual position at the time of filing, Item 5(c) of Schedule 13D requires the filer to report the date, price, and quantity of all trades in the target company executed during the 60 days that precede the filing date.² Importantly, Item 6 of Schedule 13D requires the filer to disclose whether or not derivative contracts have been used.

We collect a comprehensive sample of trades from the Schedule 13D filings. We view this sample as an interesting laboratory to study informed trading. An average Schedule 13D filing in our sample is characterized by a positive and significant market reaction upon announcement. For example, the cumulative return in excess of the market is about 6% in the $(t-10, t+1)$ window around the filing date. Moreover, stock price volatility drops by more than 10% after the filing date. Thus, Schedule 13D filers have both directional and volatility information. We can therefore classify the pre-announcement trades by Schedule 13D filers as informed trades. Note that, by its very nature, the information held by Schedule 13D filers is likely to qualify as “private information” and to be long-lived.³

We document several key results. First, we find that informed investors rarely use derivatives. Specifically, only in 76 out of 2,905 Schedule 13D filings we analyze do

²To quote from Item 5(c), filers have to “...describe any transactions in the class of securities reported on that were effected during the past sixty days or since the most recent filing of Schedule 13D, whichever is less,...”

³Collin-Dufresne and Fos (2014b) develop a theoretical model in which activist shareholders can expend effort and change firm value. In that model the market price depends on the market maker’s estimate of the activist’s share ownership, since the latter determines the effort level of the informed trader, and hence the liquidation value of the firm. This model shows that a significant part of the valuable private information pertains to the activist’s own holdings, which by definition is information known only to him.

informed investors disclose the usage of derivatives. That is, in more than 97% of cases informed investors decide to trade exclusively in the stock market. This is despite the fact that Schedule 13D filers build economically significant positions: the average toehold held at the filing date is more than 7% of outstanding shares. This finding suggests that derivatives may not be that attractive for informed traders and that they play a minor role in activists' trading strategies. That said, we find that when exchange traded options are available then usage by activists increases (from 3% to 11% of cases). In that case, they use OTC derivatives in around 40% of cases and exchange-listed derivatives in around 60% of cases. Interestingly, they often use OTC derivatives to construct synthetic long forward positions in order to avoid disclosure required under the Hart-Scott-Rodino (HSR) Act of 1976 (see Section C for further details). When they do use derivatives then activists seek to increase their overall economic exposure to the stock (and not to hedge their risk). They achieve 2.2% long exposure via derivatives and 6.3% via stocks, which together is 1% more than what they achieve when trading only stocks.

Second, we consider 522 Schedule 13D filings that satisfy the following criteria: target stocks have exchange-listed options and Schedule 13D filers trade stock only. We use this sample to study how informed trading in stock market is reflected in option prices. A unique feature of this sample is that we know not only when informed activists trade in the underlying shares, but also that they do not participate in direct trading in derivatives. These features allow us to isolate the effect of informed trading in stock market on option prices.

We find that implied volatilities decline closer to the filing date, suggesting that option prices reflect the drop in the realized volatility after the filing date. We also find that the implied volatility smile steepens substantially closer to the filing date, reflecting higher chances of a large informational event around the filing date. Since both put and call skew steepen, this suggests the informational event increases both tails of the

distribution of the underlying stock return. The evidence is consistent with findings in the literature that implied volatilities are good forecasts of future realized volatility (e.g., Poon and Granger, 2003). It also shows that option markets reflect volatility information even if informed trading occurs mostly in the stock market.⁴

Third, we reexamine results from Collin-Dufresne and Fos (2015) and ask whether option bid-ask spreads reflect the presence of informed trading. Collin-Dufresne and Fos (2015) show that even though target stocks experience abnormal positive excess returns on days when Schedule 13D filers trade (consistent with their trades having positive price impact), stock market measures of adverse selections are *lower* on those days (despite the large adverse selection risk).⁵

We find that option bid-ask spreads are *wider* when Schedule 13D filers trade in the stock market. Thus, whereas Schedule 13D filers do not trade options, option market makers widen spreads when informed trading in the stock market takes place.

Fourth, we analyze trading activity in the option market. We find that while call volume decreases closer to the filing, there is no difference between call volume on days when Schedule 13D filers trade and on days when they do not trade. When we consider order imbalance (defined as buy minus sell initiated orders) in call options, we find a higher order imbalance closer to the filing date but no difference in order imbalance on days when Schedule 13D filers trade and on days when they do not trade. Thus, the evidence

⁴Our finding that option prices reveal useful information about the distribution of future stock returns is consistent with the literature. As far as stock return predictability is concerned, Conrad et al. (2013) show that future stock returns are correlated with volatility skew, Johnson and So (2012) and Ge et al. (2015) show that future stock returns are correlated with option-to-stock volume, and Pan and Poteshman (2006) and Hu (2014) show that future stock returns are correlated with option order imbalance. Aragon and Martin (2012) show that institutional investors long positions in options predict both future stock returns and volatility and Ni et al. (2008) show that option order imbalance is correlated with future realized volatility.

⁵One potential explanation for their findings is formally developed in Collin-Dufresne and Fos (2014a), who show that the evidence is consistent with informed investors trading more aggressively when noise trading in the stock market is high. Admati and Pfleiderer (1988) and Foster and Viswanathan (1990) also present theoretical models where more information is produced when there is more noise trading.

suggests that whereas trading activity in call options decreases closer to the filing date, market participants seek a long stock exposure when they trade.

When we consider trading activity in put options, we find that volume in put options is significantly higher on days when Schedule 13D filers trade than on days when they do not trade. Moreover, we find that the ratio of put-to-call volume is larger on days when Schedule 13D filers trade. When we consider order imbalance in put options, we find that it is higher on days when Schedule 13D filers trade than when Schedule 13D filers do not trade, though the difference is not statistically significant. Overall, the results on trading activity in options are consistent with the results on volatility skew: market participants anticipate an event but are not sure about the direction of price movement.

Finally, we develop a simple model of stock and option pricing where informed trading takes place in the stock market in anticipation of a random announcement date. In the model, even though informed investors are not trading options, option implied volatilities reflect information pertaining to the announcement jump that cannot be inferred or traded via the underlying. The model can qualitatively explain many of our empirical findings such as: the increase in the realized volatility and drop on the announcement date, the drop in the implied volatility pre-announcement date and the increase in the implied-volatility smile pre-announcement.

The paper is organized as follows. Section I presents the institutional background. Section II describes the data. The magnitude of information asymmetry is analyzed in Section III. Section IV presents the main results. Section V presents a theoretical model of option pricing when there is informed trading in the underlying. Finally, Section VI concludes.

I. Institutional Background

A. *Do Derivatives Trigger Schedule 13D Filing?*

Rule 13d-1(a) of the 1934 Securities Exchange Act requires investors to file with the SEC within 10 days of acquiring beneficial ownership of more than 5% of a voting class of a company's equity securities registered under Section 12 of the Securities Exchange Act of 1934. We refer to the date when the beneficial ownership crosses the 5% threshold as 'event date' and to the date when the filing is sent to the SEC as 'filing date.'

Shares of common stock and options to purchase physical shares within 60 days are examples of equity securities that can trigger the filing. Because all exchange-listed derivatives in the United States are settled in physical delivery and are immediately exercisable, they are considered to be part of the beneficial ownership as far as the crossing of the 5% threshold is concerned.

In contrast, any instrument that is exclusively cash-settled or is not exercisable within 60 days will not result in beneficial ownership. For example, any cash-settled over-the-counter (OTC) derivative agreement (options, equity swaps, etc.) will not result in beneficial ownership and therefore will not trigger a Schedule 13D filing. For example, a shareholder who owns 3% of common stock and cash-settled options that result in additional 4% of common stock exposure upon exercise is not required to file a Schedule 13D.

To summarize, whether a derivative security triggers a Schedule 13D filing crucially depends on the way the derivative is settled.

B. *What Information on Derivatives must Schedule 13D Filings Contain?*

In this section we describe what information on derivatives needs to be disclosed in a Schedule 13D filing. Item 6 of the Schedule 13D requires the filer to “*Describe any contracts, arrangements, understandings or relationships [...] with respect to*

any securities of the issuer, including but not limited to transfer or voting of any of the securities, finder’s fees, joint ventures, loan or option arrangements, puts or calls, guarantees of profits, division of profits or loss, or the giving or withholding of proxies, naming the persons with whom such contracts, arrangements, understandings or relationships have been entered into.” Note that Item 6 covers all types of derivative contracts (settled in either physical or cash delivery). Thus, even if activists used non-traditional or cash-settled derivatives which do not count toward the 5% threshold, these positions have to be disclosed in Item 6 of the Schedule 13D filing.

The rule does not specify what information needs to be disclosed. It is therefore up to the filer to decide about the precision of disclosed information. Therefore, there is substantial variation in the precision of disclosed information, which is unfortunate for research purposes. Finally, note that all other items of Schedule 13D filing do not require disclosure of any information about derivatives as long as the subject security is common stock.⁶

II. Sample Description

A. Data Sources

We compile data from several sources. Stock returns, volume, and prices come from the Center for Research in Security Prices (CRSP). Intraday transactions data (trades and quotes) come from the Trade and Quote (TAQ) database. Daily data on prices and trading volume of exchange-traded options as well as their implied volatilities come from OptionMetrics. Order imbalance data for exchange traded options are provided by the International Securities Exchange. These data start in 2005. See Muravyev (2015) for further details. Data on trades by Schedule 13D filers come from Schedule 13D

⁶Of course, it can be that the 5% threshold was crossed with a position in a derivative security only. In this case the derivative security is the “subject security” and therefore all items of Schedule 13D filing will have information about the derivative security (the subject security).

filings (available on EDGAR) and are described next. Table A1 in the Appendix reports summary statistics of all variables.

B. The Sample of Schedule 13D Filings with Information on Trades

The sample of trades by Schedule 13D filers is constructed as follows.⁷ First, using an automatic search script, we identify 19,026 Schedule 13D filings from 1994 to 2010. The script identifies *all* Schedule 13D filings that appear on EDGAR. Next, we check the sample of 19,026 filings manually and identify events with information on trades. Since the trading characteristics of ordinary equities might differ from those of other assets, we retain only assets whose CRSP share codes are 10 or 11, that is, we discard certificates, ADRs, shares of beneficial interest, units, companies incorporated outside the U.S., Americus Trust components, closed-end funds, preferred stocks, and REITs. We further exclude stocks whose prices are below \$1 and above \$1,000. Finally, we exclude Schedule 13D/A filings (i.e., amendments to previously submitted filings) that are mistakenly classified as original Schedule 13D filings. Moreover, we exclude events during 1994 and 1995 because OptionMetrics coverage starts in 1996.

The final sample comprises the universe of all Schedule 13D filings that satisfy the above criteria from 1996 to 2010, which totals 2,905 events. Importantly, our top-down approach guarantees that the sample contains *all* Schedule 13D filings with information on trades. Figure 2 presents the time distribution of the Schedule 13D filings with information on trades in common stocks during 1996 to 2010. During the sample period, on average 194 events take place each year.

[Insert Figure 2 here]

⁷See Collin-Dufresne and Fos (2015) for detailed description of the procedure.

C. When Do Activists Use Derivatives?

Whether or not activists use derivatives has important corporate governance implications and has attracted attention of academics as well as of practitioners. For example, in their petition for changing Section 13D, Wachtell, Lipton, Rosen & Katz argue that *“The increasing use of derivatives has accelerated the ability of investors to accumulate economic ownership of shares, usually with substantial leverage.”*⁸

How often do activists use derivatives?

To address this question, we manually check all Schedule 13D filings in our sample for information on any type of derivatives. We find that activists do not disclose any information on derivatives in the vast majority of Schedule 13D filings. Specifically, we could find information on derivatives only in 76 Schedule 13D filings, corresponding to 2.62% of the sample. Given the broad formulation of disclosure requirement in Item 6 (see Section I), the evidence indicates that activists rarely participate in derivatives transactions. An alternative explanation is that activists are using derivatives without disclosing them. In this case, however, they are violating the disclosure requirements.

One possibility is that activists do not use derivatives because these securities are not available. To investigate this conjecture, we check for how many Schedule 13D filings targets have exchange-traded options. For every event, we calculate the number of days with positive option trading volume during 80-day period prior to the filing date. For each event, we set ‘Options available’ indicator to one if the number of days with days with positive option trading volume exceeds 40, and zero otherwise.

Indeed, we find that exchange-traded options are available in 577 events, corresponding to 19.86% of events. When exchange-traded options are available, the probability that an activist uses derivatives increases to 9.53%. In contrast, when exchange-traded options are not available, the probability that the activist discloses information on derivatives

⁸The full text of the petition is available at <http://www.sec.gov/rules/petitions/2011/petn4-624.pdf>.

decreases to 0.89%, corresponding to events when activists use OTC derivatives. Thus, the availability of exchange-traded options is a strong predictor of the usage of derivatives by activists.

To further investigate when activists are more likely to use derivatives, we next compare characteristics of firms that use derivatives to characteristics of firms that do not use derivatives. Results are reported in Table I. Consistently with the previous result, the evidence in columns (1) to (3) shows that activists are more likely to use derivatives when targets have exchange-traded options: when activists (do not) use derivatives, 72% (21%) of targets (do not) have exchange-traded options.

[Insert Table I here]

Activists are also more likely to use derivatives when amassing a 5% stake requires a larger capital commitment: when activists use derivatives targets' market capitalization is four times larger than when activists do not use derivatives. Additional factors that are positively associated with the usage of derivatives are high stock liquidity, large number of analysts covering the stock, low book-to-market ratio, and high institutional and activist ownership.

We next test whether activists are more likely to use derivatives when a 5% toehold in the target company meets the "Size-of-Transaction Test" specified by the Hart-Scott-Rodino (HSR) Act of 1976. The HSR Act requires parties to file notifications with the Federal Trade Commission, Department of Justice, and the *firm* when a proposed transaction—such as a merger, joint venture, stock or asset acquisition, or exclusive license—meets specified thresholds and no exemptions apply.⁹ If a notification

⁹A filing is required if the parties meet both the "size of person" and "size of transaction" thresholds. Size-of-Person Test is met if one party to the transaction has \$152.5 million or more in annual sales or total assets and the other has \$15.3 million or more in annual sales or total assets. If the acquired party is not engaged in manufacturing, the test is slightly different: while one party must meet the \$15.3 million test and the other party must meet the \$152.5 million test, in addition the acquired

is required, the transaction cannot close while the statutory waiting period runs and the agencies review the transaction. Activists shareholders fall into the group of investors that is required to issue such a notification. They view this filing requirement as costly. For instance, a prominent activist shareholder Bill Ackman referred to this filing requirement as follows: “The last thing you want to do is alert the target that you are going to buy a big stake in a company.”¹⁰

Derivative contracts can mitigate the cost of this filing. Specifically, an activist shareholder can enter into a derivative contract that provides economic exposure with no direct ownership and therefore delay the HSR filing. Specifically, an activist can build economic exposure through derivative contracts, file Schedule 13D, and only then follow the HSR filing procedure to get approval to acquire the underlying shares. Thus, derivatives can delay the HSR filing until after the Schedule 13D filing is made. This way the notification is sent to all relevant parties after activists’ intention is common knowledge.

To capture the effect of the HSR Act, we set “HSR” to indicate cases when a 5% toehold meets the “Size-of-Transaction Test” specified by the HSR Act. The evidence in Table I reveals that activists are more likely to use derivatives when crossing a 5% toehold meets the “Size-of-Transaction Test” specified by the HSR Act of 1976. Specifically, when activists (do not) use derivatives, 64% (18%) of targets have a 5% toehold that meets (does not meet) the “Size-of-Transaction Test” specified by the HSR Act. The

company must have \$15.3 million of assets or \$152.5 million of revenues. Size-of-Transaction Test is met if, as a result of the transaction, the buyer will acquire or hold voting securities or assets of the seller, valued in excess of \$76.3 million. All information and materials provided in connection with a HSR filing are treated as confidential and will not be disclosed by the government to third parties. The materials are even exempt from Freedom of Information Act requests. However, if activist’s purchase of a 5% toehold triggers HSR filing requirement, the activist is required to notify the company about the intended transaction.

¹⁰Allergan, INC. and Karah H. Parschauer against Valeant Pharmaceuticals International, INC., Valeant Pharmaceuticals International, AGMS, INC., Pershing Square Capital Management, L.P., PS Management, GP, LLC, PS Fund 1, LLC and William A. Ackman.

results therefore confirm that activists are more likely to use derivatives when an equity-only 5% toehold would trigger the HSR Act filing.

Of course, several firm characteristics that are associated with the usage of derivatives might simply proxy for the availability of exchange-listed derivatives. For example, large firms with high stock liquidity are more likely to have actively traded listed options. To address this possibility, we next compare characteristics of targets that use and do not use derivatives in the sub-sample of firms with available listed options. Results are reported in columns (4) to (6) of Table I. Consistently with our prior, we find the several firm characteristics have weaker associations with the usage of derivatives in this sub-sample (e.g., institutional ownership, book-to-market ratio, and stock liquidity).

On the other hand, three firm characteristics—market cap, the number of analysts covering the stock, activist ownership, and the HSR Act dummy—continue to be positively and significantly associated with the usage of derivatives. For example, when activists (do not) use derivatives the average number of analysts covering the target is 11.73 (9.42). This difference corresponds to 25% increase in the number of analysts covering the target. Similarly, the average market cap is \$1,056m (\$690m) when activists do (do not) use derivatives.

To conclude the analysis of firm characteristics that are associated with the usage of derivatives, we next estimate a linear probability model that predicts the usage of derivatives by Schedule 13D filers. The regressions are estimated using firm characteristics that are measured at the end of the fiscal year that precedes the Schedule 13D filing. Results are reported in Table II.

[Insert Table II here]

We find that the availability of listed options, analyst coverage, and activist ownership continue to be positively associated with the usage of derivatives. The multivariate analysis also reveals that stock return volatility is also positively and significantly

associated with the usage of derivatives. Perhaps surprisingly, the table reveals that effects of market cap and stock illiquidity become insignificant after we augment the regression with the HSR indicator.

D. How Do Activists Use Derivatives?

Schedule 13D filers disclosed the usage of derivatives in 76 cases. In this section we describe what positions in derivatives activists had. Table III characterizes the usage of derivatives in the full sample (columns (1) and (2)), in the sample with listed options (columns (3) and (4)), and in the sample of events in which activists indicated the usage of OTC derivatives.

[Insert Table III here]

Full-sample results reveal that activists seek ‘long’ stock price exposure in most of events. Specifically, activists hold long call (short put) positions in 81.6% (40.8%) of events. The activists have both long call and short put positions in 25% of events. Further, the activists have long equity swap positions in 9.2% of events. Either short call positions or long put positions are rare. In less than 3% of events activists had no long exposure through positions in derivatives. Overall, the evidence indicates that the main driving force behind the usage of derivatives by Schedule 13D filers is achieving positive exposure to targets’ stock prices.

When we consider what fraction of activists’ beneficial ownership is in derivatives, we find that activists hold on average 6.3% of outstanding common stock in direct stock ownership. In addition, activists hold 2.2% of outstanding common stock through derivatives positions. Thus, activists achieve more than 25% of the economic exposure through derivatives. We also find that when activists use derivatives, 72.4% of targets have listed stock options, 55.3% of Schedule 13D filers are activist hedge funds, and in 43.4% of events activists use over-the-counter derivatives.

When we relate this result to the percentage of outstanding shares held by activists in cases when activists do not use derivatives, we find that when activists use derivatives they hold a larger proportion of outstanding shares. Specifically, Collin-Dufresne and Fos (2015) show that Schedule 13D filers hold 7.5% of outstanding shares when no information on derivatives is disclosed, which is lower than 8.5% reported in the sample of events with information on derivatives (6.3% in direct stock ownership plus 2.2% of outstanding common stock through derivatives positions).

When we compare the full sample results to results in the sub-sample of events with listed options, we find no major changes the way the activists use derivatives. In contrast, we find that activists use derivatives more aggressively when they use over-the-counter derivatives. For instance, activists' exposure through derivatives increases from 2.2% in the full sample to 3.5% when they use over-the-counter derivatives. Similarly, activists are more likely to seek long exposure in this sub-sample: incidences on long call positions and short put positions are more likely in this sub-sample. Interestingly, while activist hedge funds stand behind 55.3% of events in the full sample, they sponsor 60.6% of Schedule 13D filings in which the usage of over-the-counter derivatives is disclosed.

E. How Do Activists Trade?

Rule 13d-1(a) does not require the filer to disclose trades in either exchange-traded options or over-the-counter contracts. Disclosure of this information is therefore voluntary. In contrast, Item 5(c) of Schedule 13D requires the filer to report the date, price, and quantity of all trades in the underlying security (common stock) executed during the 60 days that precede the filing date.

To avoid any selection bias induced by voluntary disclosure of information, hereafter we analyze the sample of Schedule 13D filings that satisfy the following two criteria. First, we select target companies that have exchange-listed options. This allows us to investigate what can be learned from option prices on informed trading by activist

shareholders in the underlying shares. Imposing this criterium leaves us with 577 Schedule 13D filings. Second, we drop events when activists use derivatives. It leaves us with 522 Schedule 13D filings. A unique feature of this sample is that we know not only when informed activists trade in the underlying shares, but also that they do not participate in direct trading in derivatives. This feature allows us to identify the effect of informed trading in stock market on option prices. Hereafter all the analysis is based on these 522 events.

For each event we extract the following information from the Schedule 13D filings: the CUSIP of the underlying security, transaction date, transaction type (purchase or sell), transaction size, and transaction price. In addition, we extract the filing date, event date (date on which the 5% threshold is crossed), and beneficial ownership of the Schedule 13D filer at the filing date. In the vast majority of cases transaction data are reported at a daily frequency. If the transaction data are at a higher-than-daily frequency, we aggregate them to the daily level. Specifically, for each day we calculate the total change in stock ownership and the average purchase price. The average price is the quantity-weighted average of transaction prices.

We analyze the trading strategy of Schedule 13D filers using the following two measures: the probability that a Schedule 13D filer trades at least one share on a given day,¹¹ and the percentage of outstanding shares traded by Schedule 13D filers.¹² Each measure of trading activity is calculated at a daily frequency. Figure 3 presents each measure for the 60 days prior to the filing date, plotted as a function of the distance to the filing date. This Figure replicates Figure I from Collin-Dufresne and Fos (2015), while restricting the sample to targets with listed options.

¹¹For every distance to the filing date, the probability that a Schedule 13D filer trades at least one share is the number of filings with a nonzero trade by the filer divided by the total number of Schedule 13D filings in the sample.

¹²For every distance to the filing date, the percentage of outstanding shares traded by Schedule 13D filers is the ratio of the number of shares traded by the Schedule 13D filer to the number of total shares outstanding.

[Insert Figure 3 here]

We see that the probability that a Schedule 13D filer trades at least one share on a given day is approximately 30% and reaches 65% 10 days prior to the filing date. Figure 3 also shows that Schedule 13D filers gradually increase the percentage of outstanding shares purchased on every trading day until 10 days prior to the filing date. For example, the average percentage of outstanding shares purchased on every trading day by the Schedule 13D filers increases from 0.05% to (0.20% to 0.25%) closer to the 10 days prior to the filing date, and then gradually decreases from (0.20% to 0.25%) to (0.10% to 0.15%). Undocumented results show that part of the increase in the trading activity during the $(t-12,t-8)$ period prior to the filing date is driven by the trading activity on the event date. Rule 13d-1(a) requires Schedule 13D filers to file with the SEC within 10 days after the event date.¹³

Summary statistics for the trading strategies of Schedule 13D filers are reported in Table IV, which replicates Table I from Collin-Dufresne and Fos (2015), while restricting the sample to targets with listed options. Columns (1) and (5) report summary statistics of all reported trades. The average (median) stock ownership on the filing date is 7.14% (6.20%). The average (median) filer purchases 4.0% (3.8%) of outstanding shares during the 60-day period prior to the filing date. This corresponds to an average (median) purchase of 2,288,796 (1,286,275) shares at an average (median) cost of \$54.1 (\$26.6) million. On days with nonzero informed volume, the filer purchases 0.3% (0.2%) of all outstanding shares.

[Insert Table IV here]

¹³When we consider the distance between the event date and the filing date, we find that Schedule 13D filers often interpret the 10-day period in terms of business days and not calendar days. This is why event dates are clustered during the $(t-12,t-9)$ period prior to the filing date.

Summary statistics for trades executed by Schedule 13D filers during the pre-event date period are reported in columns (2) and (6), summary statistics for trades on the event date are reported in columns (3) and (7), and summary statistics for trades during the post-event date period are reported in columns (4) and (8). Schedule 13D filers trade more aggressively on the event date. For example, the average (median) increase in the ownership per trading day with nonzero informed volume is 0.9% (0.4%) on the event date compared with 0.3% (0.2%) during the pre-event period.

To summarize, the evidence suggests that (1) Schedule 13D filers do not trade every day (but rather every two or three days), (2) when they trade, Schedule 13D filers trade a relatively large fraction of the daily volume (around 15% of the daily volume), and (3) Schedule 13D filers trade more aggressively on the event date.

We conclude the description of trading strategies by comparing trading strategies of Schedule 13D filers to trading strategies of Schedule 13D filers reported in Table I of Collin-Dufresne and Fos (2015), who do not impose the listed options requirement. Overall, trading strategies in the two samples are similar on several dimensions, including the filing date stock ownership and the change in stock ownership during the 60-day period. However, we find that Schedule 13D filers trade larger amounts when stock with listed options are concerned: \$54.1m versus \$16.4m in the full sample. Because companies with listed options have larger market cap, these large trades constitute a smaller portion of daily trading volume. Specifically, activist trading is 13.9% of daily turnover when listed options are available versus 31.5% in the full sample. It therefore should be harder to find a footprint of informed trading in the sub-sample with listed options. Despite that, the evidence we present in the following sections indicates that options prices contain valuable information about the future distribution of stock returns.

III. Stock Prices and Realized Volatility around the Filing Date

In this section we document changes in stock prices and realized volatility around the filing date. As we described above, on the filing date it becomes common knowledge that an activist shareholder has accumulated a significant position in the company and has an intention to influence company's management. While it has been documented that stock markets typically react positively to Schedule 13D filings (e.g., Brav et al., 2008; Klein and Zur, 2009; Collin-Dufresne and Fos, 2015), it is important to document what happens for our specific sample of Schedule 13D filings.

Figure 4 plots the average buy-and-hold return, in excess of the buy-and-hold return on the value-weighted NYSE/Amex/NASDAQ index from CRSP, from 50 days prior to the filing date to 40 days afterward. The sample includes data from 1996 to 2010. As can be seen, there is a run-up of about 3% from 50 days to one day prior to the filing date. The two-day jump in excess return observed at the filing date is around 2.5%. After that the excess return remains positive for about 10 days and cumulates to a total of 6.5%. Thus, stock market reaction to Schedule 13D filings is favorable.

[Insert Figure 4 here]

We next investigate changes in realized volatility around the filing date. The realized volatility is calculated as the absolute value of daily stock return. The results are reported in Figure 5, which plots the realized volatility from 50 days before the filing date to 50 days after. The dark (gray) line plots the realized volatility for the sample of event (matched) firms.

[Insert Figure 5 here]

Figure 5 shows that the realized volatility decreases after filing date. Specifically, we find that the realized volatility decreases from 67% prior to the filing date to 57% after

the filing date, corresponding to a 15% reduction. Thus, Schedule 13D filings have a substantial effect on the realized volatility. The Figure also reveals that there is a positive trend in realized volatility for the sample of event firms as well as for the sample of matched firms.

We next compare the changes in measures of the realized volatility after the filing date for the event stocks and for matched stocks. Results are reported in Table V and generally confirm the pattern we observe in Figure 5. Whereas the realized volatility measures increase insignificantly for the sample of matched stocks, there is a substantial reduction in these measures for the sample of event firms. For example, the realized volatility calculated using intra-day data decreases from 0.48 to 0.43 around the filing date, corresponding to a 10% reduction. When we consider the difference in changes of realized volatility between event and matched stocks, we find very similar results. The difference-in-differences estimates are negative and highly significant statistically. Overall, the evidence shows that the realized volatility drops to a lower trajectory.

[Insert Table V here]

So far, the results reveal two distinct features of Schedule 13D filings: stock prices appreciate and the realized volatility decreases around the filing. We next argue that these two pieces of information are valuable. First, note that Schedule 13D filers trade on long-lived information that, by its very nature, is not likely to be available to other market participants. In most cases, these activist shareholders know they can increase the value of the firm they invest in by their own effort (e.g., shareholder activism). Their effort level is, of course, conditional on their achieving a large stake in the firm. It is their very actions and shareholding that constitute the “private” information in many cases. Only when they file with the SEC, 10 days after their holdings reach the 5% threshold, does the information become public. The extent to which the market believes their future actions have value over and above what is already impounded in

prices can be measured using announcement returns. The evidence reported in Figure 4 strongly supports the assumption that Schedule 13D filers possess valuable information on the underlying securities when they trade in the pre-announcement period.

In addition to the average buy-and-hold return, we follow Collin-Dufresne and Fos (2015) and analyze profits made by Schedule 13D filers on purchasing stocks at the pre-announcement prices. The results are reported in the Table VI and suggest that Schedule 13D filers make significant profits. We split the sample into five market cap quantiles and report average profit measures for every quantile. For example, a Schedule 13D filer who acquires a \$62 million stake in a \$874 million market cap company (i.e., a 7.14% stake, which is the average stake size in our sample) expects to benefit \$2.35 million. This can be further broken down into a \$1.76 million profit on trades during the 60-day period and a \$0.59 million profit on the initial ownership, purchased prior to the 60-day window. The evidence also suggests that the main beneficiaries are shareholders who own shares on the announcement date. For example, shareholders of a \$874 million market cap company gain \$39 million during an average event whereas Schedule 13D filers gain \$2.3 million. Therefore, while Schedule 13D filers benefit from uninformed traders who sell their shares during the pre-announcement period, they create significant value for all other shareholders by deciding to file a Schedule 13D and intervene in a company's governance.

[Insert Table VI here]

Next, we show that the information on the drop in realized volatility is valuable. Figure 6 plots the average buy-and-hold return on selling delta-neutral option strategies from 50 days prior to the filing date to 5 days prior to the filing date. As can be seen, the abnormal return is positive and aggregates to 5.5% from 30 days to five days prior to the filing date. Thus, whereas activists do not use derivatives to benefit from the drop in volatility, a strategy that sells volatility could potentially be profitable.

[Insert Figure 6 here]

IV. Do Stock and Option Prices Reflect the Presences of Informed Trading?

In the previous section we showed that there are two types of valuable private information revealed on the filing date. First, the excess return from 50 days prior to the filing date to 10 days after the filing date is positive and cumulates to a total of 6.5%. Thus, there is ‘directional’ private information. Second, the realized volatility decreases by 15% after the filing date. This is consistent with the presence of volatility private information. In this section we investigate whether (and when) prices reveal directional information and volatility information.

As we discussed in Section II, we restrict the analysis to the sample of 522 Schedule 13D filings (target companies have exchange-listed options and Schedule 13D filers do not use derivatives). A unique feature of this sample is that we know not only when informed activists traded in the underlying shares, but also that they did not participate in direct trading in options. This feature allows us to identify the effect of informed trading in the stock market on option prices. Specifically, we can exclude the possibility that option prices are directly affected by activist trading. Moreover, we can exclude the possibility that activist shareholders selected days on which they trade in the stock market based on option market characteristics. Whereas such a selection can take place at event level (targeted firms are not selected randomly), it is not likely that such a selection is taking place when activists select on what trading days to purchase shares.

A. Stock Prices

In this section we investigate how directional private information flows into stock prices. A unique feature of our sample is that we can identify days when traders with directional private information trade. This is because Schedule 13D filers determine the filing date. They also ‘own’ the private information. However, as we have documented, in the vast

majority of events (97.4%) activist shareholders use stock market only and do not take any position in derivatives. They therefore forgo the opportunity to trade on volatility information using options and their intention is to trade on the directional information only. In this section we ask whether stock prices reflect directional information.

We begin from investigating the how stock market activity changes closer to the filing date. We analyze excess return, volatility, volume, and bid-ask spread. We compare differences in changes of these outcome variables from $(t-60,t-31)$ days prior to the filing date t to $(t-30,t-1)$ days prior to the filing date between event and matched stocks. Results are reported in Panel A of Table VII.

[Insert Table VII here]

We find that changes in excess returns are higher for event stocks relative to matched stocks. This is consistent with the evidence reported in Figure 4. We also find that volatility decreases and trading volume increases closer to the filing date. We find no significant increase in the bid-ask spread closer to the filing date. This is consistent with activists crossing the 5% toehold after a period of high noise trading activity Collin-Dufresne and Fos (2015, 2014a).

We next investigate the relation between Schedule 13D filers' trades and stock market activity measures. We compare the market-adjusted returns, volatility, trading volume, and bid-ask spread on days when Schedule 13D filers trade and on days when Schedule 13D filers do not trade during the 60-day disclosure period. Panels B, C, and D in Table VII report the results.

The evidence is consistent with trades by Schedule 13D filers affecting stock prices. Consistently with the evidence documented by Collin-Dufresne and Fos (2015), market-adjusted returns (*eret*) are higher by 0.15%-0.20% on days when Schedule 13D filers trade. Thus, the evidence indicates that on days when Schedule 13D filers trade, prices move in the 'right' direction. As 'directional' private information about the impact

of activism on firm value is incorporated in stock prices, adverse selection risk should be higher on days when they trade. Realized volatility is always higher on days when Schedule 13D filers trade, but is statistically significant only in one specification.

Is this adverse selection risk reflected in measures of adverse selection? The evidence in columns (3) and (4) of Table VII reveal that on days when Schedule 13D filers trade trading volume is higher and the bid-ask spread is lower. These results are consistent with Collin-Dufresne and Fos (2014a), who predict that informed traders should select to trade when noise trading activity is large and thus when measured price impact is smaller.

B. Option Prices

In the previous section we described how trading by activist shareholders leads to the incorporation of directional private information into stock prices. We also confirmed results first documented by Collin-Dufresne and Fos (2015) that stock-market-based adverse selection measures are lower on days when activist investors trade (and even though prices increase on those days).

In this section we ask whether informed trading by activist shareholders in the stock market leaves a footprint in the option market. Specifically, we investigate how directional private information and volatility private information are incorporate into *option* prices. Whereas informed traders could potentially trade on directional information in either stock or option markets, they could only trade on the volatility information in non-linear securities such as options. Options prices therefore provide a unique opportunity to test whether when informed investors trade in stock market their information is incorporated into option prices.

Figure 5 shows that there is a significant decrease in realized volatility on the filing date. Do option prices reflect the drop in the realized volatility after the filing date?

To address this question, we analyze the relation between *future* realized volatility and implied volatility that is reflected in option prices. The results are reported in Figure 7.

[Insert Figure 7 here]

We find that implied volatility closely follows the *future* realized volatility around the filing date. Both volatilities decrease starting 30 days prior to the filing date. The decrease in the future realized volatility is driven by the inclusion of the filing date in the 30-day period over which the volatility is calculated. The decrease in the implied volatility indicates that option prices reflect the future drop in the realized volatility.

The evidence clearly indicates that option prices reflect the information about the future drop in realized volatility. We next ask whether option prices reflect the timing and the direction of the informational event. To address this question, we plot changes in call options time slope around the filing date. Time slope is defined as the ratio of implied volatilities for call options with 30 days to expiration and call options with 365 days to expiration, minus one. Figure 8 presents the results and shows that the ratio between short-term and long-term implied volatilities increases closer to the filing date. This evidence suggests that option prices reflect a higher chance of an informational event in the short term relative to the long term.

[Insert Figure 8 here]

To further investigate whether option prices reflect higher chances of a large stock price move, we next investigate implied volatility skew. Figure 9 plots put options implied volatility skew around the filing date. Put skew is defined as the ratio of implied volatilities for out-of-the-money and at-the-money put options, minus one. We find that put skew increases substantially closer to the filing date. In contrast, there is no change in put skew for the sample of matched stocks. Figure 10 plots call options

implied volatility skew around the filing date. Call skew is defined as the ratio of implied volatilities for out-of-the-money and at-the-money call options, minus one. Similarly to the results for put options, we find that whereas call skew increases substantially closer to the filing date, there is no change in call skew for the sample of matched stocks. Overall, option prices reflect higher chances of a substantial stock price movement closer to the filing date.

[Insert Figure 9 here]

[Insert Figure 10 here]

To further support the results, we next test whether changes in implied volatility measures closer to the filing date are significant. We analyze put skew, call skew, time slope, implied volatility of call options, changes in implied volatility of call options, implied volatility of put options, changes in implied volatility of put options, and the difference in implied volatilities of call and put options. We compare differences in changes of these outcome variables from $(t-60,t-31)$ days prior to the filing date t to $(t-30,t-1)$ days prior to the filing date between event and matched stocks. Panel A in Table VIII reports the results. The results confirm our findings. We find significant increases in put skew, call skew, and time slope as well as significantly lower levels of implied volatilities closer to the filing date.

[Insert Table VIII here]

To summarize, we find that option prices change substantially closer to the filing date. Specifically, changes in implied volatilities reflect higher chances of an informational event and changes in time slope of implied volatilities indicate that market participants anticipate the timing of the event. Why do option prices change? A unique feature of our sample is that with a high level of confidence we can claim that Schedule 13D filers

do not trade options. Therefore, their trading cannot have a direct impact on option price. Option prices might also reflect information from stock market trades and prices.

In order to investigate why option prices change, we study whether changes in option prices take place on days when Schedule 13D filers trade in the stock market. If option market participants infer information from sources unrelated to Schedule 13D filers' trades, the changes in implied volatilities should be similar on days when Schedule 13D filers trade and on days when Schedule 13D filers do not trade. In contrast, if option market participants infer information from sources directly related to Schedule 13D filers' trades in the stock market, the changes in implied volatilities should be larger on days when Schedule 13D filers trade than on days when Schedule 13D filers do not trade.

Panels B, C, and D of Table VIII compare implied volatility measures on days when Schedule 13D filers trade and on days when Schedule 13D filers do not trade. The results are consistent across all outcome variables: changes in outcome variables are larger on days when Schedule 13D filers trade than on days when Schedule 13D filers do not trade.¹⁴ Thus, the evidence indicates that more information flows into *option* prices on days when Schedule 13D filers trade in the stock market.

Is it reflected in higher adverse selection risk? To address this question, we next study how informed trading in stock market is reflected in option bid-ask spreads. We first compare differences in changes of bid-ask spread from $(t-60,t-31)$ days prior to the filing date t to $(t-30,t-1)$ days prior to the filing date between event and matched stocks. Results are reported in Panel A of Table IX.

¹⁴The evidence in the last column of Table VIII shows that the difference between IV Call and IV Put is negative and significant on days when Schedule 13D filers trade. To investigate the possibility that lending fees drive this result, we analyze several proxies of the cost of borrowing shares in the stock market. Table A2 in the Appendix shows that whereas there is no significant increase in the cost of borrowing shares on days when Schedule 13D filers trade, there is a significant reduction in the number of shares available to borrow and the number of shares on loan. These results are consistent with a limited supply of shares on days when Schedule 13D filers trade.

[Insert Table IX here]

We find that closer to the filing date, option bid-ask spreads are wider for event stocks relative to matched stocks. For example, call options bid-ask spread is 35 basis points higher closer to the filing date, corresponding to more than 4% of the average spread in the sample. The differences are statistically significant across all types of options (calls, puts, OTM puts, and OTM calls).

We next investigate the relation between Schedule 13D filers' trades in the stock market and option bid-ask spreads. We compare bid-ask spreads on days when Schedule 13D filers trade and on days when Schedule 13D filers do not trade during the 60-day disclosure period. Panels B, C, and D in Table IX report the results. We find that option bid-ask spreads are wider when Schedule 13D filers trade in the underlying shares. The results are robust across different types of options and regression specifications.

So far, the evidence indicates that when Schedule 13D filers trade in the stock market, volatility information (Figure 7) as well as directional information (Figure 4) flow into prices. When it happens, adverse selection risk reflected in option prices increases. We next investigate what is the main reason for the increased adverse selection risk: directional or volatility information. To perform the analysis, we analyse the cross-sectional variation in the changes of option bid-ask spread. First, we split the sample based on the average buy-and-hold return around the filing date in excess of the buy-and-hold return of the value-weighted market from 30 days prior to the filing date to 1 day afterwards. This cross-sectional heterogeneity captures the magnitude of directional information. Second, we split the sample based on the difference in realized volatility during $(t+2,t+6)$ and the remaining sample period. This cross-sectional heterogeneity captures the magnitude of volatility information. Table X reports the results.

[Insert Table X here]

Consider the first row of the table. The evidence shows that the increase in option bid-ask spread is present irrespectively of the magnitude of the directional information. Whereas the estimate is larger when buy-and-hold return is larger, both are positive and statistically significant. Specifically, the coefficient of *itrade* changes from 0.31% to 0.41% (0.22%) when the sample with high (low) buy-and-hold return is concerned. In contrast, column (1) shows that option bid-ask spreads are wider on days when Schedule 13D filers trade only when volatility drop is large. The coefficient of *itrade* is 0.57% when the volatility drop is large (highly statistically significant) versus 0.10% when the volatility drop is small (statistically insignificant). The table also shows that the increase in option bid-ask spread is largest when both volatility drop and buy-and-hold return are large. Overall, the results are consistent with volatility information playing a larger role than directional information in the increases in option bid-ask spread.

To further understand how the information flows into option prices, we study trading activity in the option market. Specifically, we look at open interest, option-to-stock volume, option volume, put volume, and call volume. The results are reported in Table XI. Panel A compares differences in changes of these outcome variables from $(t-60,t-31)$ days prior to the filing date t to $(t-30,t-1)$ days prior to the filing date between event and matched stocks. Panels B, C, and D compare outcome variables on days when Schedule 13D filers trade and on days when Schedule 13D filers do not trade.

[Insert Table XI here]

We find that on days when Schedule 13D filers trade in the stock market, there is a significant increase in option open interest. Results in column (1) indicate an increased interest in options on days when Schedule 13D filers trade. When we study the ratio of option-to-stock volume (column (2)), we find that option volume is lower relative to stock volume on days when Schedule 13D filers trade in the stock market. We find that option volume is lower relative to stock volume even though option volume increases

on days when Schedule 13D filers trade (column (3)). This finding is consistent with the significant increase in stock market volume on days when Schedule 13D filers trade (Table VII). One interpretation of this result is that Schedule 13D filers are more likely to purchase shares when stock market volume is high. Because they select to trade based on stock market activity and not based on option market activity, stock volume is higher relative to option volume on days when Schedule 13D filers trade.

In columns (4) and (5) we analyze volume in call and put options. The evidence indicates that whereas call volume is lower closer to filing days, there is no significant difference between call volumes on days when Schedule 13D filers trade and days when they do not trade. Therefore, it is not likely that changes in call option prices are driven by abnormal trading activity. Instead, it is likely the case that option market makers adjust call option prices in response to changes in stock market trading activity and prices. In contrast, when we consider trading activity in put options, we find that put volume is significantly higher on days when Schedule 13D filers trade in the stock market. It is therefore possible that information flows into prices of put options through trading.

Option volume has little to say about trade direction, i.e. whether investors buy or sell options. To explore this dimension we analyze option order imbalance. Following the literature, order imbalance is computed as the difference between the number of buy and sell-initiated option trades by non-market-makers divided by total number of option trades for a given stock and day. Order imbalances for a sub-sample of options (such as only calls) or trades (such as trades that open new position) are defined similarly. Thus, order imbalance can range only between -1 and 1. Our data identifies who (market-maker or non market-maker) takes each side of option transaction and are aggregated at the option contract by day level. Thus we avoid an estimation error from assuming that market-makers always provide liquidity and infer trade direction from the comparison of trade price with the quote midpoint. Muravyev (2015) describes the data and order imbalance measures in detail. We consider the total order imbalance and the order

imbalance for trades when a new option contract is opened. The results are reported in Table XII.

[Insert Table XII here]

Panel A shows that put options order imbalance increases closer to the filing date and these increases are mostly driven by trades that lead to a close of the position. Thus, it seems that closer to the filing date non market makers are more likely to buy put options with the purpose to close a position. The evidence in Panels B, C, and D reveals that these increases in put order imbalance are not driven by days when Schedule 13D filers trade. When we consider order imbalance in call options, we find that the order imbalance increases closer to the filing dates and the increase is mostly driven buy openings of new positions. Panels B, C, and D reveal that these changes are not concentrated on days when Schedule 13D filers trade.

Overall, evidence in Table XII and Table VIII shows that trading patterns as well as changes in implied volatility of put options are consistent with market participants anticipating a drop in stock prices. As far as call options are concern, changes in order imbalance are consistent with higher chances of an increase in stock prices. Thus, whereas the market anticipates informational event, it does not seem to be aware about the direction of the stock price change.

V. A model of informed trading with random announcement effects

We want to understand if the empirical stylized facts we observe in stock, realized and implied volatilities are consistent with informed trading occurring in the equity market alone. For that we develop a simple model to serve as a *null hypothesis*. This model should fit some of the facts we observe in our data. First, activists accumulate shares in the equity market anonymously trading on their private information. This information

is long-lived and they trade strategically exploiting the higher unusual volume prior to the event date. Second, there is a surprise announcement that conveys information about the activist's position and information. Third, this announcement does not reveal all the information. There is residual uncertainty about the activist's actions and/or performance and therefore about the future value of the firm. Fourth, we assume the informed investor trades only the underlying stock.¹⁵

We assume that the total value of the firm is revealed to the market in a sequence of n announcement of size v_i $i = 0, \dots, n$ that occur at the random times τ_i of a Poisson counting process N_t with intensity ρ_t and where we define $\tau_0 = 0$.¹⁶ We assume that the event arrival intensity $\rho_t = \rho(t, \tau_{N_t-}, N_{t-})$ is predictable and a deterministic function of time between arrivals and that it can jump at an event date, to capture the fact that an announcement becomes more likely after the insider has been trading on his new information for some time. Especially for the case of an activist investor, it seems reasonable to assume that the intensity of an announcement starts close to zero and increases over time, since much of the information is the change in the activist's position in the firm which changes his incentives to engage in activism.¹⁷

It is useful to define the pure jump process starting from $V_0 = v_0$:

$$dV_t = v_i dN_t \tag{1}$$

which represents the sum of cumulative announcements that are public knowledge at time t .

¹⁵It would be interesting to understand why this might be the result of an equilibrium outcome. Here we ask the simpler question: under the null that they only trade in one market and that this is common-knowledge, what price action would one expect in options.

¹⁶So $N_t = \sum_{i=1}^n \mathbf{1}_{\{\tau_i \leq t\}}$ where the inter-arrival times $\tau_i - \tau_{i-1}$ are exponentially distributed with intensity parameter ρ_t for all $i > 0$.

¹⁷See Back, Collin-Dufresne and Fos (2015) for a general model of such informed trading with an endogenous terminal value.

After the last announcement at time τ_n the firm value will be:

$$V_{\tau_n} = \sum_{i=0}^n v_i. \quad (2)$$

We assume that the v_i are independent random variables that are normally distributed $v_i \sim N(0, \Sigma_0^i) \quad \forall i = 1, 2, \dots, n$.

Further, we assume that v_i is known to the insider as of time τ_{i-1} , but will be revealed to all market participants at the announcement date τ_i . So effectively, the insider has access to the information about v_i one period (of random length $\tau_i - \tau_{i-1}$) ahead of the market and can trade on his information continuously between announcement dates. However, these announcement dates are random.

The model is essentially a succession of Kyle-Back models with random announcement dates.¹⁸ It extends the Admati and Pfleiderer (1988) and Foster and Viswanathan (1990) models to allow for continuous trading in between random announcement dates.¹⁹

The activist will maximize his present value of future profits

$$\max_{X_t \in \mathcal{A}} \mathbb{E} \left[\int_0^{\tau_n} (V_{\tau_n} - P_t) dX_t \mid \mathcal{F}_0^M, v_1 \right]. \quad (3)$$

where we denote by \mathcal{F}_t^M the information filtration of the market maker generated by observing the entire past history of aggregate order flow $\{Y_s\}_{s \leq t}$ and the public announcements $\{V_s\}_{s \leq t}$. Note that in addition to the market's information at any date t the insider also knows v_{N_t+1} .

¹⁸Exponential arrival of a random terminal date has been used in previous papers such as Back and Baruch (2004) and Caldentey and Stacchetti (2010).

¹⁹Both Admati and Pfleiderer (1988) and Foster and Vishwanathan (1990) consider a sequence of myopic one-period Kyle models.

The activist must choose a trading rule (the cumulative number of shares X_t) in some admissible set \mathcal{A} defined to be the set of absolutely continuous trading strategies (i.e., $dX_t = \theta_t dt$) which are **adapted** to his private information filtration (generated by \mathcal{F}_t^M and $v_{N_{t+1}}$) and satisfy the technical restriction that $E[\int_0^T |\theta_s|^2 ds] < \infty$.²⁰

As in the standard Kyle-Back models we assume that in addition to the informed trader there are two other types of traders. Noise traders who trade randomly for liquidity purposes and market makers who are competitive and absorb the total cumulative order flow Y_t at a price they set so as to break-even.

Aggregate order flow Y_t is the sum of informed and uninformed order flow:

$$dY_t = dX_t + \sigma_t dZ_t, \quad (4)$$

where Z_t is a standard Brownian motion. We allow the volatility of uninformed order flow, $\sigma_t = \sigma(t, \tau_{N_{t-}}, N_{t-})$, to be a deterministic function of time, in between announcement dates, to model the fact that abnormal volume can change over time in a predictable fashion.²¹ We also allow for a predictable jump in noise trading volatility at every announcement date.

As we saw previously, there is substantial variation in abnormal volume that is not due to the activist's trades. Further, volume tends to be abnormally high just prior to the event date. A simple way to capture this is to model σ_t as an increasing process in between event dates.

²⁰A shown in Back, it is optimal for the activist to choose an absolutely continuous trading strategy, since, in continuous time, the market maker can immediately infer from the quadratic variation of the order flow the informed component with infinite variation. The square integrability condition is a technical requirement often used in continuous time to rule out specific arbitrage strategies such as 'doubling strategies' (see Harrison and Pliska, 1981; Dybvig and Huang, 1988).

²¹A deterministic noise trading volatility in the standard Kyle-Back model is introduced in Back and Pedersen (1998). The case of an arbitrary stochastic volatility is considered in Collin-Dufresne and Fos (2014b).

Note that in equilibrium the trading strategy will be absolutely continuous,²² i.e., $dX_t = \theta_t dt$.

An equilibrium is an admissible trading strategy $\{\theta_t\}_{t \in [0, \infty]}$ and a price process $\{P_t\}_{t \in [0, \infty]}$ that (i) solve the optimization problem (3) for the insider and (ii) satisfy the rational expectations condition for the market maker:

$$P_t = E[V_{\tau_n} | \mathcal{F}_t^M] \quad (5)$$

To solve of the equilibrium we proceed recursively. Intuitively, at every announcement date the insider has only private information about the next announcement. Thus the equilibrium looks like a sequence of equilibria with one single random announcement date, that resets at every new announcements. We discuss this more formally in the appendix. Let us first consider the simpler case where there is one single random announcement date (i.e., $n = 1$).

A. The one random announcement case ($n = 1$)

In this section we solve the problem where there is only one random and exponentially distributed announcement date.

Specifically, we solve for the equilibrium value function:

$$J(t, p, v) = \max_{\theta_s} E\left[\int_t^\tau (v - p_s)\theta_s \mathbf{1}_{\{\tau > s\}} ds \mid \mathcal{F}_t^y, v\right] \quad (6)$$

$$p_t = E[v \mid \mathcal{F}_t^y, \tau > t] \quad (7)$$

$$dy_t = \theta_t \mathbf{1}_{\{\tau > t\}} dt + \sigma_t dZ_t \quad (8)$$

²²The proof of this is analogous to Back (1992) and is intuitive since in continuous time any trade loading on the Brownian motion term would be instantaneously discovered by the market maker.

and where the prior distribution for the market maker is $v \sim N(v_0, \Sigma_0)$ and τ is Poisson distributed with deterministic intensity ρ_t . Note that p_t is the price of the stock *prior* to the announcement date. On the event date the price will jump to its announcement value v . Thus the ‘full’ price of the stock is

$$P_t = p_t \mathbf{1}_{\{\tau > t\}} + v \mathbf{1}_{\{\tau \leq t\}}. \quad (9)$$

Because we are focusing on the single announcement case, the price is constant after the first announcement. To solve the pre-announcement equilibrium, we first conjecture that the trading strategy of the insider on the set $\{\tau > t\}$ is of the form:

$$\theta_t = \beta_t(v - p_t) \quad (10)$$

Given this conjecture the market maker’s filtering problem is a standard conditionally Gaussian problem on the set $\{\tau > t\}$:

$$dp_t = \lambda_t dY_t \quad (11)$$

$$\lambda_t = \frac{\beta_t \Sigma_t}{\sigma^2} \quad (12)$$

$$d\Sigma_t = -\lambda_t^2 \sigma^2 dt \quad (13)$$

where $\Sigma_t = E[(v - p_t)^2 | \mathcal{F}_t^y]$ is the conditional posterior variance of the Market maker conditional on observing the continuous order flow. Note the crucial fact that the announcement date is unpredictable and independent of v , hence knowing $\tau > t$ does not improve the learning of the market maker, i.e., $p_t = E[v | \mathcal{F}_t^y, \tau > t] = E[v | \mathcal{F}_t^y]$.

Given these price dynamics we turn to solving the insider’s optimization problem. First, note that his value function can be rewritten as (on the set $\tau > t$):

$$J(t, p, v) = \max_{\theta_s} E \left[\int_t^\infty e^{-\int_s^t \rho_u du} (v - p_s) \theta_s ds \mid \mathcal{F}_t^y, v \right] \quad (14)$$

If we conjecture that λ_t is a deterministic function of time, then Σ_t, β_t are also deterministic. In turn the HJB equation is:

$$\max_{\theta} \left\{ J_t + \frac{1}{2} J_{pp} \lambda_t^2 \sigma_t^2 + J_p \lambda_t \theta - \rho_t J + (v - p_t) \theta \right\} = 0 \quad (15)$$

It follows that the first order condition is:

$$J_p \lambda_t + (v - p_t) = 0 \quad (16)$$

We thus guess a quadratic form

$$J(t, p, v) = \frac{(v - p)^2}{2\lambda_t} + f(t) \quad (17)$$

Using this guess in the HJB equation we find

$$f' - (v - p)^2 \frac{\lambda_t'}{2\lambda_t^2} + \frac{1}{2} \lambda_t \sigma_t^2 - \rho_t \left(\frac{(v - p)^2}{2\lambda_t} + f(t) \right) = 0 \quad (18)$$

Thus the guess is consistent if:

$$0 = f' + \frac{1}{2} \lambda_t \sigma_t^2 - \rho_t f(t) \quad (19)$$

$$\frac{\lambda_t'}{\lambda_t} = -\rho_t \quad (20)$$

Solving the equation for λ we obtain:

$$\lambda_t = \lambda_0 e^{-\int_0^t \rho_u du} \quad (21)$$

Solving the equation for $f(t)$ (subject to $f(\infty) = 0$) gives the solution:

$$f(t) = \lambda_t \int_t^{\infty} e^{-2 \int_t^s \rho_u du} \frac{1}{2} \sigma_s^2 ds \quad (22)$$

Solving for the posterior variance we find:

$$\Sigma_t = \Sigma_0 - \int_0^t \lambda_s^2 \sigma_s^2 ds \quad (23)$$

We can show the following:

Theorem 1. *There exists an equilibrium where the price process follows*

$$dP_t = \frac{\lambda_t^2 \sigma^2}{\Sigma_t} (v - P_t) dt + \lambda_t \sigma_t dZ_t + (v - P_t) d\mathbf{1}_{\{\tau \leq t\}} \quad (24)$$

and λ_t, Σ_t are given in equations (21) and (23) if we can find a constant λ_0 such that $\lim_{t \rightarrow \infty} \Sigma_t = 0$. In that equilibrium the informed investor trades as in equation (10) with $\beta_t = \frac{\lambda_t \sigma^2}{\Sigma_t}$.

Proof. First we note that if the insider follows the strategy listed in the theorem, then the price $P_t = p_t \mathbf{1}_{\{\tau > t\}} + v \mathbf{1}_{\{\tau \leq t\}}$, where p_t is defined in equation (7). That is the price is consistent with the equilibrium zero-profit condition of the market maker. It remains thus to show that θ_t given in the theorem, is an optimal trading strategy for the insider, i.e., that it solves the optimization problem (14) on $\tau > t$.

To that effect, consider an arbitrary trading strategy θ_t and apply Itô's lemma to the candidate quadratic value function (17):

$$\begin{aligned} e^{-\int_0^T \rho_s ds} J(T, p_t, v) - J(0, p_0, v) &= \int_0^T e^{-\int_0^t \rho_s ds} (dJ(t, p_t, v) - \rho_t J(t, p_t, v) dt) \\ &= - \int_0^T e^{-\int_0^t \rho_s ds} (v - p_t) (\theta_t dt + \sigma dZ_t) \end{aligned}$$

Taking expectation we find that for any admissible trading strategies:

$$J(0, p_0, v) = \mathbb{E} \left[e^{-\int_0^T \rho_s ds} J(T, p_T, v) + \int_0^T e^{-\int_0^t \rho_s ds} (v - p_t) \theta_t dt \right] \quad (25)$$

Now, note that by definition $J(T, p_T, v) \geq 0$, thus

$$J(0, p_0, v) \geq \mathbb{E} \left[\int_0^T e^{-\int_0^t \rho_s ds} (v - p_t) \theta_t dt \right] \quad (26)$$

for all θ_t and all T . In particular, taking the limit as $T \rightarrow \infty$ we have by bounded convergence:

$$J(0, p_0, v) \geq \mathbb{E} \left[\int_0^\infty e^{-\int_0^t \rho_s ds} (v - p_t) \theta_t dt \right] \quad (27)$$

Further, if we can find a trading strategy such that $\lim_{T \rightarrow \infty} \mathbb{E} \left[e^{-\int_0^T \rho_s ds} J(T, p_T, v) \right] = 0$ then we obtain an equality in equation (27) which proves the optimality of the strategy.

Now, note that

$$\begin{aligned} \mathbb{E} \left[e^{-\int_0^T \rho_s ds} J(T, p_T, v) \right] &= \mathbb{E} \left[e^{-\int_0^T \rho_s ds} \left\{ \frac{(v - p_T)^2}{2\lambda_T} + f(T) \right\} \right] \\ &= \frac{\Sigma_T^2}{2\lambda_0} + e^{-\int_0^T \rho_s ds} f(T) \end{aligned}$$

Clearly a sufficient condition for a the right-hand side to go to zero and an admissible strategy to be optimal is that $\lim_{T \rightarrow \infty} \Sigma_T = 0$ as stated in the theorem. \square

We give two examples where an equilibrium can be solved in closed form.

A.1. Constant intensity and noise trading volatility

Here we explicitly compute the equilibrium when σ, ρ are both constant.

Solving for the posterior variance and imposing the terminal condition $\lim_{t \rightarrow \infty} \Sigma(t) = 0$ we obtain:

$$\Sigma(t) = \frac{\lambda_0^2 \sigma^2}{2\rho} e^{-2\rho t} \quad (28)$$

Then an equilibrium exists if we can find λ_0 such that we satisfy the initial condition $\Sigma(0) = \Sigma_0$. Indeed, we find that the solution is:

$$\lambda_0 = \frac{\sqrt{2\rho\Sigma_0}}{\sigma} \quad (29)$$

and the corresponding posterior variance is:

$$\Sigma(t) = \Sigma_0 e^{-2\rho t} \quad (30)$$

Further, we can compute the equilibrium trading strategy:

$$\theta_t = \frac{2\rho e^{\rho t}}{\lambda_0} (v - p_t) \quad (31)$$

and the price process starts from $P_0 = v_0$ and has jump-diffusion dynamics:

$$dP_t = 2\rho(v - P_t)dt + \sqrt{2\rho\Sigma_0}e^{-\rho t}dZ_t + (v - P_t)d\mathbf{1}_{\{\tau \leq t\}} \quad (32)$$

We note that the equilibrium price prior to the announcement is a Gaussian mean-reverting process *in the filtration of the insider* with mean-reversion strength equal to twice the announcement intensity and an exponentially decreasing volatility.

We can compute its expectation and variance, conditional on the insider's information:

$$\mathbb{E}_t[p_T - v | v, \tau > T] = e^{-2\rho(T-t)}(p_t - v) \quad (33)$$

$$V_t[p_T - v | v, \tau > T] = e^{-2\rho T}(1 - e^{-2\rho(T-t)})\Sigma_0 \quad (34)$$

And we see that p_t converges in L^2 (and indeed almost surely) to v when t goes to infinity.

Note that the true price has continuous dynamics prior to the announcement and jumps to v at τ . Further its volatility jumps to zero. Instead, when there are multiple announcements then the process will start anew at τ .

A.2. Increasing event intensity and noise trading volatility

As discussed above to capture some features of the data it is useful to allow the noise trading volatility to be increasing prior to the announcement date (as we observe an increase in abnormal uninformed volume prior to the event date in our Schedule 13D trading data). Further, it also seems reasonable to assume that the event intensity increases over time. Since most of the private information prior to the announcement is about the actions of the activist, it is unlikely that announcement could occur without the activist having accumulated any shares. Thus we expect the intensity to start close to zero. Instead, the more information has already been incorporated into prices, and thus the less the amount of remaining private information, the more likely the probability of an announcement. Since the posterior variance of the announcement value is a deterministic decreasing function of time, we simply posit that the intensity is an increasing function of time. To obtain simple solutions we choose the following specification:

$$\sigma_t = \sigma_0 e^{mt} \tag{35}$$

$$\rho_t = r_0 + r_1 t \tag{36}$$

Under these conditions we can show that an equilibrium exists under some conditions on the parameters.

Corollary 1. *If the noise trading volatility and event intensity are given by equations (35) and (36) above then an equilibrium exists if and only if either (PA): $\{r_1 > 0\}$ or (PB): $\{r_1 = 0 \text{ and } m < r_0\}$.*

Under (PA) we have:

$$\lambda_0 = \frac{\sqrt{2\Sigma_0(r_0 - m)}}{\sigma_0} \quad (37)$$

$$\Sigma_t = \Sigma_0 e^{-2(r_0 - m)t} \quad (38)$$

$$\lambda_t = \lambda_0 e^{-r_0 t} \quad (39)$$

Under (PB) we have:

$$\lambda_0 = \sqrt{\frac{\Sigma_0 \sqrt{r_1} e^{-\frac{(m-r_0)^2}{r_1}}}{\sqrt{\pi} \sigma_0^2 N\left[\frac{m-r_0}{r_1/2}\right]}} \quad (40)$$

$$\Sigma_t = \Sigma_0 \frac{N\left[\frac{m-r_0-r_1 t}{\sqrt{r_1/2}}\right]}{N\left[\frac{m-r_0}{\sqrt{r_1/2}}\right]} \quad (41)$$

$$\lambda_t = \lambda_0 e^{-r_0 t - \frac{r_1}{2} t^2} \quad (42)$$

where $\mathbf{N}[\cdot]$ is the cumulative normal distribution function. In both cases the equilibrium stock price is given by:

$$dP_t = \frac{\lambda_t^2 \sigma^2}{\Sigma_t} (v - P_t) dt + \lambda_0 \sigma_0 e^{(m-r_0)t - r_1 \frac{t^2}{2}} dZ_t + (v - P_t) d\mathbf{1}_{\{\tau \leq t\}} \quad (43)$$

Proof. If the parameter conditions are not satisfied then the solution for Σ_t diverges when $t \rightarrow \infty$. Thus there does not exist a value λ_0 satisfying the requirements of theorem 1. Instead, if either condition (PA) or (PB) are satisfied we can find such a constant and the corresponding solution for the posterior variance and the price impact functions are as given in the corollary. \square

The price process is mean reverting (in the filtration of the insider) with a mean reversion coefficient that increases to infinity in both (PA) and (PB) cases. Price volatility is decreasing in the (PA) case but it is hump-shaped in the (PB) case, where it is initially increasing and eventually becomes decreasing (after $t \geq \frac{2(m-r_0)}{r_1}$).

The intuition for the behavior of stock price volatility follows from two countervailing forces. When $m > 0$ the insider wants to delay trading to trade more aggressively when there is higher noise trading volatility so he can hide better. On the contrary, the likelihood of an early announcement is an incentive for him to trade early since he worries about not being able to accumulate enough shares prior to the announcement. If $m > r_0$ then the incentive to delay dominates and the insider trades more and more aggressively as time progresses. This explains the increasing volatility which reflects the increasing rate of information arrival. Eventually however, the second order term in the event arrival intensity kicks in (via r_1) and the second effect dominates. Note that these two forces also give some intuition as to why equilibrium does not exist when $m > r_0$ and $r_1 = 0$. In that case, the incentive to delay trading to a future period always dominates the risk of early arrival and there can be no solution that leads to full revelation of the information at infinity.

B. The case with n announcement dates

The model easily generalizes to more than one announcement date. Indeed, at every announcement the insider only has private information about the next announcement. Thus the market maker can only learn about that next announcement from order flow. The equilibrium behaves as a sequence of one (random) announcement equilibria. The price is reset at every announcement date at the prior of the market maker and then follows the price process we solved previously in between announcements. Its dynamics can thus be written as starting from $P_0 = v_0$:

$$dP_t = \beta(t, \tau_{N_{t^-}}, N_{t^-})(V_{1+N_{t^-}} - P_t)dt + \lambda(t, \tau_{N_{t^-}}, N_{t^-})\sigma(t, \tau_{N_{t^-}}, N_{t^-})dZ_t + (V_{1+N_{t^-}} - P_t)dN_t \quad (44)$$

$$\beta(t, \tau, j) = \frac{\lambda(t, \tau, j)\sigma(t, \tau, j)^2}{\Sigma(t, \tau, j)} \quad \forall j \geq 0 \quad (45)$$

$$\lambda(t, \tau, j) = \lambda_0^{j+1} e^{-\int_{\tau}^t \rho(s, \tau, j) ds} \quad \forall j \geq 0 \quad (46)$$

$$\Sigma(t, \tau, j) = \Sigma_0^{j+1} - \int_{\tau}^t \lambda(s, \tau, j)^2 \sigma(s, \tau, j)^2 ds \quad \forall j \geq 0 \quad (47)$$

It follows from our analysis of the one announcement case, that an equilibrium exists if we can find a sequence of initial conditions λ_0^j such that $\lim_{t \rightarrow \infty} \Sigma(t, \tau, j - 1) = 0$ for each $j = 1, \dots, n$.²³

As we see this model delivers a jump diffusion model for the stock price, where both the price level and the price volatility experience a jump on the announcement date. The magnitude of the observed jump in level and in volatility of the stock price depend on how much information has already been impounded in the price due to trading by the informed investor, which will condition how close the market price is to the fair value that is known by the informed investor and thus influence the size of the announcement jump in the level of the price. The jump in volatility will depend on how much private information remains after the trading by the informed investor relative to the amount of new private information that arises at the event date, where we assume the informed investor gets new private information.

If we think of our Schedule 13D filers, then how much new information becomes available to the informed investor on the first announcement date depends on the nature of the activism. For example, if the activist is performing a corporate governance action, then

²³In particular, if both $\rho(s, \tau, j)$ and $\sigma(s, \tau, j)$ only depend on $s - \tau$ then these initial conditions are independent of the realizations of the events.

on the filing date he will likely get new information on the willingness of other board members to agree to the measures etc... So it is plausible that new private information arises around the announcement date. In most cases we would expect that the amount of new private information created is smaller however, than the prior uncertainty (i.e., $\Sigma_0^2 < \Sigma_0^1$). Instead, if we think of an M&A type of announcement or a large strategic investment announcement then the new private information created by this announcement might be greater than in the first round (i.e., $\Sigma_0^2 > \Sigma_0^1$).

Information about these relative levels of volatility will be present in option prices but not in the level of the stock price, even if (it is common-knowledge that) the insider only trades in the underlying stock price. We show this below, where we solve for option prices in this context.

C. Option prices

Suppose the price follows equation (44) with two announcements ($n = 2$) for simplicity. We can rewrite the price process from equation (44) as:

$$dP_t = \sigma_P(t, \tau_{N_{t-}}, N_{t-})d\hat{Z}_t + J(t, \tau_{N_{t-}}, N_{t-})dN_t \quad (48)$$

where \hat{Z}_t is a standard Brownian motion in the filtration of the market maker and the jumps have a normal distribution $J(t, \tau, j) \sim \mathcal{N}(0, \Sigma(t, \tau, j))$. The volatility $\sigma_p(t, \tau, j) = \lambda(t, \tau, j)\sigma(t, \tau, j)$ is deterministic between jumps. Thus, in the filtration of the market maker the process follows a Gaussian Jump-diffusion martingale process with zero drift.²⁴ We use this feature to derive a closed-form solution for the option price in our model.

Suppose options on that stock are traded and it is common-knowledge that informed traders are not trading these options. Then the market maker will set call option prices

²⁴Note that the jump compensator is zero because the jump has zero mean.

prior to the first announcement (i.e., on $t < \tau_1$) so that he breaks-even on purchases by uninformed agents, i.e., such that:

$$\begin{aligned}
C(P_t, K, t, T) &= \mathbb{E}[|P_T - K|^+ | \mathcal{F}_t^Y, \tau_1 > t] \\
&= S_{t,0,T}^0 \mathbb{E}_t[|P_T - K|^+ | \tau_1 > T] + \int_t^T \delta S_{t,0,s}^0 \left\{ S_{s,s,T}^1 \mathbb{E}_t[|P_T - K|^+ | \tau_1 = s, \tau_2 > T] \right. \\
&\quad \left. + \int_s^T \delta S_{s,s,u}^1 \mathbb{E}_t[|P_T - K|^+ | \tau_1 = s, \tau_2 = u] \right\}
\end{aligned} \tag{49}$$

where $C(P, K, t, T)$ denotes the price of the option written on P at strike K at time t with maturity T and we define for $\tau \leq t$:

$$S_{t,\tau,T}^j = \mathbb{E}[\mathbf{1}_{\{\tau_{j+1} > T\}} | \mathcal{F}_t^Y, \tau_j = \tau] = e^{-\int_t^T \rho(s,\tau,j) ds} \tag{50}$$

which denotes the probability that event τ_{j+1} does not occur between t and T conditional on $\tau_j = \tau \leq t$. We also define $\delta_u S_{t,\tau,u}^j = S_{t,\tau,u}^j \rho(u, \tau, j) du$ as the probability that the event τ_{j+1} occurs at u (conditional on $\tau_j = \tau \leq t$).

We can compute the various expectations in the option price formula as follows.

$$\mathbb{E}[|P_T - K|^+ | \mathcal{F}_t^Y, \tau_1 > t] = \mathbb{E}[|P_t + \int_t^T \sigma_P(s, 0, 0) d\hat{Z}_s - K|^+ | \mathcal{F}_t^Y, \tau_1 > t] \tag{51}$$

$$= NC(P_t - K, \int_t^T \sigma_P(s, 0, 0)^2 ds) \tag{52}$$

where we define the function:

$$NC(k, \Sigma) = \mathbb{E}[|\epsilon\sqrt{\Sigma} + k|^+] \quad (53)$$

$$= \int_{-k/\sqrt{\Sigma}}^{\infty} (x\sqrt{\Sigma} + k)\mathbf{n}(x)dx \quad (54)$$

$$= k\mathbf{N}(k/\sqrt{\Sigma}) + \sqrt{\Sigma}\mathbf{n}(k/\sqrt{\Sigma}) \quad (55)$$

where ϵ is a standard normally distributed random variable and $\mathbf{n}(x)$ and $\mathbf{N}(x)$ are the normal density and normal cumulative density function respectively.

Similarly, we have

$$\mathbb{E}_t[|P_T - K|^+ | \tau_1 = s, \tau_2 > T] = \mathbb{E}_t[|P_t + \int_t^s \sigma_P(u, 0, 0)d\hat{Z}_u + \int_s^T \sigma_P(u, s, 1)d\hat{Z}_u + J(s, 0, 0) - K|^+ | \tau_1 = s, \tau_2 > T] \quad (56)$$

$$= NC(P_t - K, \int_s^T \sigma_P(u, s, 1)^2 du + \Sigma(t, 0, 0)) \quad (57)$$

$$\mathbb{E}_t[|P_T - K|^+ | \tau_1 = s, \tau_2 = u] = \mathbb{E}_t[|P_t + \int_t^s \sigma_P(v, 0, 0)d\hat{Z}_v + \int_s^u \sigma_P(v, s, 1)d\hat{Z}_v + J(s, 0, 0) + J(u, s, 1) - K|^+ | \tau_1 = s] \quad (58)$$

$$= NC(P_t - K, \Sigma(t, 0, 0) + \Sigma_0^2) \quad (59)$$

Putting everything together we get the value of the call option prior to the first announcement, i.e., on $t < \tau_1$. A similar formula obtains for the value after the first event, i.e., on $\tau_1 < t < \tau_2$:

$$C(P_t, K, t, T) = \mathbb{E}[|P_T - K|^+ | \mathcal{F}_t^Y, \tau_2 > t > \tau_1] \quad (60)$$

$$= S_{t, \tau_1, T}^1 \mathbb{E}_t[|P_T - K|^+ | \tau_2 > T] + \int_t^T \delta S_{t, \tau_1, s}^1 \mathbb{E}_t[|P_T - K|^+ | \tau_2 = s] \quad (61)$$

$$= S_{t, \tau_1, T}^1 NC(P_t - K, \int_t^T \sigma_P(s, \tau_1, 1)^2 ds) + \int_t^T \delta S_{t, \tau_1, s}^1 NC(P_t - K, \Sigma(t, \tau_1, s)) \quad (62)$$

We can now compute option implied volatilities and prices along various trajectories.

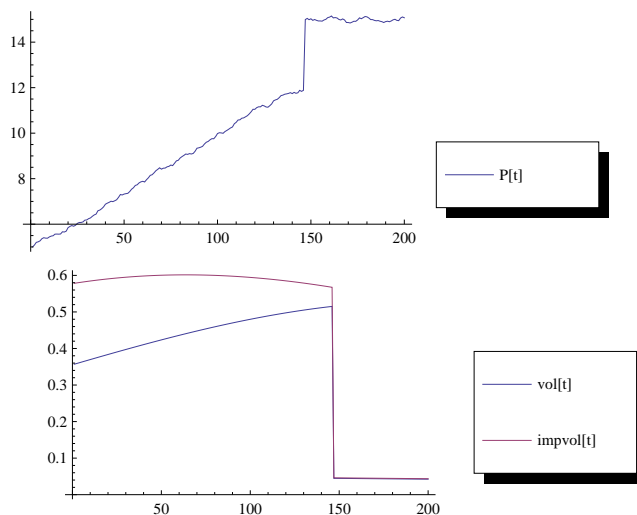


Figure 1:

First panel plots price path with positive jump on announcement. Second panel plots realized versus implied volatilities around the announcement.

We see that this simple model can replicate (qualitatively) some observed features in our data, namely:

- A positive announcement jump on the event date (if the insider spots an undervalued firm),
- An increase in the realized volatility prior to, and drop on, the event date (if noise trading volatility is increasing prior to the event).

- A decrease in the implied volatility on options (if the new uncertainty created after the event is less than uncertainty remaining on the event).
- An increase in both Put skew and Call skew prior to the event (due to the common jump in level and volatility).

However, this simple model cannot explain an increase in option Bid-ask spreads or Option volume, since it assumes that all the informed trading occurs in the underlying stock price. An increase in bid-ask spreads would require that market makers perceive the likelihood of informed trading in options.

Interestingly, the increase in both the put and call skew generated by the model is largely due to the anticipated jump in realized volatility combined with the jump in the level of the stock price. Unlike stocks the cross-section of option prices reflects the anticipated jump in volatility. If some agents had superior information about the latter then options would be the natural venue to trade on that volatility specific information.

VI. Conclusion

In this paper we exploit a novel data set on stock transactions by Schedule 13D filers. We find robust, consistent strong evidence that trades by Schedule 13D filers contain valuable information: both announcement returns and profits realized by the filers are substantial. Moreover, we show that on days when Schedule 13D filers trade, prices tend to move up. We therefore classify pre-filing trades by Schedule 13D filers as informed.

We have also documented features of Sched13D activists' derivative trading. They trade little in derivatives (2.6%), but more (10%) when listed option markets are available. They use derivative to leverage up their position in stocks significantly. Even when they do not trade in derivatives, option markets seem to respond to their trades. On days when activists trade in stocks, realized volatility increases, implied volatilities decrease,

Bid-Ask spreads in Options widen, and Put volume increases. Implied volatilities are good predictors of future realized volatility which increases prior to the announcement, but drops on the event date. Many of these findings are consistent with a model of informed trading in the stock when uninformed noise trading increases prior to the announcement date. However, the model cannot explain why spreads and option volume would increase prior to the announcement date. This would require informed trading in options (or the perception thereof by market makers). Further, the increase in Bid-Ask spreads in options seems to reflect volatility specific information.

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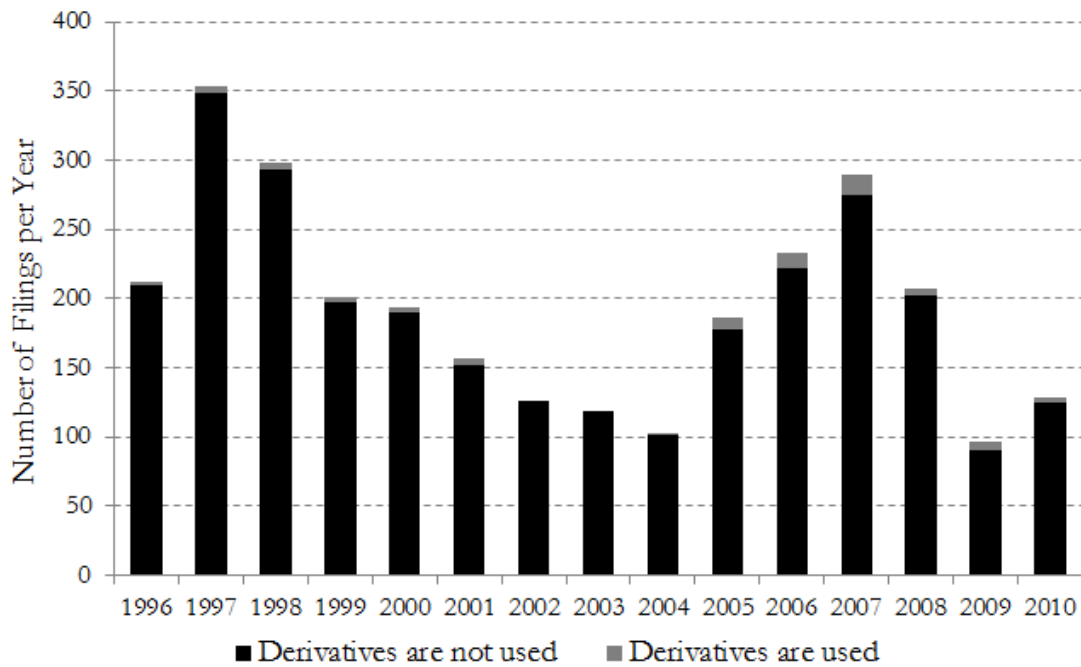


Figure 2:
Time distribution of Schedule 13D filings. This chart plots the number of Schedule 13D filings that satisfy the criteria listed in Section II. The dark bars represent Schedule 13D filings with no information on derivatives. The gray bars represent Schedule 13D filings with information on derivatives.

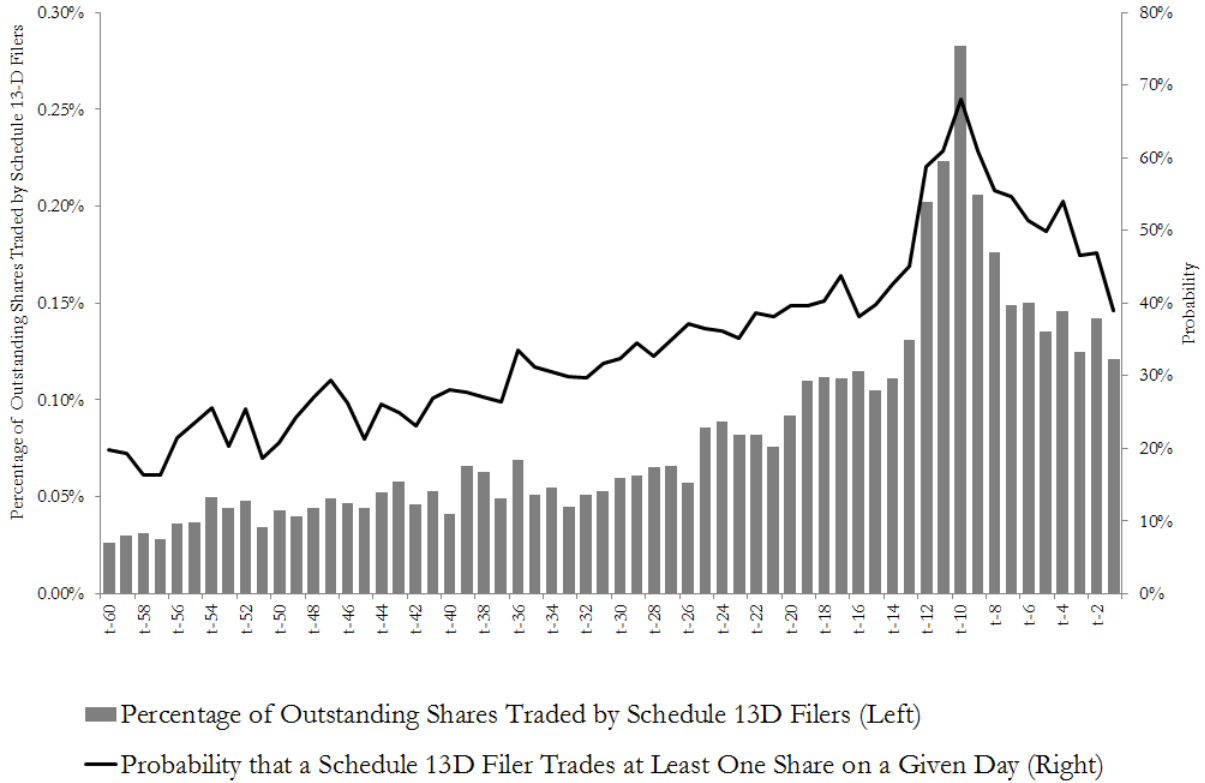


Figure 3: **Trading strategy of Schedule 13D filers before the filing day.** The solid line (right axis) plots the probability that a Schedule 13D filer trades at least one share on a given day. For every distance to the filing date, $t - \tau$, the probability that a Schedule 13D filer trades at least one share is the number of filings with a nonzero trade by the filer divided by the total number of Schedule 13D filings in the sample. We define the distance to the filing date as the number of days between a trading day, τ , and the filing date, t . The filing date corresponds to the day of filing with the SEC. The dark bars (left axis) represent the percentage of outstanding shares traded by Schedule 13D filers, from 60 days prior to the filing date. For every Schedule 13D filing and distance to the filing date, $t - \tau$, we calculate the percentage of outstanding shares traded by the filer as the ratio between the number of shares traded by the filer and the number of shares outstanding. If no trade is reported on a given day by the filer, the percentage of outstanding shares traded by the filer is set to zero. Then, for every distance to the filing date, $t - \tau$, the percentage of outstanding shares traded by Schedule 13D filers is the average (across all filings) of the percentage of outstanding shares traded. The sample covers 522 Schedule 13D filings in which there are listed options on target firms.

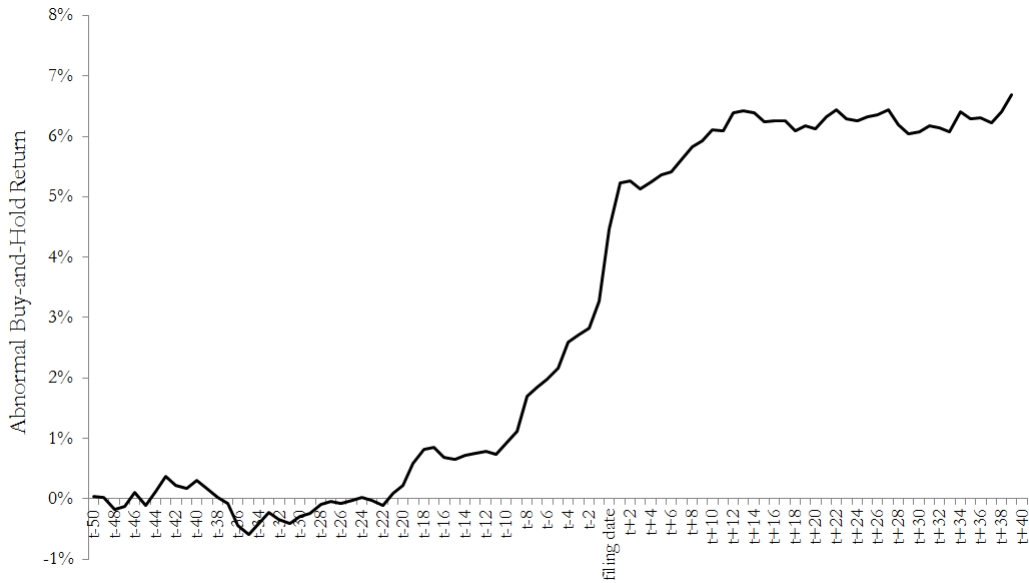


Figure 4:
Buy-and-hold abnormal return around the filing date. The solid line plots the average buy-and-hold return around the filing date in excess of the buy-and-hold return of the value-weighted market from 50 days prior to the filing date to 40 days afterwards. The filing date is the day on which the Schedule 13D filing is submitted to the SEC. The sample covers 522 Schedule 13D filings in which there are listed options on target firms.

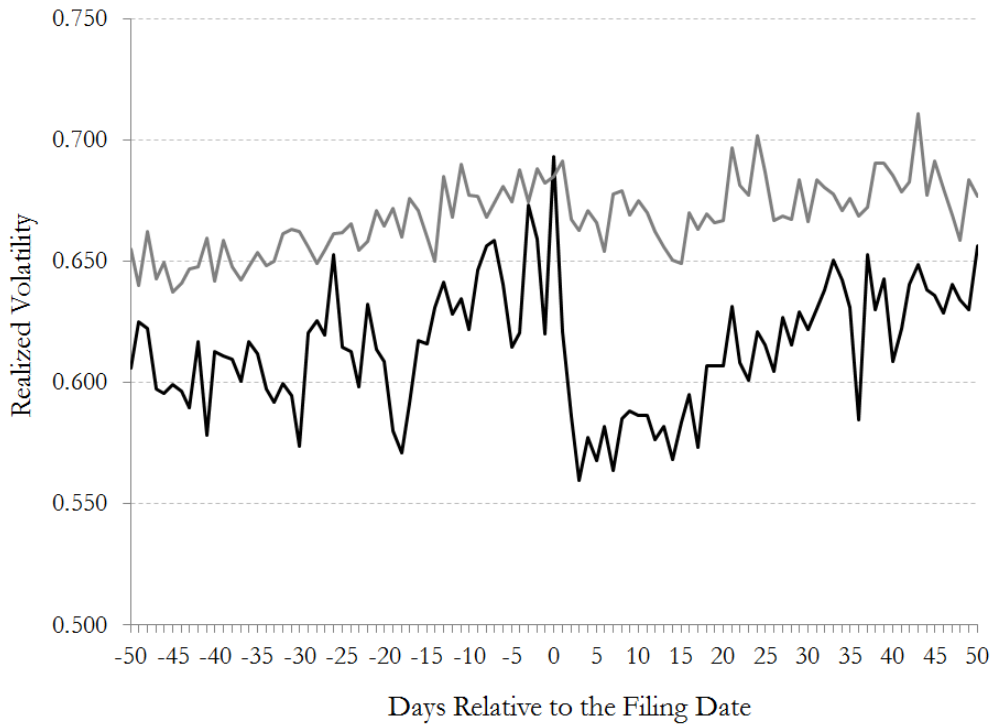


Figure 5:
Realized Volatility. This chart plots the realized volatility from 50 days before the filing date to 50 days after. The dark (gray) line plots the realized volatility for the sample of event (matched) firms. Matched stocks are assigned based on the same industry, exchange, and market cap. The sample covers 522 Schedule 13D filings in which there are listed options on target firms.

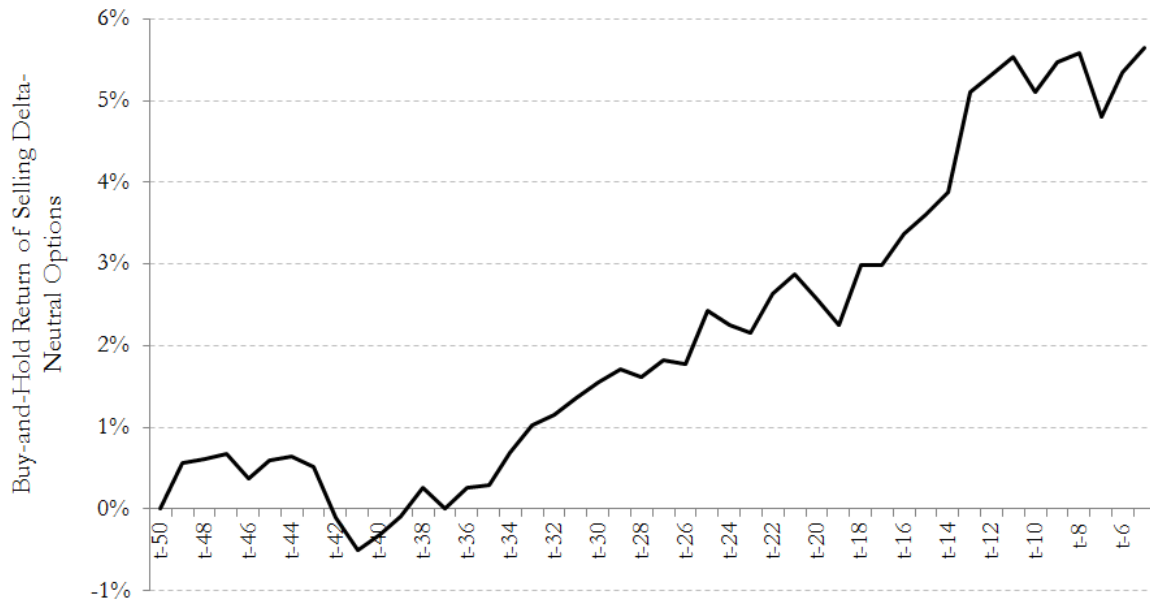


Figure 6:

Buy-and-hold abnormal return on selling delta-neutral option strategies. The solid line plots the average buy-and-hold return on selling delta-neutral option strategies from 50 days prior to the filing date to 5 days prior to the filing date. The strategy for betting on a drop in volatility is to sell options (both calls and puts) that are close to at-the-money (their prices are most sensitive to volatility information) and then (delta) hedges them by trading the underlying stock (making it immune to small directional changes in the stock price). The portfolio is revised daily. The filing date is the day on which the Schedule 13D filing is submitted to the SEC. The sample covers 522 Schedule 13D filings in which there are listed options on target firms.

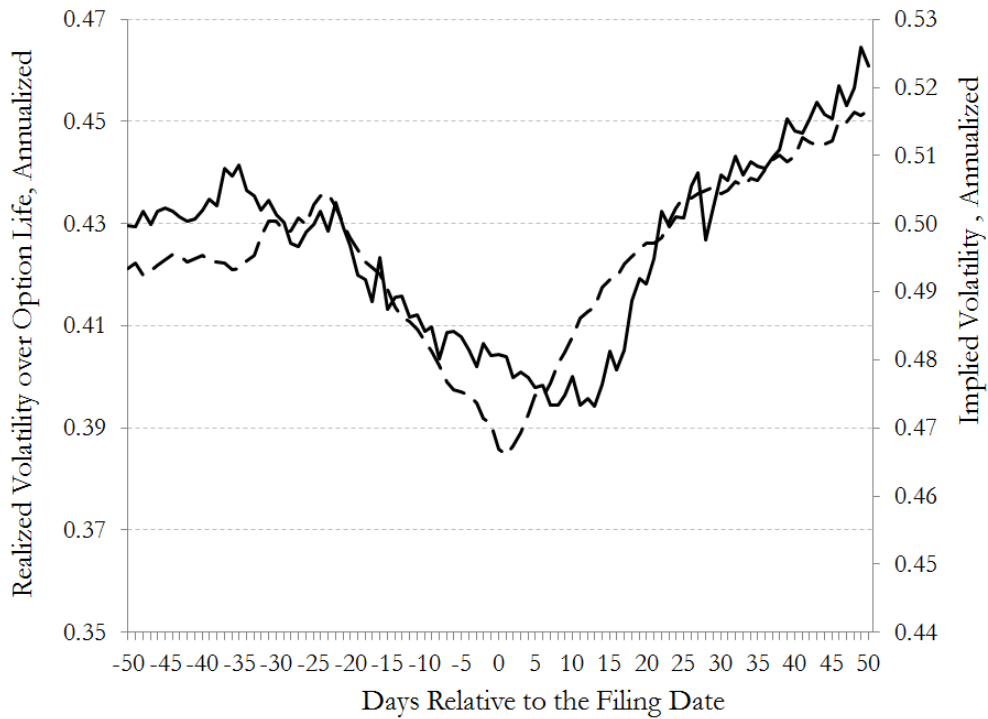
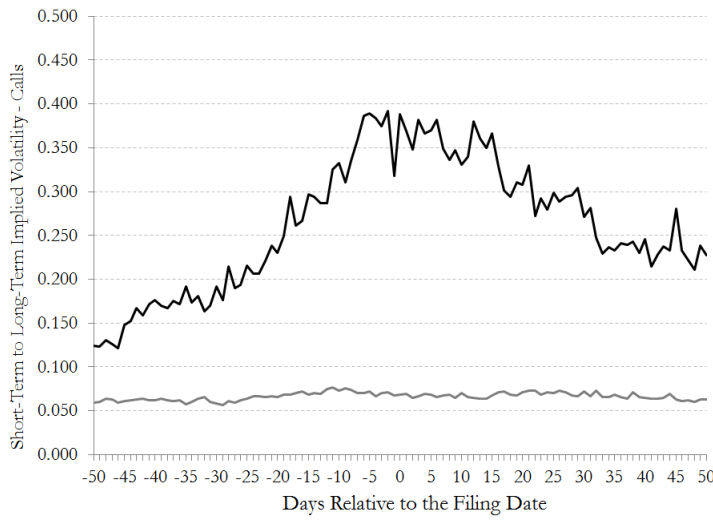
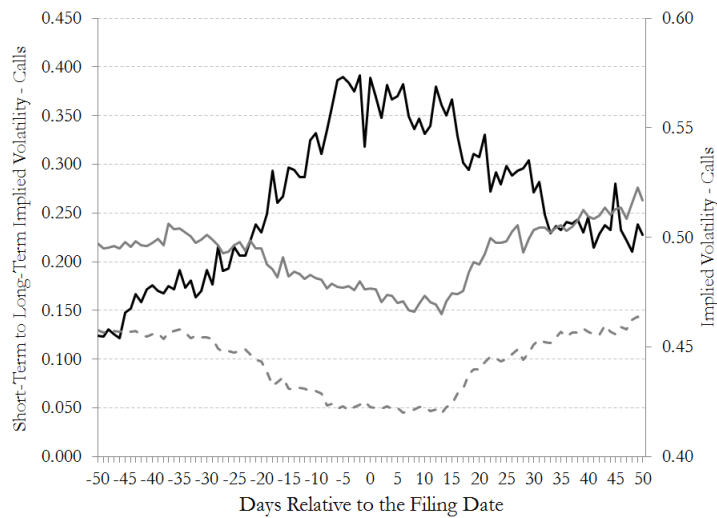


Figure 7:
Realized and Implied Volatilities. This chart plots the expected realized and implied volatilities from 50 days before the filing date to 50 days after. The dark line plots the average realized volatility over the next month. Dashed line plots implied volatilities of at-the-money options with one months till expiration. The sample covers 522 Schedule 13D filings in which there are listed options on target firms.



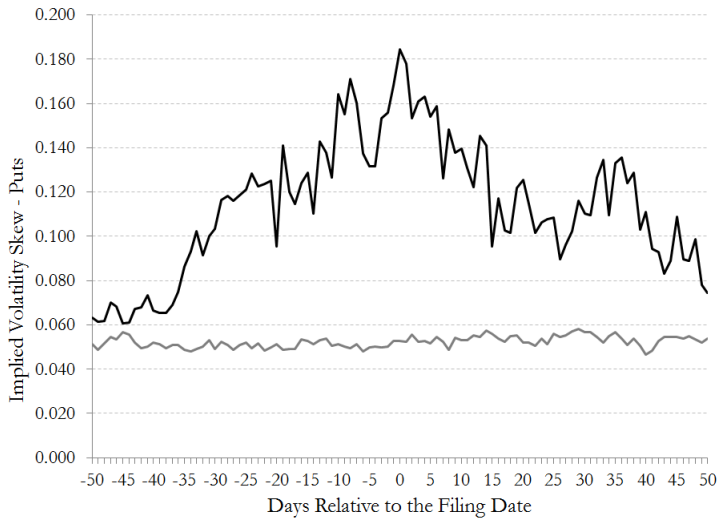
(a) Call Options Implied Volatility Time Slope.



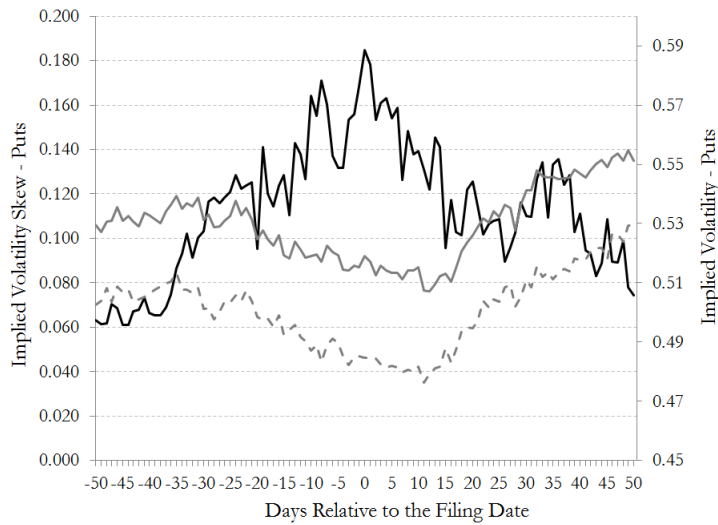
(b) Call Options Implied Volatility

Figure 8:

Call Options Implied Volatility Time Slope. In Panel A the dark (gray) line plots the time slope for the sample event (matched) firms from 50 days before the filing date to 50 days after. Time slope is defined as the ratio of implied volatilities for call options with 30 days to expiration and call options with 365 days to expiration, minus one. Implied volatilities are provided by OptionMetrics and are calculated based on 30 days to expiration. The sample covers 522 Schedule 13D filings in which there are listed options on target firms. Matched stocks are assigned based on the same industry, exchange, and market cap. In Panel B the dark line plots the time slope for the sample event firms. Gray line plots implied volatility for call options with 30 days to expiration. Dashed line plots implied volatility for the at-the-money put options with 365 days to expiration.



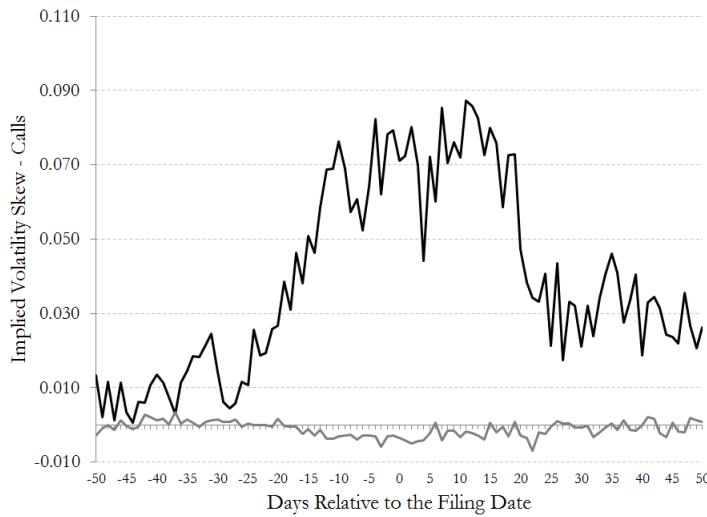
(a) Put Options Implied Volatility Skew: Event and matched samples



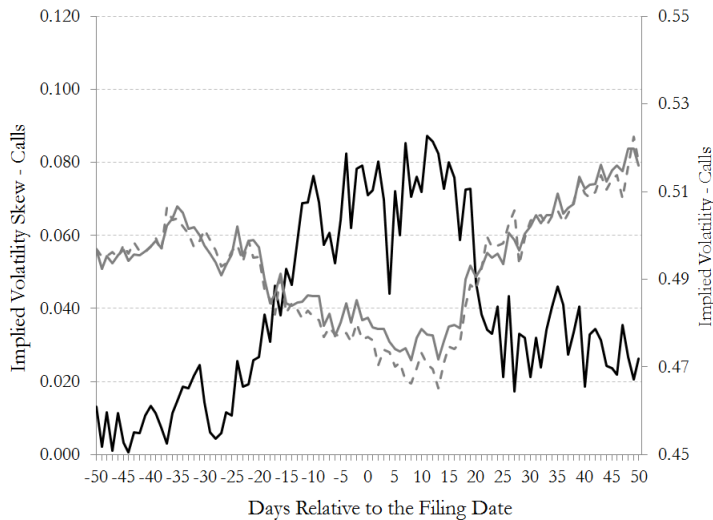
(b) Put Options Implied Volatility

Figure 9:

Put Options Implied Volatility Skew. In Panel A the dark (gray) line plots the skew for the sample event (matched) firms from 50 days before the filing date to 50 days after. Skew is defined as the ratio of implied volatilities for out-of-the-money and at-the-money put options, minus one. Implied volatilities are provided by OptionMetrics and are calculated based on 30 days to expiration. An option is out-of-the-money (at-the-money) if delta is -0.3 (-0.5). The sample covers 522 Schedule 13D filings in which there are listed options on target firms. Matched stocks are assigned based on the same industry, exchange, and market cap. In Panel B the dark line plots the skew for the sample event firms. Gray line plots implied volatility for the out-of-the-money put options. Dashed line plots implied volatility for the at-the-money put options.



(a) Call Options Implied Volatility Skew: Event and matched samples



(b) Call Options Implied Volatility

Figure 10:

Call Options Implied Volatility Skew. In Panel A the dark (gray) line plots the skew for the sample event (matched) firms from 50 days before the filing date to 50 days after. Skew is defined as the ratio of implied volatilities for out-of-the-money and at-the-money call options, minus one. Implied volatilities are provided by OptionMetrics and are calculated based on 30 days to expiration. An option is out-of-the-money (at-the-money) if delta is 0.3 (0.5). The sample covers 522 Schedule 13D filings in which there are listed options on target firms. Matched stocks are assigned based on the same industry, exchange, and market cap. In Panel B the dark line plots the skew for the sample event firms. Gray line plots implied volatility for the out-of-the-money call options. Dashed line plots implied volatility for the at-the-money call options.

Table I:

When Do Activists Use Derivatives? This table presents characteristics of targets when activist use and do not use derivatives. Columns (1) to (3) report results for all Schedule 13D filing with available data on firm characteristics (2,466 events). Columns (4) to (6) report results for subsample with available listed options (548 events; see Section II for description of the “options available” criteria). Firm characteristics are measured at the end of the past fiscal year. Columns (1) and (4) report averages for targets when activist use derivatives. Columns (2) and (5) report averages for targets when activist do not use derivatives. Columns (3) and (6) report differences between (1) and (2) and (4) and (5) accordingly as well as t -statistics of the difference. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	Full sample			Sample with available options		
	Use Derivatives (1)	Do Not Use Derivatives (2)	Diff (3)	Use Derivatives (4)	Do Not Use Derivatives (5)	Diff (6)
OPTIONS AVAILABLE	0.72	0.21	0.52*** [10.59]			
MARKET CAP	896.98	211.42	685.56*** [12.93]	1056.69	690.79	365.9*** [3.49]
ILLIQUIDITY	0.1342	0.4860	-0.3518*** [-4.98]	0.0455	0.0584	-0.0129* [-1.83]
BM	0.61	0.77	-0.15** [-2.13]	0.58	0.47	0.1062* [1.89]
ANALYST	10.36	3.80	6.56*** [10.39]	11.73	9.42	2.31** [2.25]
STOCK RETURN	0.0069	0.0081	-0.0012 [-0.23]	0.0076	0.0124	-0.0048 [-0.75]
STOCK RETURN VOL	0.5255	0.5527	-0.0272 [-0.84]	0.4936	0.4978	-0.0041 [-0.12]
INST	0.7224	0.4492	0.2731*** [7.29]	0.7542	0.7157	0.0385 [1.04]
INST AHF	0.0829	0.0598	0.0231*** [2.64]	0.0836	0.0575	0.026** [2.56]
HSR	0.6389	0.1846	0.4543*** [9.71]	0.7692	0.5645	0.2047*** [2.87]

Table II:

When Do Activists Use Derivatives? Multivariate Analysis. This table presents estimates of a linear probability model that predicts the usage of derivatives by Schedule 13D filers. Sample covers 2,030 Schedule 13D filings with available information on firm characteristics. Firm characteristics are measured at the end of the fiscal year that precedes the Schedule 13D filing. Table reports estimated coefficients and t -statistics. The t -statistics are calculated using heteroscedasticity robust standard errors. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)
OPTIONS AVAILABLE	0.0372** [2.01]	0.0348* [1.90]
MARKET CAP	0.0200*** [2.99]	0.0100 [1.45]
ILLIQUIDITY	0.0176** [2.04]	0.0092 [1.01]
HSR		0.0379** [2.21]
BM	0.0094* [1.68]	0.0085 [1.53]
ANALYST	0.0036** [2.27]	0.0035** [2.16]
STOCK RETURN	-0.0384 [-0.38]	-0.0197 [-0.19]
STOCK RETURN VOL	0.0397** [2.00]	0.0395** [2.01]
INST	-0.0322 [-1.43]	-0.0211 [-0.92]
INST AHF	0.1938** [2.44]	0.2018** [2.53]
CONSTANT	-0.1145*** [-3.83]	-0.0793*** [-2.77]
N	2,030	2,030

Table III:

How Do Activists Use Derivatives? This table shows how activists use derivatives. Columns (1) and (2) report results for all Schedule 13D filing with information on derivatives (76 events). Columns (3) and (4) report results for sub-sample with available listed options (55 events; see Section II for description of the “options available” criteria). Columns (5) and (6) report results for sub-sample with over-the-counter derivatives being used by activists (33 events).

Sample type: Sample size:	Full Sample 76 events (1)	Listed Options 55 events (2)	Over-the-counter 33 events (3)
<i>Types of derivatives</i>			
Long Call	0.816	0.800	0.909
Short Put	0.408	0.436	0.515
Long Call and Short Put	0.250	0.273	0.424
Long Equity Swap	0.092	0.109	0.152
Short Call	0.036	0.036	0.000
Long Put	0.000	0.000	0.000
No Long Exposure	0.026	0.036	0.000
<i>Ownership structure</i>			
Beneficial ownership - derivatives	0.022	0.022	0.035
Beneficial ownership - common stock	0.063	0.062	0.047
<i>Sample type</i>			
Options Available	0.724		0.758
Activist hedge funds	0.553	0.618	0.606
Over-the-counter	0.434	0.455	

Table IV:

Trading Strategy of Schedule 13D Filers. This table presents descriptive statistics on Schedule 13D filers' trading strategies. The sample covers 522 Schedule 13D filings in which there are listed options on target firms. Columns (1) to (4) report cross-event means of characteristics and columns (5) to (8) report cross-event medians of characteristics. Columns (1) and (5) report descriptive statistics for the full sample, which covers all days with informed trades during the 60-day period before the filing date. The filing date is the day on which the Schedule 13D filing is submitted to the SEC. Columns (2) and (6) report descriptive statistics for days with informed trades during the pre-event date period ("Before"). The event date is the day on which the filer's ownership exceeds the 5% threshold. Columns (3) and (7) report descriptive statistics for the event date. Columns (4) and (8) report descriptive statistics for days with informed trades during the post-event date period ("After"). An informed trade is a trade executed by a Schedule 13D filer. Stock ownership on the filing date is the total beneficial ownership of the Schedule 13D filer on the filing date. Number of trading days is the number of days with informed trades during the corresponding period. % of trading days with informed trades is the ratio of days with informed trades to the number of trading days. Informed volume (per trading day) is the total number of shares traded by a Schedule 13D filer (per trading day) on days with informed trades. Dollar informed volume (per trading day) is the total dollar amount traded by a Schedule 13D filer (per trading day) on days with informed trades. Change in stock ownership (per trading day) is the increase in stock ownership (per trading day), as percentage of the number of shares outstanding, on days with informed trades. Market-adjusted return is the stock return in excess of the CRSP value-weighted return. Daily turnover is daily volume on days with informed trades divided by the number of shares outstanding. % informed turnover is the percentage of daily turnover that corresponds to the trades executed by Schedule 13D filers.

	Mean				Median			
	Full Sample (1)	Before (2)	Event Date (3)	After (4)	Full Sample (5)	Before (6)	Event Date (7)	After (8)
Stock ownership on the filing date	7.14%				6.20%			
Number of trading days	16.6	13.7	1.0	4.1	15	12	1	4
% of trading days with informed trades	38.8%	35.8%	100.0%	54.5%	35.7%	31.4%	100.0%	60.0%
Informed volume	2,288,796	1,718,291	342,779	584,040	1,286,275	882,216	152,950	277,700
Informed volume per trading day	173,773	170,269	342,779	148,746	86,858	79,623	152,950	75,717
Informed volume (m\$)	54.1	41.1	8.0	13.2	26.6	17.9	3.2	5.8
Informed volume per trading day (m\$)	4.0	3.9	8.0	3.4	1.8	1.7	3.2	1.6
Change in stock ownership	4.0%	2.8%	0.9%	1.1%	3.8%	2.7%	0.4%	0.8%
Change in ownership per trading day	0.3%	0.3%	0.9%	0.3%	0.2%	0.2%	0.4%	0.2%
Market-adjusted return	0.32%	0.38%	0.28%	0.36%	0.14%	0.14%	0.14%	0.09%
Daily turnover	3.0%	3.5%	3.8%	2.2%	1.9%	1.9%	2.1%	1.6%
% of informed turnover (real PIN)	13.9%	12.7%	22.9%	15.6%	10.6%	9.2%	17.8%	12.2%

Table V:

Realized Volatility around the Filing date. This table compares the level of realized volatility before and after the filing date. Daily volatility is based on absolute value of daily stock return. Intraday volatility is computed from the sum of squared 5-minute returns over a trading day. The returns are computed from the TAQ trade transaction data. Both realized volatility measures are annualized. The sample covers 522 Schedule 13D filings in which there are listed options on target firms. Column (1) reports the average level of realized volatility for 50 days that precede the filing date. Column (2) reports the average level of realized volatility for 50 days after the filing date. Column (3) reports the average change in realized volatility around the filing date and the t -stat of the difference. Columns (4) to (6) repeat the analysis for the sample of matched stocks. Matched stocks are assigned based on the same industry, exchange, and market cap. Column (7) reports the average difference-in-difference in the realized volatility and the t -stat of the difference. *** indicates statistical significance at the 1% level.

	Event Stocks			Matched Stocks			
	Before	After	Difference	Before	After	Difference	Diff-in-diff
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Realized volatility (daily)	0.4091	0.3657	-0.0434*** [-5.10]	0.4310	0.4395	0.0086 [1.52]	-0.0520*** [-5.09]
Realized volatility (intra-day)	0.4759	0.4331	-0.0428*** [-4.97]	0.5023	0.5092	0.0069 [1.19]	-0.0497*** [-4.80]

Table VI:

Profits from Informed Trades. This table presents summary statistics for three measures of profits. *Trading Profit* is defined as $\mathbf{q}'(p_{post} - \mathbf{p})$, where \mathbf{q} is the vector of trades (purchases are positive and sales are negative), p_{post} is the post-announcement price, and \mathbf{p} is the vector of transaction prices. The post-announcement price is the average price during the week that follows the filing date. *Total Profit* is defined as $Trading\ Profit + (p_{post} - p_0)w_0$, where p_0 is the price of the first transaction disclosed in the Schedule 13D filing and w_0 is the initial ownership, established prior to the first transaction disclosed in the Schedule 13D filing. *Value Created* is defined as $(p_{post} - p_0)SHOUT$, where $SHOUT$ is the number of shares outstanding. The sample covers 522 Schedule 13D filings in which there are listed options on target firms. Average measures of profits as well as t -statistics are reported for five Market CAP quantiles, where Market CAP is the market capitalization of the targeted company. ** and *** indicate statistical significance at the 5% and 1% levels, respectively.

Market CAP Quantile	Market CAP (1)	Trading Profit (2)	Total Profit (3)	Value Created (4)
Q1 - low	214,795,218	(15,119) [-0.09]	52,892 [0.16]	(2,224,586) [-0.35]
Q2	438,976,302	1,011,851*** [3.56]	1,850,709*** [2.75]	25,966,410** [2.55]
Q3	873,588,004	1,758,625*** [4.62]	2,345,792** [2.35]	39,050,138** [2.26]
Q4	1,760,772,119	1,999,809*** [4.73]	2,791,390** [2.54]	57,376,458** [2.57]
Q5 - high	3,916,358,736	2,675,665*** [4.95]	3,720,508** [2.52]	53,740,776* [1.87]

Table VII:

Stock market outcomes. This table analysis market-adjusted returns, volatility, trading volume, and bid-ask spread when Schedule 13D filers trade. The sample covers 522 Schedule 13D filings in which there are listed options on target firms. Market-adjusted return (*eret*) is the stock return in excess of the CRSP value-weighted return. Realized volatility (*volatility*) is based on the absolute value of daily stock return. Bid-ask spread (*baspread*) is the percentage spread, calculated using daily close ask and bid. The sample covers the 60-day disclosure period only. Panel A analyzes differences in changes in outcome variables between event and matched firms during ($t-1,t-30$) and ($t-31,t-60$) periods before the filing date. Matched stocks are assigned based on the same industry, exchange, and market cap. Panels B, C, D compare the outcome variables on days when Schedule 13D filers trade and on days when Schedule 13D filers do not trade. In Panel B we report estimates of the basic regression: $y_{it} = \gamma_1 itrade_{it} + \eta_i + \epsilon_{it}$, where y_{it} is a measure of trading activity for company i on day t , $itrade$ indicates days on which Schedule 13D filers trade in stock market, and η_i are event fixed effects. Panel C repeats the analysis using measures of the abnormal trading activity, which are calculated by taking the difference between the event stock and the matched stock trading activity measures. Panel D repeats the analysis in Panel C while including four Fama-French factors and VIX as controls. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	<i>eret</i> (1)	<i>volatility</i> (2)	(log) <i>vol</i> (3)	<i>baspread</i> (4)
Panel A: ($t-1,t-30$) vs ($t-31,t-60$) for event vs matched stocks				
<i>event</i> * ($t-1,t-30$)	0.0010** [2.15]	-0.0009* [-1.73]	0.1709*** [7.20]	-0.0003 [-1.18]
N	958	958	958	957
Panel B: Raw measures, no controls				
<i>itrade</i>	0.0015*** [3.51]	0.0008* [1.83]	0.3766*** [16.11]	-0.0004*** [-3.26]
N	41,261	41,261	41,261	39,698
Event fixed-effects	YES	YES	YES	YES
Panel C: Matched measures, no controls				
<i>itrade</i>	0.0020*** [4.30]	0.0004 [0.86]	0.3492*** [13.06]	-0.0004*** [-3.23]
N	35,945	35,945	35,947	34,394
Event fixed-effects	YES	YES	YES	YES
Panel D: Matched measures, with controls				
<i>itrade</i>	0.0019*** [4.16]	0.0004 [0.84]	0.3496*** [13.01]	-0.0004*** [-3.28]
N	35,917	35,917	35,919	34,366
Event fixed-effects	YES	YES	YES	YES

Table VIII:

Option market: Implied Volatility. This table presents the relation between informed trading in stock market and implied volatility. The sample covers 522 Schedule 13D filings in which there are listed options on target firms. The sample covers the 60-day disclosure period only. Put skew is defined in Figure 9. Call skew is defined in Figure 10. Time slope is defined in Figure 8. Change in IV Call is change in implied volatility of at-the-money call options. IV Call is implied volatility of at-the-money call options. IV Put is implied volatility of at-the-money put options. Change in IV is the daily change in the value of IV. Implied volatilities are provided by OptionMetrics and are calculated based on 30 days to expiration. Panel A analyzes differences in changes in outcome variables between event and matched firms during $(t-1, t-30)$ and $(t-31, t-60)$ periods before the filing date. Matched stocks are assigned based on the same industry, exchange, and market cap. Panels B, C, D compare the outcome variables on days when Schedule 13D filers trade and on days when Schedule 13D filers do not trade. In Panel B we report estimates of the basic regression: $y_{it} = \gamma_1 itrade_{it} + \eta_i + \epsilon_{it}$, where y_{it} is a measure of trading activity for company i on day t , $itrade$ indicates days on which Schedule 13D filers trade in stock market, and η_i are event fixed effects. Panel C repeats the analysis using measures of the abnormal trading activity, which are calculated by taking the difference between the event stock and the matched stock trading activity measures. Panel D repeats the analysis in Panel C while including four Fama-French factors and VIX as controls. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	Put skew	Call skew	Time slope	IV Call	Change in IV Call	IV Put	Change in IV Put	IV Call minus IV Put
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: $(t-1, t-30)$ vs $(t-31, t-60)$ for event vs matched stocks								
<i>event</i> * $(t-1, t-30)$	0.0198***	0.0175***	0.0901***	-0.0256***	-0.0005	-0.0225***	-0.0007*	-0.0017
	[3.68]	[4.43]	[6.84]	[-3.47]	[-1.23]	[-3.10]	[-1.82]	[-1.00]
N	958	958	958	958	958	958	958	958
Panel B: Raw measures, no controls								
<i>itrade</i>	0.0217***	0.0175***	0.1190***	-0.0304***	-0.0023***	-0.0279***	-0.0010*	-0.0029**
	[3.70]	[3.82]	[7.42]	[-4.61]	[-4.25]	[-4.31]	[-1.86]	[-2.08]
N	41,136	41,136	41,136	41,136	40,601	41,136	40,601	41,333
Event fixed-effects	YES	YES	YES	YES	YES	YES	YES	YES
Panel C: Matched measures, no controls								
<i>itrade</i>	0.0487***	0.0347***	0.1578***	-0.0339***	-0.0026***	-0.0309***	-0.0014**	-0.0030*
	[4.06]	[3.63]	[6.15]	[-5.11]	[-4.18]	[-4.62]	[-2.30]	[-1.78]
N	35,843	35,843	35,843	35,843	35,843	35,843	35,843	35,843
Event fixed-effects	YES	YES	YES	YES	YES	YES	YES	YES
Panel D: Matched measures, with controls								
<i>itrade</i>	0.0483***	0.0356***	0.1577***	-0.0347***	-0.0026***	-0.0317***	-0.0013**	-0.0030*
	[4.08]	[3.71]	[6.14]	[-5.19]	[-4.24]	[-4.71]	[-2.25]	[-1.78]
N	35,815	35,815	35,815	35,815	35,346	35,815	35,346	35,815
Event fixed-effects	YES	YES	YES	YES	YES	YES	YES	YES

Table IX:

Option market: Bid-ask spread. This table presents the relation between informed trading in stock market and option market bid-ask spread. The sample covers 522 Schedule 13D filings in which there are listed options on target firms. The sample covers the 60-day disclosure period only. Bid-ask spread is the percentage spread, calculated using daily close ask and bid. Panel A analyzes differences in changes in outcome variables between event and matched firms during $(t-1,t-30)$ and $(t-31,t-60)$ periods before the filing date. Matched stocks are assigned based on the same industry, exchange, and market cap. Panels B, C, D compare the outcome variables on days when Schedule 13D filers trade and on days when Schedule 13D filers do not trade. In Panel B we report estimates of the basic regression: $y_{it} = \gamma_1 \text{itrade}_{it} + \eta_i + \epsilon_{it}$, where y_{it} is a measure of trading activity for company i on day t , itrade indicates days on which Schedule 13D filers trade in stock market, and η_i are event fixed effects. Panel C repeats the analysis using measures of the abnormal trading activity, which are calculated by taking the difference between the event stock and the matched stock trading activity measures. Panel D repeats the analysis in Panel C while including four Fama-French factors and VIX as controls. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	All options (1)	Call options (2)	OTM Call options (3)	Put options (4)	OTM Put options (5)
Panel A: $(t-1,t-30)$ vs $(t-31,t-60)$ for event vs matched stocks					
<i>event</i> * $(t-1,t-30)$	0.0035*** [3.52]	0.0032*** [3.12]	0.0029* [1.90]	0.0030** [2.57]	0.0032** [1.98]
N	927	923	905	916	919
Panel B: Raw measures, no controls					
<i>itrade</i>	0.0031*** [3.85]	0.0029*** [3.70]	0.0022* [1.85]	0.0023*** [2.62]	0.0048*** [3.82]
N	34,206	32,509	26,070	31,918	28,700
Event fixed-effects	YES	YES	YES	YES	YES
Panel C: Matched measures, no controls					
<i>itrade</i>	0.0031*** [3.30]	0.0028*** [2.98]	0.0018 [1.25]	0.0028*** [2.67]	0.0040*** [2.76]
N	29,424	27,939	21,781	27,185	23,903
Event fixed-effects	YES	YES	YES	YES	YES
Panel D: Matched measures, with controls					
<i>itrade</i>	0.0032*** [3.40]	0.0030*** [3.10]	0.0018 [1.23]	0.0030*** [2.77]	0.0040*** [2.77]
N	29,397	27,914	21,757	27,158	23,884
Event fixed-effects	YES	YES	YES	YES	YES

Table X:

Option market: Bid-ask spread and information type. This table presents the relation between changes in option market bid-ask spread when informed trading in stock market takes place and type of private information. The sample covers 522 Schedule 13D filings in which there are listed options on target firms. The sample covers the 60-day disclosure period only. The table reports estimates of γ_1 and the corresponding t -statistics from the basic regression: $baspread_{it} = \gamma_1 itrade_{it} + \eta_i + \epsilon_{it}$, where y_{it} is bid-ask spread for company i on day t , $itrade$ indicates days on which Schedule 13D filers trade in stock market, and η_i are event fixed effects. Bid-ask spread is the percentage spread, calculated using daily close ask and bid. CAR is the average buy-and-hold return around the filing date in excess of the buy-and-hold return of the value-weighted market from 30 days prior to the filing date to 1 day afterwards. Column (1) reports results for all values of CAR. Column (2) reports results when CAR is below median. Column (3) reports results when CAR is above median. Column (4) reports the difference between estimates in columns (3) and (2). Volatility drop is the difference in realized volatility during $(t+2, t+6)$ and the remaining sample period. The first row reports results for all values of volatility drop. The second row reports results when volatility drop is below median. The third row reports results when volatility drop is above median. The fourth row reports the difference between estimates in the second and the third rows. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

CAR:	All (1)	Low (2)	High (3)	High-Low (4)
Volatility drop:				
All	0.0031*** [3.86]	0.0022** [2.17]	0.0041*** [3.20]	0.0019 [1.24]
Low	0.0010 [1.24]	0.0019 [1.51]	0.0001 [0.09]	-0.0018 [-1.11]
High	0.0057*** [3.84]	0.0025 [1.53]	0.0090*** [3.63]	0.0075** [2.20]
High-Low	0.0047** [2.17]	0.0006 [0.29]	0.0089*** [3.32]	

Table XI:

Option market: Trading Activity. This table presents the relation between informed trading in stock market and option market trading activity. The sample covers 522 Schedule 13D filings in which there are listed options on target firms. The sample covers the 60-day disclosure period only. Panel A analyzes differences in changes in outcome variables between event and matched firms during $(t-1, t-30)$ and $(t-31, t-60)$ periods before the filing date. Matched stocks are assigned based on the same industry, exchange, and market cap. Panels B, C, D compare the outcome variables on days when Schedule 13D filers trade and on days when Schedule 13D filers do not trade. In Panel B we report estimates of the basic regression: $y_{it} = \gamma_1 \text{itrade}_{it} + \eta_i + \epsilon_{it}$, where y_{it} is a measure of trading activity for company i on day t , itrade indicates days on which Schedule 13D filers trade in stock market, and η_i are event fixed effects. Panel C repeats the analysis using measures of the abnormal trading activity, which are calculated by taking the difference between the event stock and the matched stock trading activity measures. Panel D repeats the analysis in Panel C while including four Fama-French factors and VIX as controls. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	Open interest (log) (1)	Option-to-stock volume ratio (2)	Option volume (log) (3)	Put volume (log) (4)	Call volume (log) (5)	Put-to-call volume ratio (6)
Panel A: $(t-1, t-30)$ vs $(t-31, t-60)$ for event vs matched stocks						
<i>event</i> * $(t-1, t-30)$	0.0386 [1.02] 958	-0.8633 [-1.63] 958	-0.1274 [-1.41] 958	0.0382 [0.42] 958	-0.2003** [-2.07] 958	0.0087 [1.38] 958
N						
Panel B: Raw measures, no controls						
<i>itrade</i>	0.0857*** [2.93] 40,947 YES	-1.7767*** [-3.94] 40,947 YES	-0.0018 [-0.02] 40,947 YES	0.2388*** [3.01] 40,947 YES	-0.1147 [-1.41] 40,947 YES	0.0194*** [3.42] 40,947 YES
N						
Event fixed-effects						
Panel C: Matched measures, no controls						
<i>itrade</i>	0.0547* [1.72] 35,703 YES	-1.8775*** [-3.46] 35,703 YES	-0.0128 [-0.15] 35,703 YES	0.2504*** [2.67] 35,703 YES	-0.1252 [-1.36] 35,703 YES	0.0213*** [3.24] 35,703 YES
N						
Event fixed-effects						
Panel D: Matched measures, with controls						
<i>itrade</i>	0.0552* [1.75] 35,675 YES	-1.9397*** [-3.59] 35,675 YES	-0.0159 [-0.19] 35,675 YES	0.2503*** [2.68] 35,675 YES	-0.1307 [-1.42] 35,675 YES	0.0218*** [3.31] 35,675 YES
N						
Event fixed-effects						

Table XII:

Option market: Order Imbalance. This table presents the relation between informed trading in stock market and option market order imbalance. The sample covers 522 Schedule 13D filings in which there are listed options on target firms. Order imbalance is the difference in the proportion of buy- and sell-initiated returns. The sample covers the 60-day disclosure period only. Panel A analyzes differences in changes in outcome variables between event and matched firms during $(t-1,t-30)$ and $(t-31,t-60)$ periods before the filing date. Matched stocks are assigned based on the same industry, exchange, and market cap. Panels B, C, D compare the outcome variables on days when Schedule 13D filers trade and on days when Schedule 13D filers do not trade. In Panel B we report estimates of the basic regression: $y_{it} = \gamma_1 itrade_{it} + \eta_i + \epsilon_{it}$, where y_{it} is a measure of trading activity for company i on day t , $itrade$ indicates days on which Schedule 13D filers trade in stock market, and η_i are event fixed effects. Panel C repeats the analysis using measures of the abnormal trading activity, which are calculated by taking the difference between the event stock and the matched stock trading activity measures. Panel D repeats the analysis in Panel C while including four Fama-French factors and VIX as controls. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	All options		Put options		Call options	
	All	Open	All	Open	All	Open
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: $(t-1,t-30)$ vs $(t-31,t-60)$ for event vs matched stocks						
<i>event</i> * $(t-1,t-30)$	-0.0053	0.0158	0.0257**	0.0179	0.0132	0.0320**
	[-0.44]	[1.13]	[2.27]	[1.35]	[1.05]	[2.27]
N	423	423	423	423	423	423
Panel B: Raw measures, no controls						
<i>itrade</i>	-0.0154	-0.0114	0.0169	0.0225*	-0.0054	0.002
	[-1.37]	[-0.90]	[1.54]	[1.85]	[-0.45]	[0.15]
N	13,113	13,113	13,113	13,113	13,113	13,113
Event fixed-effects	YES	YES	YES	YES	YES	YES
Panel C: Matched measures, no controls						
<i>itrade</i>	-0.0106	-0.011	0.0229	0.0246	0.0143	0.0102
	[-0.72]	[-0.66]	[1.52]	[1.37]	[0.93]	[0.58]
N	10,338	10,338	10,338	10,338	10,338	10,338
Event fixed-effects	YES	YES	YES	YES	YES	YES
Panel D: Matched measures, with controls						
<i>itrade</i>	-0.012	-0.0118	0.0239	0.026	0.0132	0.0098
	[-0.82]	[-0.72]	[1.58]	[1.45]	[0.86]	[0.56]
N	10,338	10,338	10,338	10,338	10,338	10,338
Event fixed-effects	YES	YES	YES	YES	YES	YES

Appendix for
“Informed Trading and Option Prices: Evidence from Activist Trading”

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Table A1:

Summary statistics. Panel A reports summary statistics for stock market variables. Panel B reports summary statistics for option market variables. Panel C reports summary statistics for firm characteristics. All potentially unbounded variables are pre-winsorized at the 1% and 99% extremes. Columns (1) and (2) report the mean and standard deviation of each variable. Columns (3)–(9) report their values at the 1st, 5th, 25th, 50th, 75th, 95th, and 99th percentiles.

Variable Name	Mean (1)	SD (2)	1% (3)	5% (4)	25% (5)	50% (6)	75% (7)	95% (8)	99% (9)
Panel A. Stock market variables									
Excess Return	-0.0002	0.0313	-0.1009	-0.0508	-0.0152	-0.0002	0.0141	0.0517	0.1062
Volatility	0.0223	0.0242	0.0002	0.0006	0.0061	0.0147	0.0294	0.0710	0.1338
Volatility, Annualized	0.4412	0.4804	0.0034	0.0121	0.1211	0.2907	0.5833	1.4067	2.6511
Realized Vol, Annualized	0.5175	0.3824	0.0571	0.1441	0.2651	0.3969	0.6420	1.3288	2.0765
Bid-Ask Spread	0.0061	0.0095	0.0002	0.0003	0.0008	0.0018	0.0072	0.0271	0.0498
(log) Volume	12.9108	1.2036	10.0257	10.9081	12.1046	12.8949	13.7029	14.9645	15.8899
Option Implied Lending Fee	0.0151	0.0364	-0.0507	-0.0125	0.0027	0.0064	0.0137	0.0748	0.2298
Actual Lending Fee	0.0054	0.0106	0.0000	0.0010	0.0022	0.0030	0.0035	0.0170	0.0807
Difficulty to Borrow	1.4210	1.2306	1.0000	1.0000	1.0000	1.0000	1.0000	4.0000	8.0000
Utilization	0.2975	0.2350	0.0000	0.0174	0.1052	0.2387	0.4420	0.7801	0.9044
(log) Available to Short	16.2918	1.1042	10.2463	14.6922	15.7929	16.3782	16.9797	17.7951	18.4041
(log) Quantity Shorted	14.4739	2.3127	0.0000	12.1746	13.9975	14.8622	15.5619	16.5130	17.1442
Panel B. Option market variables									
(log) Open Interest	13.3312	1.5986	9.8508	10.7974	12.1943	13.2388	14.4042	16.1567	17.1965
Opt to Stock Volume	11.0066	22.5263	0.0000	0.0000	0.4084	2.6336	10.1160	53.5803	140.6059
(log) Put Volume	5.5082	4.7646	0.0000	0.0000	0.0000	7.2306	9.5105	12.2361	13.7787
(log) Call Volume	7.4322	4.2349	0.0000	0.0000	6.1377	8.6410	10.3675	12.6749	14.0925
Put skew	0.0538	0.1097	-0.1116	-0.0334	-0.0014	0.0194	0.0743	0.2333	0.6983
Call skew	-0.0002	0.0920	-0.2044	-0.1119	-0.0369	-0.0043	0.0107	0.1423	0.5120
Time slope	0.0886	0.2351	-0.2564	-0.1402	-0.0233	0.0463	0.1365	0.4015	1.5847
IV(t-1)-IV(t)	0.0038	0.0879	-0.2582	-0.1317	-0.0395	0.0001	0.0417	0.1516	0.3345
IV Call	0.5151	0.2320	0.1133	0.2216	0.3508	0.4643	0.6406	0.9671	1.2995
IV Put	0.5242	0.2345	0.1276	0.2300	0.3575	0.4722	0.6503	0.9772	1.3356
IV Call - IV Put	-0.0087	0.0586	-0.2363	-0.1066	-0.0272	-0.0057	0.0117	0.0811	0.1968
Spread, % - ATM	0.0769	0.0346	0.0176	0.0279	0.0499	0.0732	0.0996	0.1416	0.1724
Spread, % - Call ATM	0.0813	0.0385	0.0168	0.0280	0.0512	0.0762	0.1064	0.1538	0.1818
Spread, % - Call OTM	0.1485	0.0505	0.0385	0.0667	0.1111	0.1435	0.1833	0.2381	0.2500
Spread, % - Put ATM	0.0693	0.0356	0.0141	0.0236	0.0420	0.0627	0.0893	0.1415	0.1746
Spread, % - Put OTM	0.1362	0.0480	0.0361	0.0625	0.1016	0.1324	0.1667	0.2250	0.2500
Order Imbalance - Total	-0.0203	0.3881	-0.8571	-0.6667	-0.2600	0.0000	0.2222	0.6667	0.8571
Order Imbalance - Open	0.0039	0.4355	-0.8889	-0.7500	-0.2952	0.0000	0.3077	0.7500	0.8889
Order Imbalance - Puts	-0.0257	0.4026	-0.8889	-0.7500	-0.2500	0.0000	0.1538	0.7000	0.8750
Order Imbalance - Puts Open	-0.0067	0.4309	-0.9000	-0.7500	-0.2500	0.0000	0.2143	0.7500	0.9091
Order Imbalance - Calls	-0.0418	0.4077	-0.8750	-0.7500	-0.3158	0.0000	0.1944	0.6667	0.8571
Order Imbalance - Calls Open	0.0091	0.4518	-0.9000	-0.7500	-0.3000	0.0000	0.3500	0.7500	0.9000
Panel C. Firm characteristics									
OPTIONS AVAILABLE	0.2222	0.4158	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000
MARKET CAP	4.2113	1.5800	0.9660	1.7093	3.0751	4.0841	5.2875	7.0443	7.9461
ILLIQUIDITY	0.4756	0.5933	0.0127	0.0237	0.0872	0.2513	0.6203	1.7384	3.1201
BM	0.7617	0.5962	-0.3447	0.1185	0.3746	0.6299	0.9853	1.9475	3.3276
ANALYST	3.9935	5.3926	0.0000	0.0000	0.0000	2.0000	6.0000	16.0000	24.0000
STOCK RETURN	0.0081	0.0441	-0.1061	-0.0631	-0.0163	0.0058	0.0310	0.0839	0.1560
STOCK RETURN VOL	0.5519	0.2705	0.1616	0.2220	0.3479	0.4959	0.6930	1.1151	1.4529
INST	0.4574	0.2918	0.0035	0.0361	0.2071	0.4282	0.6975	0.9667	1.0000
INST AHF	0.0605	0.0676	0.0000	0.0000	0.0046	0.0413	0.0864	0.2066	0.3180
HSR	0.1979	0.3985	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000

Table A2:

Cost of borrowing shares This table presents the relation between informed trading in stock market and proxies for the cost of borrowing shares. Each column reports results in a sub-sample of 522 Schedule 13D filings in which there are listed options on target firms and there are data on the cost borrowing shares. The sample covers the 60-day disclosure period only. *Implied fee* is the lending fee implied by option prices. *Actual lending fee* is the fee that share lenders pay to short the stock (annualized in bp, provided by the Markit database). *Difficult to borrow* is a proxy for the difficulty of borrowing a share (provided by the Markit database). *Utilization* is the ratio of shares on loan to the number of shares that can be borrowed. *Available* is the number of shares available for shorting. *On loan* is the number of actually shorted shares. Panel A analyzes differences in changes in outcome variables between event and matched firms during $(t-1,t-30)$ and $(t-31,t-60)$ periods before the filing date. Matched stocks are assigned based on the same industry, exchange, and market cap. Panels B, C, D compare the outcome variables on days when Schedule 13D filers trade and on days when Schedule 13D filers do not trade. In Panel B we report estimates of the basic regression: $y_{it} = \gamma_1 \text{itrade}_{it} + \eta_i + \epsilon_{it}$, where y_{it} is a measure of trading activity for company i on day t , itrade indicates days on which Schedule 13D filers trade in stock market, and η_i are event fixed effects. Panel C repeats the analysis using measures of the abnormal trading activity, which are calculated by taking the difference between the event stock and the matched stock trading activity measures. Panel D repeats the analysis in Panel C while including four Fama-French factors and VIX as controls. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	Implied fee	Actual lending fee	Difficult to borrow	Utilization	Available (log)	On loan (log)
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: $(t-1,t-30)$ vs $(t-31,t-60)$ for event vs matched stocks						
<i>event</i> * $(t-1,t-30)$	-0.0071**	0.0006	0.0115	0.0026	-0.0963***	-0.1056*
	[-2.50]	[0.85]	[0.36]	[0.30]	[-5.09]	[-1.94]
N	208	151	455	455	455	455
Panel B: Raw measures, no controls						
<i>itrade</i>	0.0006	0.0006	0.0051	-0.003	-0.0253*	-0.0344
	[0.30]	[1.10]	[0.19]	[-0.54]	[-1.79]	[-0.76]
N	4,052	4,266	15,121	15,121	15,121	15,121
Event fixed-effects	YES	YES	YES	YES	YES	YES
Panel C: Matched measures, no controls						
<i>itrade</i>	-0.0028	0.0005	0.0013	-0.0045	-0.0761***	-0.1174**
	[-1.26]	[0.78]	[0.05]	[-0.72]	[-6.00]	[-2.25]
N	3,011	3,081	13,150	13,155	13,155	13,155
Event fixed-effects	YES	YES	YES	YES	YES	YES
Panel D: Matched measures, with controls						
<i>itrade</i>	-0.0027	0.0006	0.0018	-0.0039	-0.0758***	-0.1154**
	[-1.28]	[0.82]	[0.07]	[-0.63]	[-6.03]	[-2.27]
N	3,011	3,081	13,150	13,155	13,155	13,155
Event fixed-effects	YES	YES	YES	YES	YES	YES