Informed Trading in the Stock Market and Option Price Discovery☆

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This version: March 2020

☆We thank Kerry Back, Tarun Chordia, Benjamin Golez (discussant), Charles Jones, Marcin Kacperczyk (discussant), Patrik Sandas (discussant), Vish Viswanathan (discussant), Jiang Wang and seminar participants at Boston College, Baruch College, the Said School of Business, St Gallen University, Penn State University, Case Western Reserve, HEC Montreal, the IFSID 2015 conference on Financial Derivatives in Montreal, the 2016 Econometric Society Meetings in Geneva, the Fifth ITAM Finance Conference, the 2016 Cavalcade, the 2016 SFI Research Days, the third FARFE conference, the 2016 Chicago Conference on Derivatives and Volatility, and the 2017 AFA conference for their helpful comments and suggestions. We are also grateful to Nicholas Panos from the SEC for educating us on the institutional details related to this study. Virginia Jiang, Cong Gu, Yujia Liu, Xin Luo, Victoria Ngo-Lam, Karina Olague, Eunji Oh, Ye Sun, Sofiya Teplitskaya, Tong Tong, Tiantao Zheng, and Pei Zou provided excellent research assistance. The Internet Appendix to this paper can be found at https://sites.google.com/a/bc.edu/vyacheslav-fos/home/research.

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Abstract

When activist shareholders file Schedule 13D filings, the average stock price volatility drops by about 10%. Prior to filing days, volatility information is reflected in option prices. Using a comprehensive sample of trades by Schedule 13D filers which reveals on what days and in what markets they trade, we show that on days when activists accumulate *shares*, options-implied volatility decreases, implied volatility skew increases, and implied volatility time-slope increases. The evidence is consistent with a theoretical model where it is common knowledge that informed trading occurs only in the stock market and market makers update option prices based on stock price and order-flow dynamics.

It has long been argued that option markets should provide an interesting trading avenue for investors seeking to exploit an informational advantage. Options may, for example, provide valuable embedded leverage (Black, 1975). They may also allow investors to achieve better liquidity or to hide their information more effectively (Back, 1993; Biais and Hillion, 1994; Easley, O'Hara, and Srinivas, 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; Chan et al., 2002; Chakravarty et al., 2004; Pan and Poteshman, 2006). On the other hand, Muravyev, Pearson, and Broussard (2013) suggests that no economically significant price discovery occurs in the option market. Thus, whether and how informed investors actually use options and what informational linkages there are between option and stock markets remain open questions.

In this paper we use data on a class of informed investors' trading behavior to revisit the following questions. Does private information flow from stock markets to option markets? How do investors who possess valuable private information contribute to the flow of information between these two markets?

Addressing these questions is challenging because the identity of informed investors and the timing of their trades 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. following M&A announcements) or assuming that a class of investors is informed (e.g. corporate insiders or institutional investors). Researchers have also used traders that are involved in illegal insider trading to study informed trading in options (Augustin et al., 2014; Kacperczyk and Pagnotta, 2016).[1] Whereas these traders are clearly informed, there are selection concerns because these traders were caught precisely because they were trading in a very unusual way.

[1]See Ahern (2017) for comprehensive analysis of illegal insider trading networks.

In this paper we use a dataset that gives us detailed information about the timing of both stock and option trades by investors we can identify as having substantial private information as we study informational linkages between stock and option markets. More specifically, we follow Collin-Dufresne and Fos (2015) and exploit 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 in a publicly traded company if they are interested in influencing the management of the company.[2] Moreover, Item 5(c) of Schedule 13D requires a filer to report the dates, prices, and quantities of all trades in a subject security of a target company executed during the 60 days that precede a filing date. We thus have detailed information on the time, price, and quantity of Schedule 13D stock trades. In addition to having to report their actual positions at the time of filing, Item 6 of Schedule 13D requires filers to disclose any derivative contracts that have been entered. Thus, we have detailed information on the use of derivatives by Schedule 13D filers.

To the best of our knowledge, this is the first paper to use Schedule 13D trades to study informational linkages between option and stock markets. We document several new facts. First, we find that Schedule 13D filings contain information about the volatility of stock returns. Stock price volatility drops by about 10% after the filing date. Whereas stock-price implications of Schedule 13D filings have been studied before (e.g., Brav, Jiang, Partnoy, and Thomas, 2008; Collin-Dufresne and Fos, 2015), the evidence pertaining to changes in volatility is new.[3]

[2]The disclosure requirement applies to any class of securities, including common stock, preferred stock, and options.

[3]Confirming findings reported in previous research, the average Schedule 13D filing in our sample earns a statistically significant cumulative return in excess of the market of about 6% in the (t-10,t+1) window around the filing date. 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. Back, Collin-Dufresne, Fos, Li, and Ljungqvist (2018) 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, because the latter determines the effort level of an informed trader, and

Second, we show that volatility information is reflected in option prices prior to Schedule 13D filing days. We find that option-implied volatilities decline closer to filing dates, suggesting that option prices anticipate the future drop in realized volatility after the filing date. In fact, when we split target firms in our dataset into large (positive), average, and small (negative) future changes in realized volatility, we find that implied volatilities correctly track future realized volatilities in each sample. We further find that implied volatility smiles and time-slopes steepen substantially closer to filing dates, reflecting higher chances of a large informational event.

Third, we document when and how this class of informed traders uses derivatives. We find that Schedule 13D filers rarely use derivatives. Specifically, only in 66 out of 2,905 Schedule 13D filings we analyze do informed investors disclose the usage of derivatives. That is, in about 98% of cases, Schedule 13D filers decide to trade exclusively in the stock market. They do this despite the fact that these filers build economically significant positions: the average toehold held on a filing date is more than 7% of outstanding shares. This finding suggests that derivatives may not be that attractive for this class of informed traders and that they play a minor role in activists' trading strategies.

This result is consistent with the theoretical model developed in Easley et al. (1998), which predicts that informed traders are not likely to use derivatives if the leverage advantage conferred by options is not large enough. Their model also predicts that usage of derivatives should increase if they are more liquid. Consistently, we find that when exchange-traded options are available, usage by activists increases (from 2% to 10% of the cases). When they do use derivatives, activists seek to increase their overall economic exposure to a stock (and not to hedge their risk). They achieve 2.3% long exposure (as measured by the percentage of outstanding shares) via derivatives and

hence the liquidation value of a 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.

6.4% via stocks, which together is 1.2% more than what they achieve when trading only stocks. Importantly, we argue that the results regarding the usage of options are likely to hold among other classes of informed traders. For instance, the findings are likely representative of hedge funds, which hold more than 3 trillion dollars under management and therefore may not find the leverage imbedded in options attractive. Of course, we do not believe that the evidence represents how all types of informed traders trade. For instance, individual investors who are leverage-constrained are likely to use options more often.

Fourth, we investigate how information on upcoming Schedule 13D filings becomes reflected in option prices. There are three possible channels. First, direct trading of options by Schedule 13D filers could move option prices to reflect their information. Insofar as usage of derivatives is so limited across Schedule 13D filers, this channel seems unlikely. Second, information leakages, e.g. trader talk, could lead to informed trading in options by other traders. We find that price run-ups in the stock market occur almost exclusively on days when Schedule 13D filers acquire stocks, suggesting that it is the direct price impact of Schedule 13D filers that moves stock prices rather than information 'leakage.' Third, option market makers can set option prices in reaction to stock-price and order-flow information.

To illustrate the implications of this last channel, we develop a theoretical model building on the dynamic Kyle (1985) model of Collin-Dufresne and Fos (2016a) where uninformed volume can be time-varying. In our model an informed trader accumulates shares anonymously in a secondary market in anticipation of several random announcement dates on which her private information about a firm will be released. We interpret the first announcement date as the Schedule 13D filing and the subsequent announcement as information about the actual activism campaign. We assume that options are also traded on the underlying firm and that it is common knowledge that the informed agent trades only the stock. This implies that option prices are set by the competitive market maker only in response to the stock-order flow.

We show that this simple model can generate many of the empirically observed stylized facts about stock-price volatility and implied-option volatilities and, in particular: (i) a positive announcement jump on an event date (as an insider purchases shares in an undervalued firm and not all information is incorporated prior to the announcement), (ii) a sharp drop in realized volatility on an announcement date (where the announcement reveals remaining private information and thus reduces uncertainty), (iii) a decrease in implied volatility (which reflects an expected future drop in volatility), and (iv) an increase in put and call skew and in the time slope prior to an event (owing to the expected jump in volatility and the spot price on an announcement date).

In the model, even though the informed investor trades only in the stock market, her information about the future jump in the spot price and in volatility on the announcement date is incorporated in option prices through information conveyed by the stock market order flow. Further, because the informed investor tends to trade more aggressively when uninformed stock-order flow is high, both informed and total stock-order flow tend to drive stock-price volatility as well as option-implied volatilities. To test this claim we focus on events for which Schedule 13D filers do not report any use of derivatives, corresponding to 98% of events. We find that, on days when activists accumulate *shares*, option-implied volatility decreases, volatility skew increases, the implied volatility time slope steepens, and option bid-ask spreads widen. Also consistent with the model, we find that the drop in stock volatility around the announcement is largely concentrated among firms that experience a large drop in volume on and after the announcement date.

Our main empirical finding is that stock order flow contributes significantly to the price discovery in option markets. To further support this interpretation, we find that controlling for observable stock market trading activity and price dynamics explains a significant part (but not all) of the change in the measures of implied volatility and option bid-ask spreads on days when Schedule 13D filers trade. Further, we find that the cross-market impact of Schedule 13D filers' stock trades on option-implied volatilities and bid-ask spreads is stronger if stock and option markets are more fully integrated, as measured by the magnitude of observed put-call parity violations. Finally, we show that option market outcomes change not only on days when Schedule 13D filers trade stocks, but also on surrounding days and more significantly in the two days following activists' trades. These findings are consistent with the idea that option market makers are not observing the actual activists' stock trades, but rather learning from a set of signals that are correlated with the activists' trading activity in the stock market.

The paper contributes to several strands of the literature.

First, the paper informs the literature that studies how information flows into option prices. Regarding stock-return predictability, Cremers and Weinbaum (2010) show that future stock returns are correlated with implied volatility skew, Johnson and So (2012) and Ge et al. (2015) show that future stock returns are correlated with option-to-stock volume, while Pan and Poteshman (2006) and Hu (2014) show that future stock returns are correlated with option order imbalances. 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 imbalances are correlated with future realized volatility. Our contribution is to show, using a unique feature of our data that provides information regarding when Schedule 13D filers trade in both stock and option markets, that information flows into option prices when Schedule 13D filers trade stocks.[4]

[4] A recent paper by Goncalves-Pinto et al. (2017) argues that the option-to-stock predictability could be attributable to temporary price pressure in the stock market (as a result of uninformed trading) that is not reflected in the option market. They document empirically that the actual stock price exhibits short-lived deviations from the option-implied stock prices that are correlated with the signed order-flow in the stock market. Interestingly, we also find (see table A10 in the Appendix) that there are significant deviations of actual stock prices and option-implied stock prices on days when (informed) activists trade

Second, the paper contributes to the literature that studies option markets around major corporate events. The literature considers merger-and-acquisition deals (e.g. Cao et al., 2005; Augustin et al., 2014), analyst revisions (e.g. Hayunga and Lung, 2014), stock splits (e.g. Gharghori et al., 2016), and illegal insider trading (e.g. Kacperczyk and Pagnotta, 2016; Ahern, 2017). Whereas the existing empirical literature on Schedule 13D filings is focused on stock-price changes (e.g. Brav et al., 2008; Klein and Zur, 2009; Collin-Dufresne and Fos, 2015), our paper is the first to show that stock volatility drops around Schedule 13D filings. Moreover, we are the first to analyze the flow of private directional and volatility information into option prices during these events. Importantly, our analysis is based on precise information about the timing (days) and location (stocks vs. options) of informed trades.

Third, the paper contributes to the literature that studies the relation between realized and future volatility. The existing literature suggests that implied volatility is a good forecaster of future realized volatility (e.g. Poon and Granger, 2003). Our contribution is to show that implied volatility also forecasts private information events, such as Schedule 13D filings. A distinctive feature of Schedule 13D filings is that the occurrence of an event is controlled by an informed trader—the Schedule 13D filer. That is, even though the mere occurrence of the informational event is the Schedule 13D filer's private information, option prices are informative about the timing of the event.

Finally, our paper contributes to the literature that studies the use of derivatives by activist shareholders.[5] Theoretical studies suggest that activist shareholders may use derivatives to separate positions in a firm's shares and votes (e.g. Brav and Mathews,

in the stock market, but their price impact is permanent and the changes in option-implied volatilities observed on these days are persistent.

[5]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."*. The full text of the petition is available at http://www.sec.gov/rules/petitions/2011/petn4-624.pdf.

2011; Burkart and Lee, 2015). Christoffersen et al. (2007) document an active market for votes and document that the average vote sells for zero price. Anecdotal evidence pertaining to the usage of derivatives to decouple economic exposure and voting rights are reported by Hu and Black (2007). Our paper contributes to the literature by showing that Schedule 13D filers rarely use derivatives despite the fact that exchange-listed options are settled in physical delivery and therefore carry voting rights upon exercise. Moreover, when activists do use derivatives, they seek to increase their overall economic exposure to the associated stock. Thus, our large body of sample-based evidence does not support the idea that derivatives are generally used by activists to decouple economic exposure from voting rights.

I. Institutional Background and Sample Description

Rule 13d-1(a) of the 1934 Securities Exchange Act requires investors to file a Schedule 13D 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 beneficial ownership crosses the 5% threshold as the 'event date' and to the date when the filing is sent to the SEC as the 'filing date.'

Shares of common stock and options to purchase physical shares within 60 days are examples of equity securities that can trigger a Schedule 13D filing. Because all exchange-listed equity options in the United States are settled in physical delivery and are immediately exercisable, they count towards the computation of the 5% beneficial ownership threshold. In contrast, any instrument that is exclusively cash-settled or is not exercisable within 60 days does not. 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. Thus, whether a derivative security triggers a Schedule 13D filing depends crucially on how the derivative is settled.

Item 6 on 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 that do not count toward the 5% threshold, these positions have to be disclosed in Item 6 on Schedule 13D filing. We therefore use Item 6 to identify whether a Schedule 13D filer uses derivatives.[6]

Information regarding trades executed by Schedule 13D filers is reported in Item 5(c). 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.[7]

Our sample of Schedule 13D filings with information on trades is constructed as follows.[8] First, using an automatic search script, we identify 19,026 Schedule 13D filings from 1994 through 2010. The script identifies *all* Schedule 13D filings that appear on

[6]The rule does not specify what information needs to be disclosed. It is up to the filer to decide the precision of the information she discloses. Therefore, we find substantial variation in the precision of disclosed information. Finally, note that no other items on a Schedule 13D filing requires disclosure of any information about derivatives as long as the subject security is common stock. Of course, the 5% threshold might be crossed with a position in a derivative security only. In this case the derivative security is the "subject security" and therefore all items on a Schedule 13D filing will include information about the derivative security (the subject security).

[7]To 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,..."

[8]See Collin-Dufresne and Fos (2015) for a detailed description of the procedure.

EDGAR. Next, we check the sample of 19,026 filings manually and identify events with information on trades. Because 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 or 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 through 2010, which totals 2,905 events. During the sample period, on average 194 events take place each year. Importantly, our top-down approach guarantees that the sample contains *all* Schedule 13D filings with information on trades. The time-series distribution of events is reported in the Appendix (Figure A1).

For each event in our sample we extract the following information on a given transaction from the Schedule 13D filings: the CUSIP of the underlying security, the transaction date, the transaction type (purchase or sell), the transaction size, and the transaction price. In addition, we extract the filing date, the event date (the 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 daily frequency. If the transaction data represent a higher-than-daily frequency, we aggregate them at 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 compile additional 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. In table A1 we define all variables and in table A2 in the Appendix we report summary statistics for all variables.

II. Stock Prices, Realized Volatility, and Volume around the Filing Date

In this section we document changes in stock prices, realized volatility, and trading volume around the filing date. On the filing date it becomes common knowledge that an activist shareholder has accumulated a significant position in a company and has an intention to influence the company's management. 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 in which they invest 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 shareholdership that constitute the "private" information in such cases. Only when they file with the SEC, at most 10 days after their holdings reach the 5% threshold, does the information become public. The extent to which the market believes their future actions provide value over and above what is already impounded in prices can be measured using announcement returns. The evidence reported in panel A of figure 1 strongly supports the assumption that Schedule 13D filers possess valuable information on underlying securities when they trade in the pre-announcement period.[9]

[9] This evidence has been well documented in previous research (e.g. Brav et al. 2008) and is reported here for completeness and because it is useful for understanding option returns. In addition to the average buy-and-hold return, we follow Collin-Dufresne and Fos (2015) and analyze profits made by Schedule 13D filers from purchasing stocks at pre-announcement prices. The results are reported in table A3 in the Appendix and suggest that Schedule 13D filers make significant profits. 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 to the tune of $2.35 million.

[Insert figure 1 here]

We next investigate changes in realized volatility around the filing date. The realized volatility is calculated as the absolute value of daily stock returns (and for robustness we also computed realized volatility measures from intra-day data). The results are reported in panel B of figure 1, 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) stocks. Matched stocks are assigned based on the same industry, market cap, and previous year volatility. We find that the realized volatility is about 48% for event and matched stocks prior to the filing date. It jumps up on the filing date to 52% (when the event becomes common knowledge), corresponding to an 11% increase. After the filing date the realized volatility decreases to about 44%. The results represented in figure A2 in the Appendix shows that there is a similar pattern of realized volatility around the filing date in the full sample of Schedule 13D filings (i.e., when we remove the requirement that target stocks have listed options). Table A4 in the Appendix shows that the sharp increase in realized volatility on the filing date and the drop in realized volatility on days that follow the filing date are statistically significant.

We turn next to changes in stock-trading volume around the filing date. The results are reported in panel A of figure 2, which plots the average (log) stock volume from 50 days before the filing date to 50 days after. The dark (gray) line plots the average stock volume for the sample of event (matched) stocks. Matched stocks are assigned based on the same industry, market cap, and previous year volatility. We find that the average stock volume increases closer to the filing date. It jumps down on the filing date. After the filing date the average stock volume for event stocks is indistinguishable from the average stock volume for matched stocks.

As we will see in section V, our model predicts that the behavior of stock-price volatility around the announcement should be driven largely by the behavior of uninformed volume. In particular, if uninformed volume drops after the announcement, then we would expect to observe a drop in price volatility, which should recover if uninformed volume recovers. Indeed, in the model, if uninformed volume in the stock decreases, informed agents trade less aggressively after the announcement, which lead to a decrease in the stock volatility. Consistent with this prediction, the results represented in panel B in figure 2 show that the drop in stock volume around the announcement date is larger when the drop in realized volatility around the announcement date is larger.

[Insert figure 2 here]

The results reported in table I confirm the pattern we observe in figures 1 and 2. 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 0.47 to 0.43 around the filing date, corresponding to a 9% reduction. When we consider the difference in changes in realized volatility between event and matched stocks, we find very similar results. The difference-in-differences estimates are negative and highly significant statistically. Similarly, we find that stock trading volume drops significantly after the filing date for the sample of event firms. The change in trading volume for the sample of matched stock is insignificant. Overall, the evidence shows that the realized volatility and trading volume drop after the filing date. It takes more than thirty days for the realized volatility to recover.

[Insert table I here]

Realized volatility can drop for several reasons. First, activist shareholders can promote changes in corporate policies that reduce uncertainty about future stock performance. This channel is unlikely to explain the results because the drop in volatility is temporary (recovering in about thirty days),[10] unlike the jump in the stock-price level, which is much more persistent. Indeed, it often takes activist shareholders several quarters to implement the desired changes in corporate policies. Moreover, these changes are likely to have a long-term impact. Second, volatility can drop because residual uncertainty is resolved as a result of the announcement and filing of the activists' intentions. Third, volatility can drop if the trading patterns of market participants change after the filing date. In section V we develop a theoretical model that demonstrates how these last two channels affect volatility and in section VI we present some evidence that is consistent with this mechanism. First, however, we investigate whether, *prior* to the Schedule 13D filing date, option-implied volatilities contain information about the future announcement jump in return and volatility.

III. Option-implied Volatilities around the Filing Date

In this section we investigate whether volatility information is incorporated into *option* prices. Panel A in figure 3 shows both *future* 30-day realized volatility and 30-day option-implied volatility. Both volatilities decrease in lock-step starting 30 days prior to the filing date. Clearly, the average implied volatility closely tracks the average *future* realized volatility of our target firms around the filing date. Further evidence that implied volatilities efficiently predict future realized volatility can be gleaned by considering the profitability of a trading strategy that would sell delta-hedged option straddles to benefit from the future drop in realized volatility around the filing date. Such a strategy would earn an average pre-transaction-cost excess return of 5.5% during the 30 pre-filing days, which would be dwarfed by the option bid-ask spread (around 8%) and stock transaction costs (see figure A4 in the Appendix).

[10] Indeed, figure A3 in the Appendix plots the realized volatility from 245 days before the filing date to 235 days after and confirms that the drop in realized volatility is temporary and lasts for about 30 days.

[Insert figure 3 here]

To further investigate the relation between implied and future realized volatilities, we test whether the predictability holds when we condition on future changes in realized volatility. Specifically, we consider three sub-samples: (1) events with large drops in realized volatility around filing dates, (2) events with small changes in realized volatility around filing dates, and (3) events with an increase in realized volatility around filing dates. We report the results in figure 4. The results again clearly indicate that even *conditionally* implied volatility predicts future realized volatility.

[Insert figure 4 here]

We next ask whether option prices reflect the timing and size of the informational event. To address this question, we plot changes in the time slope around the filing date. The time slope is defined as the ratio of implied volatilities for at-the-money call options with 30 days to expiration to call options with 365 days to expiration minus one. Panel B in figure 3 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.

To further investigate whether option prices reflect higher chances of a large stock price move, we next investigate implied volatility skews. Panels C and D of figure 3 plot the implied volatility skews of put and call options around the filing date. Put skew is defined as the ratio of implied volatilities for out-of-the-money to at-the-money put options minus one. We find that put skew rises substantially closer to the filing date. In contrast, there is no change in put skew for the sample of matched stocks. Call skew is defined as the ratio of implied volatilities for out-of-the-money to at-the-money call options minus one. As is the case for put options, we find that call skew rises substantially closer to the filing date for our target stocks, but that there is no change in call skews for the sample of matched stocks.

These results show that option prices reflect higher chances of substantial stock price movement closer to the filing date. The results reported in table II confirm the pattern we observe in figure 3. In this table we compare differences in changes in 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. In panel A in table II we report the results for put skew, call skew, the time slope, the implied volatility of call options, and the implied volatility of put options. Confirming patterns documented in figure 3, we find significant increases in put skew, call skew, and the time slope as well as significantly lower levels of implied volatilities closer to the filing date. Thus, option prices change substantially closer to the filing date. Specifically, changes in implied volatilities reflect higher chances of an informational event and changes in the time slope of implied volatilities indicate that market participants anticipate the timing of the event. In panel B we report the results for changes in stock market outcomes closer to the filing date. Consistently with Collin-Dufresne and Fos (2015), we find that changes in excess returns and trading volume are larger for event stocks relative to matched stocks.

[Insert table II here]

Overall, the evidence indicates that option-implied volatilities contain information about the upcoming Schedule 13D announcement jump in return and volatility, even though it is not common knowledge that the activist is purchasing shares. In the remaining part of the paper, we investigate *how* information flows into option prices. An obvious possibility is that activists also trade options and thus that their trading activity in the option market is driving option prices. We explore this channel next.

IV. Do Activists Trade Derivatives?

How often do activists trade derivatives? To address this question, we manually check all Schedule 13D filings in our sample for information derivatives of any type. We find that activists do not use derivatives in the vast majority of Schedule 13D campaigns. Specifically, we could find information on derivatives only in 66 Schedule 13D filings, corresponding to 2.27% of the sample.

This result is consistent with the theoretical model developed in Easley et al. (1998). The model predicts that informed traders are not likely to use derivatives if the leverage effect of options is not strong enough. That most of the Schedule 13D filers in our sample are hedge funds suggests that they have access to other sources of leverage. Leverage may also explain the striking difference in the use of derivatives between activist shareholders and illegal insider traders. In a recent paper, Kacperczyk and Pagnotta (2016) document that traders who are accused of illegal insider trading often use derivatives. These traders are often private individuals who find leverage embedded in options particularly attractive.

Easley et al. (1998) also predict that informed traders are more likely to use derivatives if these securities are more liquid. 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 an 80-day period prior to the filing date. For each event, we set an 'Options available' indicator to one if the number of days with positive option trading volume exceeds 40 and zero otherwise.

Indeed, we find that exchange-traded options are available in 580 events, corresponding to 20% of the events.[11] When exchange-traded options are available, the probability that an activist uses derivatives (including OTC) is 10%. In contrast, when

[11] Mayhew and Mihov (2004) study factors influencing the selection of stocks for option listing.

exchange-traded options are not available, the probability that the activist discloses information about derivatives decreases to 0.34%. Thus, the availability of exchange-traded options is a strong predictor of the use of derivatives by activists. In the Internet Appendix we provide further evidence regarding the characteristics of campaigns in which derivatives and the characteristics of campaigns in which derivatives are not used.

Overall, the evidence indicates that in the vast majority of cases Schedule 13D filers do not use derivatives. This results fits well with the evidence that implied volatilities efficiently predict future realized volatility and with the lack of profitability of a trading strategy that would sell delta-hedged option straddles to benefit from the future drop in realized volatility around the filing date (see figure A4 in the appendix). This finding is also consistent with the view that informed trading in option markets is associated with higher risk of detection.[12]

Schedule 13D filers could use derivatives to either increase their exposure to the underlying security, to hedge their exposure to the underlying security, or to benefit from volatility information. Indeed, whereas informed traders can potentially trade on directional information in either stock or option markets, they can trade on volatility information only in non-linear securities such as options. In the Internet Appendix we show that activists seek 'long' stock-price exposure in most events, suggesting that the main driving force behind the use of derivatives by Schedule 13D filers is achieving positive exposure to targets' stock prices.

[12] In his Bloomberg article, Matt Levine writes, "*As I may have mentioned over and over and over and over and over again, the first rule of insider trading is just don't insider trade, but the second rule is: If you have inside information about an upcoming merger, don't buy short-dated out-of-the-money call options on the target. The SEC will get you!*" See https://www.bloomberg.com/view/articles/2014-06-17/there-might-be-a-lot-of-insider-trading. Consistently with this view, Kacperczyk and Pagnotta (2016) find that traders caught in illegal insider trading cases often use derivatives. Ahern (2017) documents that illegal insiders caught trading options tend to be less sophisticated, one-time traders. It could however also indicate that Schedule 13D filers misreport their option trading to the SEC (but given they are actually filing a Schedule 13D this seems like a dangerous strategy).

Overall, the evidence suggests that activists rarely use derivatives, as we found evidence of such use in only 66 out of 2,905 events. When they do so, they seek long stock-price exposure. Activists lacked long exposure through positions in derivatives in less than 2% of the 66 events. Given that activists trade so few options, it is surprising that option prices seem to anticipate the future behavior of stock volatility around the activist announcement date. Clearly, the information that flows to the option market does not come from activists' direct trading in options. Could it be a result of the cross-market price impact? That is, could the observed option price behavior reflect rational option market-making in response to the stock price and order flow? To investigate such a possibility, we next analyze the predictions of a theoretical model.

V. How Should Option Prices React to Informed Trading (only) in the Underlying Security?

We want to understand if the empirical stylized facts we observe in stock, realized, and implied volatilities are consistent with rational market-making in options when it is common knowledge that informed investors trade only in the underlying stock. For that we develop a simple model to serve as a benchmark. The equilibrium model of the stock price is based on Collin-Dufresne and Fos (2016b)'s model of informed trading with random announcements.[13] To save on space we simply describe the model's main features and relegate to Appendix A the detailed description and derivations.

The contribution of this section is to investigate what this model implies for the behavior of option prices. This is a useful benchmark model, as we can fit (at least qualitatively) several stylized facts about activists' *stock* trading and investigate the predictions for option prices in a model where market makers would know that informed

[13] Their model extends the Kyle (1985) model of insider trading to allow for both a random announcement date with time-varying intensity and time-varying noise-trading volatility (see also Collin-Dufresne and Fos (2016a) for the case with a fixed announcement date).

traders trade only the underlying stock and not the option. The main features of our model are as follows.

We assume that the total value of the firm, V_t, has three components:

$$V_t = v_0 + v_1 \mathbf{1}_{\{\tau_1 \leq t\}} + v_2 \mathbf{1}_{\{\tau_2 \leq t\}}, \tag{1}$$

where v_0 is the value known to all market participants at τ_0, v_1 will be revealed on the announcement date $\tau_1 > \tau_0 = 0$, and v_2 will be revealed at time $\tau_2 > \tau_1$. We assume that the informed trader knows v_i at time τ_{i-1}. That is, she is always one step ahead of other market participants regarding the upcoming information announcement.[14] We can think of the first announcement, v_1, as information related to the intentions of the activist that are revealed to all market participants by the initial 13D filing and the second component, v_2, as information related to the ultimate success of the eventual campaign, which is discovered only by the activist immediately after the filing date. For future reference we define the counting process as $N_t = \sum_{i=1}^{2} \mathbf{1}_{\{\tau_i \leq t\}}$.

The announcement dates are publicly observable, unpredictable, stopping times, with arrival intensity given by $\rho(t, N_{t^-}, \tau_{N_{t^-}})$ with:[15]

$$\rho(t, i, \tau) = r_0^i + r_1^i (t - \tau). \tag{2}$$

Specifically, we assume that the intensity of the next announcement increases at a deterministic rate ($r_1^i \geq 0$) from the previous announcement to capture the fact that, as

[14]We model the informational advantage of the activist and abstract from explicitly modeling the 'activism technology' and real actions that activists would typically have to perform to increase firm value. The latter could be done following Back et al. (2018) and would have similar implications for the dynamics of prices around the announcement date.

[15]The model is essentially a succession of Kyle-Back models with random announcement dates. Exponential arrival of a random terminal date has been used in previous papers such as Back and Baruch (2004) and Caldentey and Stacchetti (2010), but with constant arrival intensity. Stochastic intensity is introduced in Collin-Dufresne and Fos (2016b).

the activist accumulates a larger and larger stake, the likelihood of the announcement increases.[16]

The informed trader maximizes his present value of future trading profits:

$$\max_{X_t \in \mathcal{A}} \mathrm{E}\left[\int_0^{\tau_2} (V_{\tau_2} - P_t)\, dX_t \,|\mathcal{F}_0^I\right]. \tag{3}$$

where we denote by $\mathcal{F}_t^I$ the information filtration of the informed agent, which comprises all the information available to the market maker as well as the advance knowledge of the next announcement value $v_{1+N_{t-}}$.

The market maker's information filtration, $\mathcal{F}_t^M$, is generated by observing the entire past history of aggregate order flow $\{Y_s\}_{s\le t}$ and public announcements $\{V_s\}_{s\le t}$. In addition, she has priors that the v_i are independent random variables that are normally distributed $v_i \sim N(0, \Sigma^i)\ \ \forall i = 1, 2.$[17]

The activist must choose a trading rule (the cumulative number of shares X_t) in some admissible set $\mathcal{A}$ defined as the set of absolutely continuous trading strategies (i.e., $dX_t = \theta_t dt$) that are adapted to his private information filtration, $\mathcal{F}_t^I$ and satisfy some technical square-integrability restriction.[18]

[16] The reality of Schedule 13D filings is that in our model the announcement occurs within 10 days after the first time the activist's stake passes the 5% threshold. The activist controls both when the stake passes the 5% threshold and the exact timing of Schedule 13D filing. That is, the stopping time is predictable in the insider's filtration and unpredictable in the market's filtration, which renders the model difficult to solve. Our framework is a reduced-form approximation to simplify the analysis.

[17] In our model, market makers trade options based on the information they extract from the stock order flow. They face uninformed traders only in options, but they do not earn positive profits on average on their options' trades, because we assume they are risk-neutral and competitive, as in Kyle (1985). A richer model might allow for a finite number of non-competitive market makers in the option market. But, this is clearly beyond the capacity of our current setup to model.

[18] A shown in Back, it is optimal for the activist to choose an absolutely continuous trading strategy, because, in continuous time, the market maker can immediately infer from the quadratic variation in 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).

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 P_t they set so as to break even given their priors about the firm value and the observed order flow.

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

$$dY_t = dX_t + \sigma(t, N_{t^-}, \tau_{N_{t^-}})dZ_t, \tag{4}$$

where Z_t is a standard Brownian motion. We model the volatility of the uninformed order flow as a deterministic increasing function of time between announcement dates to capture systematic variation in abnormal volume (in excess of the activist's trades) we observe around the announcement.[19] Indeed, there is substantial variation in abnormal volume that is not a result of the activist's trades. Volume tends to be abnormally high and increasing prior to the event date, then to jump down after the announcement and returns to normal after a few days (see figure 2). We capture this by modeling σ_t as a process starting at σ^0 then increasing at rate m^0 until the first announcement date τ_1, when it jumps to a lower level σ^1 and then grows at rate m^1 until τ_2, when we assume the firm is liquidated (thus volume falls to $\sigma^2 = 0$ thereafter). Specifically, we assume:

$$\sigma(t, i, \tau) = \sigma^i e^{m^i(t-\tau)} \ \ \forall i = 0, 1, 2. \tag{5}$$

[19]A deterministic form of 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 (2016a).

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 competitive market maker on $t \leq \tau$:

$$P_t = \mathrm{E}[V_{\tau_2} \mid \mathcal{F}_t^M]. \tag{6}$$

We obtain the following characterization of the equilibrium:

Theorem 1. *If the noise-trading volatility and event intensity are given by equations (2) and (5) above then, if either (PB): $\{r_1^i > 0\}$ or (PA): $\{r_1^i = 0$ and $m^i < r_0^i\}$, an equilibrium exists where the price starts at $P_0 = v_0$ and responds linearly to order flow at $t < \tau_2$, that is $dP_t = \lambda(t, N_{t^-}, \tau_{N_{t^-}})dY_t$, where the insider's optimal trading strategy is $dX_t = \theta(t, N_{t^-}, \tau_{N_{t^-}})dt$, where*

$$\theta(t, i, \tau) = \frac{\lambda(t, i, \tau)\sigma(t, i, \tau)^2}{\Sigma(t, i, \tau)}(\hat{V}_{t^-} - P_{t^-}), \tag{7}$$

where $\hat{V}_t = V_t + v_{N_t+1}$ is the sum of all announcements (past and upcoming) known to the insider. Under (PA) we have:

$$\Sigma(t, i, \tau) = \Sigma^{i+1} e^{-2(r_0^i - m^i)(t-\tau)}, \tag{8}$$

$$\lambda(t, i, \tau) = \lambda^i e^{-r_0^i(t-\tau)}, \tag{9}$$

$$\lambda^i = \frac{\sqrt{2\Sigma^{i+1}(r_0^i - m^i)}}{\sigma^i}. \tag{10}$$

Under (PB) we have:

$$\Sigma(t,i,\tau) = \Sigma^{i+1}\frac{\mathbf{N}[\frac{m^i - r_0^i - r_1^i(t-\tau)}{\sqrt{r_1^i/2}}]}{\mathbf{N}[\frac{m^i - r_0^i}{\sqrt{r_1^i/2}}]}, \tag{11}$$

$$\lambda(t,i,\tau) = \lambda^i e^{-r_0^i(t-\tau)-\frac{r_1^i}{2}(t-\tau)^2}, \tag{12}$$

$$\lambda^i = \sqrt{\frac{\Sigma^{i+1}\sqrt{r_1^i}e^{-\frac{(m^i-r_0^i)^2}{r_1^i}}}{\sqrt{\pi}(\sigma^i)^2 N[\frac{m^i-r_0^i}{\sqrt{r_1^i/2}}]}}. \tag{13}$$

where $\mathbf{N}[\cdot]$ *is the cumulative normal distribution function. It follows that in the filtration of the insider, the price process follows a mean-reverting jump-diffusion process:*

$$dP_t = \frac{\sigma_P(t, N_{t^-}, \tau_{N_{t^-}})^2}{\Sigma(t, N_{t^-}, \tau_{N_{t^-}})}(\hat{V}_{t^-} - P_{t^-})dt + \sigma_P(t, N_{t^-}, \tau_{N_{t^-}})dZ_t + (V_t - P_{t^-})dN_t, \tag{14}$$

where the stock volatility is:

$$\sigma_P(t,i,\tau) = \lambda(t,i,\tau)\sigma(t,i,\tau) = \lambda^i e^{(m-r_0^i)(t-\tau)-\frac{r_1^i}{2}(t-\tau)^2}. \tag{15}$$

Proof. All proofs are in Appendix A. □

The price process is mean-reverting (in the filtration of the insider) with a mean reversion coefficient that increases over time to infinity in both the (PA) and (PB) cases. Price volatility is always decreasing in the (PA) case but can be hump-shaped in the (PB) case, where it is initially increasing if $m > r_0^i$ 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 uninformed volume is expected to increase ($m > 0$), the insider wants to delay trading to trade more aggressively when there will be more noise trading so he can hide more effectively. On the other hand, the likelihood of an early announcement is an incentive for her to trade early because she 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 that 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.[20]

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 depends on how much information has already been impounded in the price as a result of trading by the informed investor. Specifically, the size of the jump in the level of the price will depend on how close the informed trader's trading has driven the market price to the post-announcement value.

The jump in volatility on the other hand will depend on two forces, namely (i) how much new uncertainty arises on the announcement date, and (ii) the behavior of uninformed volume around the announcement date. To better understand this point, note that the information that is released on the announcement date τ_i about v_i reduces uncertainty. Yet, the new information that is obtained by the insider at τ_i about v_{i+1} generates new private information. Second, how much of that new private information will be released into prices around the announcement date depends on the behavior of uninformed volume. If uninformed volume drops around the announcement date, then even if there is a lot of new private information created by the announcement, the informed agent will want to delay trading on this information around the announcement to wait for more noise-trading liquidity. On net, therefore, we would expect to see short-term price volatility dynamics driven by (uninformed) trading volume around

[20] Note that these two forces also generate an 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.

the announcement, and longer-term price volatility driven by the extent to which the announcement generates more or less volatility about the future prospect of the firm than it resolves.

The volume of new information that becomes available to Schedule 13D filers on the first announcement date depends on the nature of the activism. For example, if the activist is performing a corporate governance action, then on the filing date he will likely obtain new information indicating the willingness of board members to agree to the action. In addition, the activist will likely obtain information on the willingness of other shareholders to support the campaign. So it is plausible that new private information arises around the announcement date.

Information regarding 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 trades only in the underlying stock price. Similarly, information about future announcement intensity (r_0^i, r_1^i) and about the expected future noise-trading volatility (m^i) will affect implied-option volatilities, but not the level of the stock price.

To confirm this we now solve for option prices in this model. The competitive market maker sets option prices in a way that facilitates breaking even on average. Because it is common knowledge that informed agents do not trade options, the equilibrium price for a call option with a strike of K and a maturity T set for a date $t < \tau_1$ is simply $C(P_t, K, t, T) = \mathrm{E}[|P_T - K|^+ \,|\, \mathcal{F}_t^Y, \tau_1 > t]$. We note that in the filtration of the market maker the price process given in equation (14) can be written as:

$$dP_t = \sigma_P(t, N_{t^-}, \tau_{N_{t^-}}) d\hat{Z}_t + J(t, N_{t^-}, \tau_{N_{t^-}}) dN_t, \qquad (16)$$

where $\hat{Z}_t$ is a standard Brownian motion in the filtration of the market maker and the jumps follow a normal distribution $J(t, j, \tau) \sim \mathcal{N}(0, \Sigma(t, j, \tau))$. The volatility $\sigma_p(t, j, \tau) = \lambda(t, j, \tau)\sigma(t, j, \tau)$ is deterministic between jumps. Thus, in the filtration of the market maker the process follows a Gaussian jump-diffusion martingale process with zero drift.[21]

In Appendix A we derive a closed-form solution for the value of the call option prior to the first announcement, i.e., on $t < \tau_1$:[22]

$$
\begin{aligned}
C(P_t, K, t, T) =& \mathrm{E}[|P_T - K|^+ \,|\, \mathcal{F}_t^Y, \tau_1 > t] \\
=& S_{t,T}^{0,0} NC\left(P_t - K, \Sigma(t,0,0) - \Sigma(T,0,0)\right) \\
&+ \int_t^T \delta S_{t,s}^{0,0} \Big\{ S_{s,T}^{1,s} NC\left(P_t - K, \Sigma(t,0,0) + \Sigma^2 - \Sigma(T,1,s)\right) \\
&+ \int_s^T \delta S_{s,u}^{1,s} NC(P_t - K, \Sigma(t,0,0) + \Sigma^2) \Big\},
\end{aligned} \tag{17}
$$

where

$$
S_{t,T}^{j,\tau} = \mathrm{E}[\mathbf{1}_{\left\{\tau_{j+1} > T\right\}} \,|\, \mathcal{F}_t^Y, \tau_j = \tau] = e^{-\int_t^T \rho(s,j,\tau) ds} \tag{18}
$$

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 $\delta_u S_{t,u}^{j,\tau} = S_{t,u}^{j,\tau} \rho(u,j,\tau) du$, i.e., the 'probability' that the event τ_{j+1} occurs at u (conditional on $\tau_j = \tau \leq t$) and the function:

$$
NC(k, \Sigma) = k\mathbf{N}(k/\sqrt{\Sigma}) + \sqrt{\Sigma}\mathbf{n}(k/\sqrt{\Sigma}),
$$

where $\mathbf{n}(x)$ and $\mathbf{N}(x)$ are the normal density and normal cumulative density function, respectively.

We can now compute option-implied volatilities and prices along various trajectories.[23] Figure 5 shows that this simple model can replicate (qualitatively) some observed

[21] Note that the jump compensator is zero because the jump has a zero mean in the market maker's filtration.

[22] A similar formula obtains for the value after the first event, i.e., on $\tau_1 < t < \tau_2$; see the appendix. The value of a put option can be obtained from put-call parity.

[23] We compute implied volatilities relative to the constant volatility model, which is the natural benchmark for our Kyle-type model. That assumes the stock price is an arithmetic Brownian-

features in our data. Panels (a) and (b) show that, for a particular realization of noise-trading volatility, the trajectory of the price, the realized volatility, and the 3-month-option-implied volatility. For this particular simulated price path, the informed investor trades in a firm whose prices starts at $P_0 = 10$ and, at the announcement, which occurs at $\tau = 0.33$, jumps to $P_\tau = 11$. As a result of the price impact of the informed investor's purchases, we observe a positive price run-up prior to the announcement, such that about half of the private information is impounded in the price prior to the announcement return jump. Realized volatility increases from around 30% initially to 40% around the announcement date as the informed investor trades more and more aggressively, as the volume of uninformed trading is increasing and the announcement becomes more likely.

[Insert figure 5 here]

On the announcement date, there is a positive jump in the price level and a concurrent jump down in the realized volatility as all the uncertainty about the initial announcement value is resolved and because, insofar as uninformed volume drops after the announcement, the informed investor refrains from trading aggressively on the new private information generated around the announcement date. Subsequently, when uninformed volume recovers, price volatility recovers. From about 3 months prior to the announcement, 3-month implied volatility decreases, reflecting the anticipated downward jump in realized volatility. Implied volatility recovers after the announcement.

Panel (c) plots the implied volatility skew on 3-months options observed at $t = 0.25$, that is, about one month prior to the announcement. This skew shows that out-of-the-money options are more expensive than the constant volatility 'Black-Scholes' benchmark. The increase in both the put and call skew generated by the model is attributable largely to the anticipated jump in realized volatility rather than to the

---

motion with constant volatility $dP_t = \sigma dZ_t$. In that case, the benchmark option-pricing model is $C(P_0, K, \sigma, T) = E[|P_T - K|^+] = NC(P_0 - K, \sigma^2 T)$.

jump in the level of the stock price. Indeed, since the market maker is risk-neutral in our model, in his filtration the expected size of the announcement return is zero.[24] Thus, the increase in the put option skew is not attributable to the higher likelihood of a 'crash.'[25] Rather, it is attributable to the expected jump in volatility. Further, the possibility of a large jump in either direction from the point of view of the market maker increases the Kurtosis of the underlying security and thus contributes to making short-dated out-of-the-money options more expensive than the Black-Scholes constant volatility benchmark. Unlike stocks, the cross-section of option prices reflects the anticipated jump in volatility.

Panels (d) and (e) show, respectively, the behavior of the call skew and the time slope over time. We observe that in the three months preceding the expected announcement date (for this simulation $\mathrm{E}[\tau] = 0.4$ and the realization $\tau = 0.33$) both the call skew and the time slope steepen, reflecting market's perception a jump event is increasingly likely.

Lastly, panel (f) shows how uninformed volume as measured by noise-trading volatility and the informed trader's expected trading rate both increase until the announcement date. On the announcement date, noise-trader volatility drops and, as a result, the informed trader expects to trade much less aggressively. This creates a link between the volume patterns shown in panel (f) and the realized volatility patterns shown in panel (b), which is consistent with empirical stylized facts about stock volume around the filing date presented in figure 2 as well as with the empirical evidence

[24] We note that, in the data on 13D filings, we observe positive announcement returns on average. This is consistent with the model, in the sense that filings are observed conditional on activists having acquired shares. Activists who short stocks, which they estimate are over-valued, and for which there would be a negative average announcement return in the model, are not required to file. Indeed, Appel and Fos (2019) document negative and significant announcement returns for public short-selling campaigns by activist hedge funds.

[25] The classic literature on the implied-option skew focuses on index options and the crash risk and associated risk premium to explain the expensive puts (Rubinstein, 1994; Bates, 2008). The importance of a jump in volatility to fit the skew empirically has also been documented for index options (Duffie et al., 2000; Pan, 2002). On individual options, out-of-the-money calls also tend to be expensive—that is, one tends to observe a smile in post-1987 crash data (Bollen and Whaley, 2004).

reported in Collin-Dufresne and Fos (2015) that they discuss in footnote 10 according to which activists trade much more aggressively when total volume is high, in particular immediately before the filing date.

To summarize the above discussion, our model can generate many of the empirically observed stylized facts about stock-price volatility and implied-option volatilities. We note that, in particular: (i) a positive announcement jump on the event date (as the insider purchases shares in an undervalued firm and not all information is incorporated prior to the announcement), (ii) a sharp drop in realized volatility on the announcement date (as private information is revealed), (iii) a decrease in the implied volatility of options (which reflects the expected future drop in volatility), and (iv) an increase in put and call skew and the time slope prior to the event (as a result of the expected jump in volatility and the spot price).

Even though the informed investor trades only on the stock market, her information about the future announcement jump in return and volatility is incorporated in option prices through information conveyed by the stock-market order flow. Further, as the informed investor tends to trade more aggressively when uninformed stock-order flow is high, both the informed and total stock-order flows tend to drive stock-price volatility as well as option-implied volatilities. We next investigate this result empirically.

VI. Informed Order Flow and Option-implied Volatilities

We investigate whether stock-order flow and, in particular, informed stock purchases by Schedule 13D filers, drives price discovery in the option market, as suggested by the previously developed model.

A. Unconditional results

To test this proposed relationship between stock-order flow and price discovery, we focus in this section on the 522 Schedule 13D filings where activists do not report any derivatives trading; that is, we drop the 66 events where activists report trading in derivatives.[26] We estimate the following regression:

$$y_{it} = \gamma_1 itrade_{it} + X_t' \gamma_2 + \eta_i + \epsilon_{it}, \tag{19}$$

where y_{it} is an option market outcome variable (we focus on implied volatility, skew, the time slope, option volume, and option bid-ask spreads) for company i on day t, $itrade$ indicates days on which Schedule 13D filers trade on the stock market, X is a vector of control variables (four Fama-French factors and VIX), and η_i are event fixed effects. The results are reported in table IV.

If Schedule 13D filers' informed stock-order flow indeed carries information about the future announcement return and subsequent volatility drop, we would then expect statistically significant γ_1 coefficients, indicating that option markets are significantly affected by the informed investors' stock trades.

[Insert table IV here]

First, we compare implied volatility measures on days when Schedule 13D filers trade stocks ($itrade$ equals one) and on days when Schedule 13D filers do not trade stocks ($itrade$ equals zero). The results are reported in panels A and B of table IV and suggest that changes in outcome variables are larger on days when Schedule 13D filers trade stocks than on days when Schedule 13D filers do not trade stocks. Specifically, put- and call-implied volatility skew measures increase, the time slope increases, and

[26] See Appendix D for the analysis of events that involve activists' use of derivatives.

put- and call-implied volatilities decrease when Schedule 13D filers trade stocks. Thus, more information flows into *option* prices on days when Schedule 13D filers trade on the stock market.

Next, we consider the relation between Schedule 13D filers' trades and option-market bid-ask spreads. The results are reported in panel C of table IV. We find that option bid-ask spreads are wider when Schedule 13D filers trade in the underlying shares. The results are robust across distinct types of options. The positive relation between option market bid-ask spreads and trades by Schedule 13D filers on the stock market suggests that option market makers price the increase in adverse selection risk on days when Schedule 13D filers trade stocks.

We note that the model discussed in the previous section cannot explain an increase in bid-ask spreads linked to adverse selection risk, because it assumes that it is common knowledge that informed investors trade only stocks. To the extent that market makers perceive that a higher likelihood of informed stock-order flow also comes with a higher chance of informed trading in options, however, it is natural to expect that they would raise bid-ask spreads on options.[27]

To further understand how the information flows into option prices, we study trading activity in the option market. Specifically, we look at put and call volume and option order-imbalance measures. The results are reported in panels D and E of table IV. We find that put volume increases significantly on days when Schedule 13D filers trade on the stock market. Put volume increases for both in-the-money and out-of-the-money put options. On the other hand, call volume decreases (not statistically significantly) so that total option volume is not significantly different from zero. The results reported in panel E show no significant change in the measures of order imbalance on days when

[27]This larger bid-ask spread might then also prevent informed investors from trading in options (Easley et al., 1998). Solving a theoretical model where the informed investor can trade dynamically both the option and the stock is beyond the scope of this paper (see Back, 1993).

Schedule 13D filers trade stocks. If anything, we see slightly more put buying, which could be responsible for higher put volume.[28]

Overall, the results show that changes in implied volatilities happen largely on days when Schedule 13D filers trade on the underlying equity market even though they do not trade any derivatives.[29]

B. Conditional analyses

Our theory predicts that informed stock-order flow conveys information to option market makers about the future likelihood of the announcement, the magnitude of the under-valuation of the stock, and the jumps in return and volatility observed on the announcement date. To investigate these predictions we focus on a conditional analysis, where we split the sample based on the cumulative return from 30 days prior to 1 day after the announcement, based on the magnitude of the drop in volatility at the announcement. For each sub-sample, we report estimates of γ_1 in regression (19). We report the results in table V.

[Insert table V here]

In panel A we report the result of the split 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. The evidence shows that changes in implied volatility, implied volatility skew, the implied volatility time slope,

[28]Order imbalance ranges between -1 and +1. Our data identify who (the market maker or the non-market maker) takes each side of option transaction and are aggregated at the option contract by day level. Muravyev (2015) describes the data and order imbalance measures in detail.

[29]In table A8 in the Internet Appendix we investigate whether the relation between informed order flow and implied volatility measures is explained by the so-called 'leverage effect.' Specifically, we augment regression (19) with current and lagged stock returns, the current and lagged absolute value of stock returns, and the lagged change in implied volatility. The findings indicate that the coefficient on *itrade* remains almost unchanged when these control variables are added to the regression. Thus, the leverage effect is not likely to drive the results.

and stock trading volume on days when Schedule 13D filers trade stocks are larger in the high buy-and-hold return sub-sample than in the low buy-and-hold return sub-sample. For instance, the coefficient on *itrade* for the change in implied volatility is negative and significant in the high buy-and-hold return sub-sample and economically small and statistically insignificant in the low buy-and-hold return sub-sample. When we consider the option bid-ask spread, we find that, in both the high and low buy-and-hold return sub-samples the coefficient on *itrade* for the change in the option bid-ask is positive and economically significant. However, whereas the point estimate is slightly larger in the high than in the low buy-and-hold return sub-sample (0.40% versus 0.27%), the difference is not statistically significant.

In panel B we report the results of the split based on the difference between realized volatility during (t+2,t+6) and during the remaining sample period. The evidence shows that changes in implied volatility, implied volatility skew, the implied volatility time slope, the option bid-ask spread, and stock trading volume on days when Schedule 13D filers trade stocks are larger in the large volatility drop sub-sample than in the small volatility drop sub-sample. For instance, the coefficient on *itrade* for the change in implied volatility skew is positive and significant in the large volatility-drop sub-sample and economically small and statistically insignificant in the small volatility-drop sub-sample. When we consider option volume, we find that the coefficient on *itrade* is negative but insignificant in the large volatility-drop sub-sample and positive and marginally significant in the small volatility-drop sub-sample.

If price discovery in option markets reflects stock market price and order-flow dynamics, we would expect option prices to better reflect private information that flows into stock prices as the level of integration between two markets increases. To test this empirically, we use the negative of the average absolute difference between implied volatility for call and put options during (t-90,t-60) prior to the filing date as a proxy for integration between the stock and option markets. The results are reported in panel C of table V.

We find that the coefficient on *itrade* in the implied volatility, implied volatility skew, the implied volatility time slope, and option bid-ask spread regressions is significantly larger when the level of integration is high. For instance, when we consider implied volatility regression, the coefficient is -0.0419 when the level of integration is high versus -0.0183 when the level of integration is low. The difference between the two coefficients is highly statistically significant. Thus, information flows into option prices on days on which Schedule 13D filers trade on the stock market are stronger when the level of integration between the two markets is high.[30]

If option prices reflect trading activity on the stock market, expanding the list of control variables to include measures of price and volume activity on the stock market should reduce the coefficient on *itrade*. To investigate this possibility, we estimate equation (19) while expanding the list of control variables to include measures of price and volume activity on the stock market. We report the results in table VI.

[Insert table VI here]

In column (1) we report estimates derived from the basic specification, which controls for four Fama-French factors and VIX. When we augment the specification with the stock market bid-ask spread, stock volume, and realized volatility (column (4)), the coefficient on *itrade* significantly decreases in the implied-volatility regression (panel A), the implied-volatility skew regression (panel B), and the implied-volatility time-slope regression (panel C). For instance, the coefficient on *itrade* in the implied-volatility regression decreases from 0.0341 to 0.0213, suggesting that these stock market characteristics explain about one-half of the coefficient. The same observables, however,

[30] In table A9 in the Appendix we report the results of considering several alternative proxies for integration between the stock and option markets.

do not seem to explain a significant part of the *itrade* coefficient in the option bid-ask spread regression (panel D). These results support our conjecture that observable stock characteristics lead market participants to adjust option prices to reflect information on implied-volatility measures on days when Schedule 13D filers trade on the underlying equity market.

We conclude the conditional analysis by investigating whether option market outcome variables change not only on days when Schedule 13D filers trade stocks, but also on surrounding days. If option market makers observed trades by Schedule 13D filers, option market outcome variables would differ from their normal levels only on days when Schedule 13D filers trade stocks. In contrast, if option market makers use a variety of observable characteristics (that are not directly observable to the econometrician) that provide them with an imperfect signal of the activists' trading activity, then option market outcome variables would be expected to differ from their normal levels also on days surrounding Schedule 13D filers' trades. To test this hypothesis, we estimates the following regression:

$$y_{it} = \sum_{\tau=-2}^{\tau=2} \gamma_\tau itrade_{it-\tau} + \eta_i + X_t'\beta + \epsilon_{it}, \tag{20}$$

where y_{it} is an outcome variable for company i on day t minus the outcome variable for the matched stock, $itrade_{it-\tau}$ indicates days before and after days on which Schedule 13D filers trade on the stock market, X is a vector of control variables, and η_i are event fixed effects. The results are reported in table VII. In columns (1), (3), (5), and (7) we report estimates derived from regression (19) and in columns (2), (4), (6), and (8) we report estimates derived from regression (20).

[Insert table VII here]

We find that implied volatility, implied-volatility skew, and the implied-volatility time slope experience significant changes in the few days that surround days when

Schedule 13D filers trade the underlying stock. For instance, implied volatility is lower not only on the day when Schedule 13D filers trade the stock but also in the two days prior. Similarly, implied-volatility skew and the implied-volatility time slope are higher in the two days prior as well as the day after Schedule 13D filers trade stocks. Only the option bid-ask spread and put volume seem to be statistically significantly different when $itrade = 1$. These results are consistent with the use by option market makers of variables observable to them to infer volatility information.

Overall, the results reported in this section support the mechanism described in Section V and suggest a strong link between the magnitude of stock-price and volatility changes around the filing date and the flow of information into option prices on days when Schedule 13D filers trade stocks. Further supporting this mechanism, we find that the flow of information is stronger when stock and option markets are more fully integrated. In addition, the results support our conjecture that observable stock characteristics lead market participants to adjust option prices to reflect information on implied-volatility measures on days when Schedule 13D filers trade on the underlying equity market. The key finding that links these results to the model is that information flows into option prices even when Schedule 13D filers do not trade any derivatives.

VII. Conclusion

In this paper we use Schedule 13D data on trades by activist investors, who on average have substantial private information, to study how directional and volatility information flows into stock and option prices. We find that Schedule 13D filing dates reveal information about both the direction and volatility of stock returns. We find that both types of information are reflected in stock and option prices prior to Schedule 13D filing days.

We find that this class of informed investors rarely use derivatives. They rarely trade in derivatives (2.2% of Schedule 13D filings), but they do so more often (10% of

Schedule 13D filings) when listed option markets are available. Schedule 13D filers use derivatives to leverage up their positions in stocks. Interestingly, even when informed investors do not trade in derivatives, option markets seem to respond to their trades on the stock market. On days when they trade in stocks, implied volatilities decrease, implied-volatility skew increases, and the implied-volatility time slope increases.

We develop a theoretical model of informed trading with rational market-making in options when it is common knowledge that informed investors trade only in the underlying stock. The model is consistent with the increase in stock prices and the drop in realized volatility on announcement dates. Importantly, the model explains the behavior of option-implied volatility, implied-volatility skew, and the implied-volatility time slope prior to announcement dates.

References

Admati, A., Pfleiderer, P., 1988. A theory of intraday patterns: Volume and price variability. The Review of Financial Studies 1 (1), 3–40.

Ahern, K. R., 2017. Information networks: Evidence from illegal insider trading tips. Journal of Financial Economics 125 (1), 26–47.

Amihud, Y., January 2002. Illiquidity and stock returns: Cross-section and time-series effects. Journal of Financial Markets 5 (1), 31–56.

Appel, I., Fos, V., 2019. Active short selling by hedge funds, working paper.

Aragon, G., Martin, S., 2012. A unique view of hedge fund derivatives usage: Safeguard or speculation? Journal of Financial Economics 105 (2), 436–456.

Augustin, P., Brenner, M., Subrahmanyam, M., 2014. Informed options trading prior to m&a announcements: Insider trading?, working paper.

Back, K., 1993. Asymmetric information and options. Review of Financial Studies 6 (3), 435–472.

Back, K., Baruch, S., 2004. Information in securities markets: Kyle meets glosten and milgrom. Econometrica 72 (2), 433–465.

Back, K., Collin-Dufresne, P., Fos, V., Li, T., Ljungqvist, A., 2018. Activism, strategic trading, and liquidity. Econometrica 86 (4), 1431–1463.

Back, K., Pedersen, H., 1998. Long-lived information and intraday patterns. Journal of Financial Markets 1, 385–402.

Bates, D., 2008. The market for crash risk. Journal of Economic Dynamics & Control 32, 2291–2321.

Biais, B., Hillion, P., 1994. Insider and liquidity trading in stock and options markets. Review of Financial Studies 7 (4), 743–780.

Black, F., 1975. Fact and fantasy in the use of options. Financial Analysts Journal 31 (4), 36–41+61–72.

Bollen, N., Whaley, R., 2004. Does net buying pressure affect the shape of implied volatility functions? Journal of Finance 59, 711–753.

Brav, A., Jiang, W., Partnoy, F., Thomas, R., August 2008. Hedge fund activism, corporate governance, and firm performance. The Journal of Finance 63 (4), 1729–1775.

Brav, A., Mathews, R. D., 2011. Empty voting and the efficiency of corporate governance. Journal of Financial Economics 99 (2), 289 – 307.

Burkart, M., Lee, S., 2015. Signalling to dispersed shareholders and corporate control. The Review of Economic Studies, 1–41.

Caldentey, R., Stacchetti, E., 2010. Insider trading with a random deadline. Econometrica 78 (1), 245–283.

Cao, C., Griffin, J., Chen, Z., 2005. Informational content of option volume prior to takeovers. Journal of Business 78 (3), 1073–1109.

Chakravarty, S., Gulen, H., Mayhew, S., 2004. Informed trading in stock and option markets. The Journal of Finance 59 (3), 1235–1258.

Chan, K., Chung, P., Fong, W.-M., 2002. The informational role of stock and option volume. Review of Financial Studies 15 (4), 1049–1075.

Christoffersen, S., Geczy, C., Musto, D., Reed, A., 2007. Vote trading and information aggregation. The Journal of Finance 62 (6), 2897–2929.

Collin-Dufresne, P., Fos, V., 2015. Do prices reveal the presense of informed trading? The Journal of Finance 70 (4), 1555–1582.

Collin-Dufresne, P., Fos, V., 2016a. Insider trading, stochastic liquidity, and equilibrium prices. Econometrica 84 (4), 1441–1475.

Collin-Dufresne, P., Fos, V., 2016b. Insider trading with a random horizon, working paper.

Cremers, M., Weinbaum, D., 2010. Deviations from put-call parity and stock return predictability. Journal of Financial and Quantitative Analysis 45 (2), 335–367.

Duffie, D., Pan, J., Singleton, K., 2000. Transform analysis and asset pricing for affine jump-diffusions. Econometrica 68 (6), 1343–1376.

Dybvig, P., Huang, C.-f., 1988. Nonnegative wealth, absence of arbitrage, and feasible consumption plans. Review of Financial Studies 1 (4), 377–401.

Easley, D., O'Hara, M., Srinivas, P. S., 1998. Option volume and stock prices: Evidence on where informed traders trade. The Journal of Finance 53 (2), 431–465.

Ge, L., Tse-Chun, L., Pearson, N., 2015. Why does the option to stock volume ratio predict stock returns?, Journal of Financial Economics, forthcoming.

Gharghori, P., Maberly, E. D., Nguyen, A., 2016. Informed trading around stock split announcements: Evidence from the option market, journal of Financial and Quantitative Analysis, forthcoming.

Goncalves-Pinto, L., Grundy, B. D., Hameed, A., VAnDer Heijden, T., Zhu, Y., 2017. Why do option prices predict stock returns? the role of price pressure in teh stock market, working paper.

Harrison, J. M., Pliska, S. R., 1981. Martingales and stochastic integrals in the theory of continuous trading. Stochastic processes and their applications 11 (3), 215–260.

Hayunga, D., Lung, P., 2014. Trading in the options market around financial analysts consensus revisions. Journal of Financial and Quantitative Analysis 49 (3), 725–747.

Hu, H. T., Black, B., 2007. Hedge funds, insiders, and the decoupling of economic and voting ownership: Empty voting and hidden (morphable) ownership. Journal of Corporate Finance 13 (23), 343 – 367.

Hu, J., 2014. Does option trading convey stock price information? Journal of Financial Economics 111 (3), 625–645.

Johnson, T., So, E., 2012. The option to stock volume ratio and future returns. Journal of Financial Economics 106 (2), 262–286.

Kacperczyk, M., Pagnotta, E., 2016. Chasing private information, working paper.

Klein, A., Zur, E., January 2009. Entrepreneurial shareholder activism: Hedge funds and other private investors. The Journal of Finance 64 (1), 187–229.

Kyle, A., November 1985. Continuous auctions and insider trading. Econometrica 53 (6), 1315–1335.

Mayhew, S., Mihov, V., 2004. How do exchanges select stocks for option listing? The Journal of Finance 59 (1), 447–471.

Muravyev, D., 2015. Order flow and expected option returns, Journal of Finance, forthcoming.

Muravyev, D., Pearson, N. D., Broussard, J. P., 2013. Is there price discovery in equity options? Journal of Financial Economics 107 (2), 259–283.

Ni, S., Pan, J., Poteshman, A., 2008. Volatility information trading in the option market. The Journal of Finance 63 (3), 1059–1091.

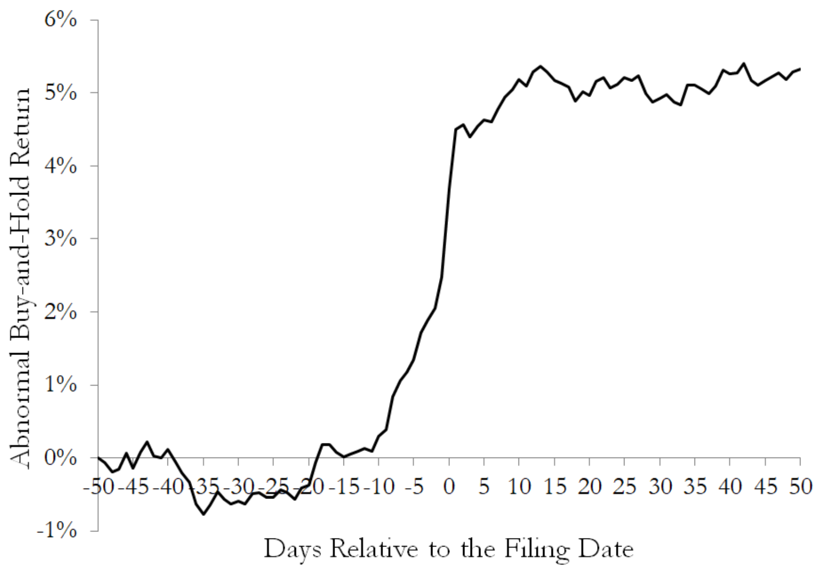
Pan, J., 2002. The jump-risk premia implicit in options: evidence from an integrated time-series study. Journal of Financial Economics 63 (1), 3 – 50.

Pan, J., Poteshman, A., 2006. The information in option volume for future stock prices. Review of Financial Studies 19 (3), 871–908.

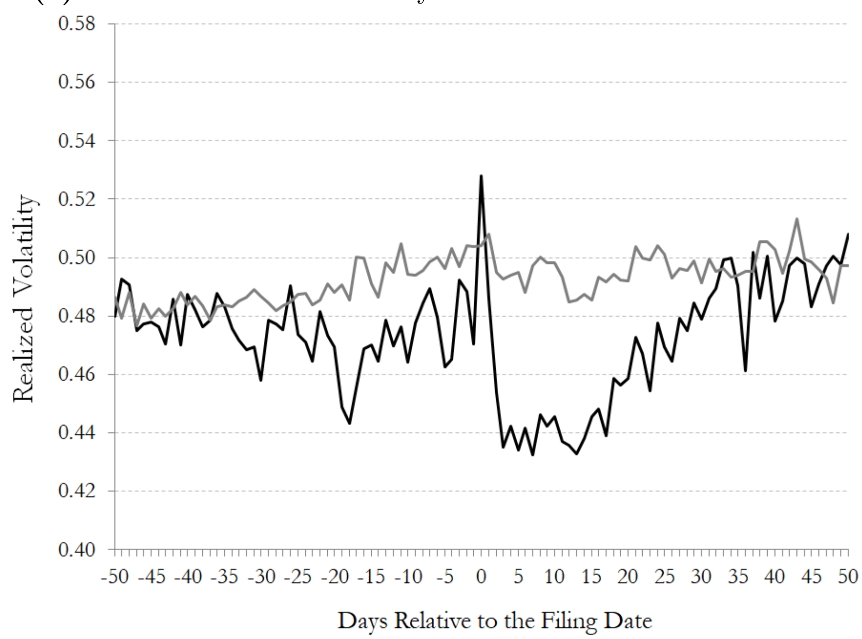
Poon, S.-H., Granger, C., 2003. Forecasting volatility in financial markets: A review. Journal of economic literature 41 (2), 478–539.

Rubinstein, M., 1994. Implied binomial trees. Journal of Finance 49, 771–818.

Vijh, A., 1990. Liquidity of the CBOE equity options. The Journal of Finance 45 (4), 1157–1179.

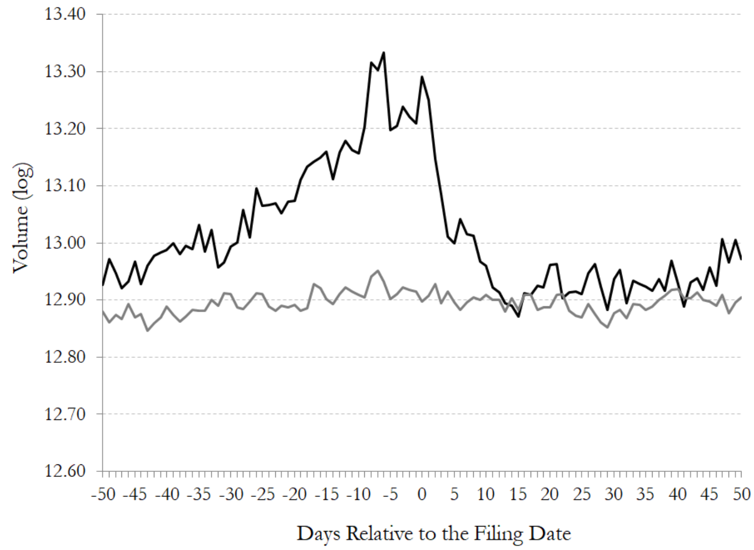


(a) BHAR in excess of the buy-and-hold return of the market.

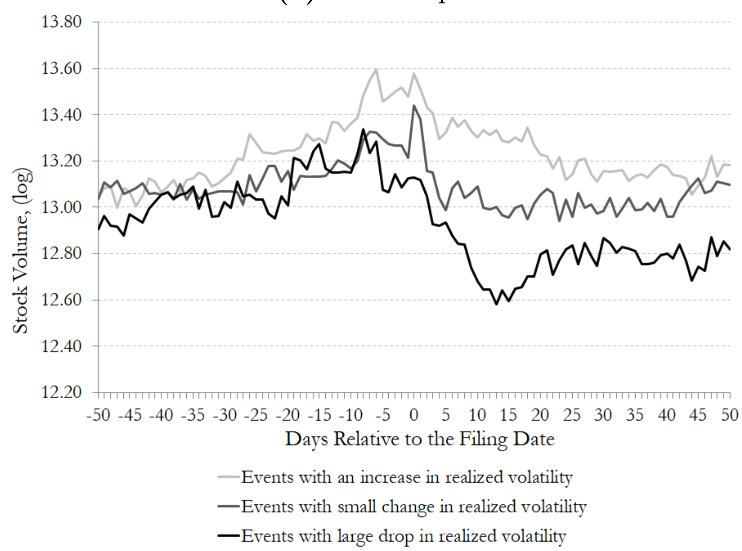


(b) Realized volatility.

Figure 1
Stock Return and Volatility around the filing date. In panel A the solid line plots the average buy-and-hold stock return around the filing date in excess of the buy-and-hold return on the value-weighted market from 50 days prior to the filing date to 50 days afterwards. Panel B plots the realized volatility from 50 days before the filing date to 50 days after. The realized volatility is defined in table A1. The dark (gray) line plots the realized volatility for the sample of event (matched) stocks. Matched stocks are assigned based on the same industry, market cap, and previous year volatility. The filing date is the day on which the Schedule 13D filing is submitted to the SEC. The sample covers 580 Schedule 13D filings in which there are listed options on target firms.

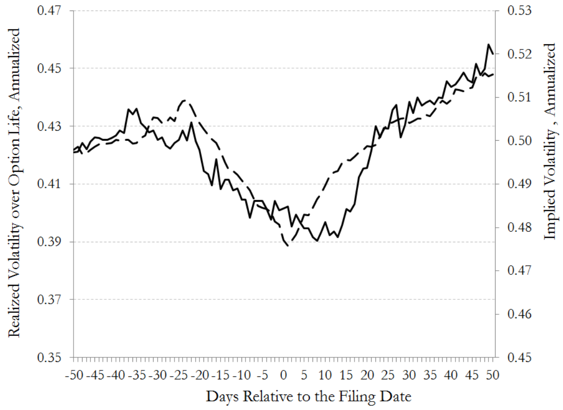


(a) Full sample.

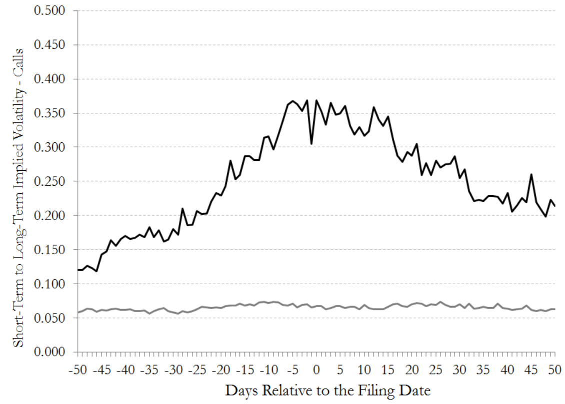


(b) Conditional results.

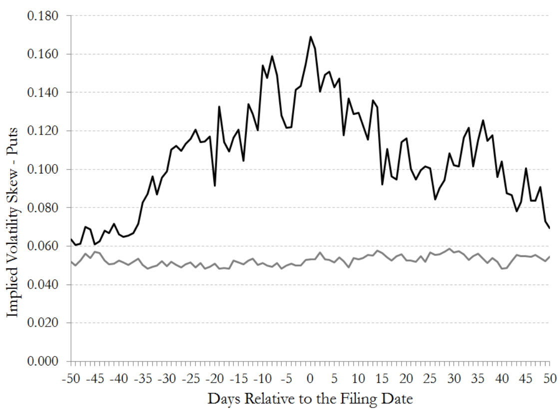
Figure 2
Stock volume around the filing date. This figure plots the average (log) stock volume over from 50 days before the filing date to 50 days after. In panel A, the dark (gray) line plots the average (log) volume for the sample of event (matched) stocks. Matched stocks are assigned based on the same industry, market cap, and previous year volatility. In panel B, the light grey line plots the average (log) volume for events with an increase in realized volatility around the filing date. The dark grey line plots the average (log) volume for events with small changes in realized volatility around the filing date. The dark line plots the average (log) volume for events with large drops in realized volatility around the filing date. All outcome variables are defined in table A1. The sample covers 580 Schedule 13D filings in which there are listed options on target firms.



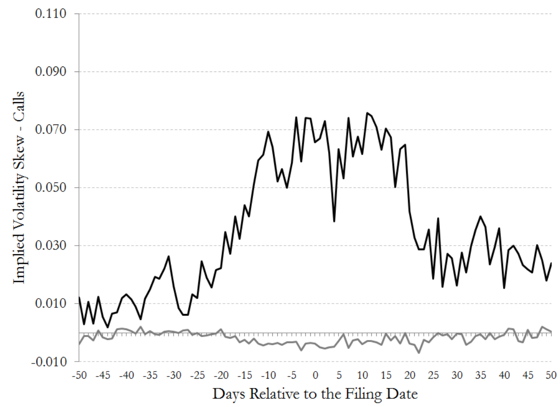
(a) Expected realized and implied volatilities



(b) Time slope

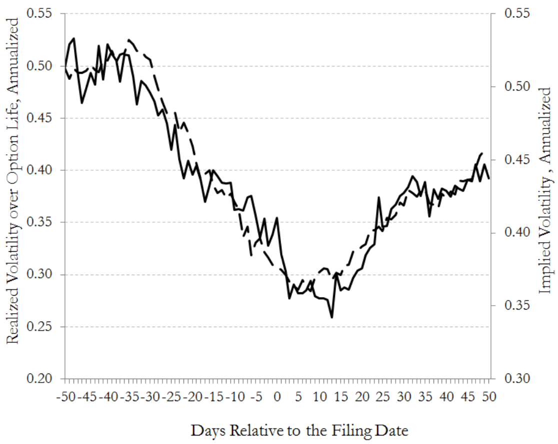


(c) Put options implied volatility skew

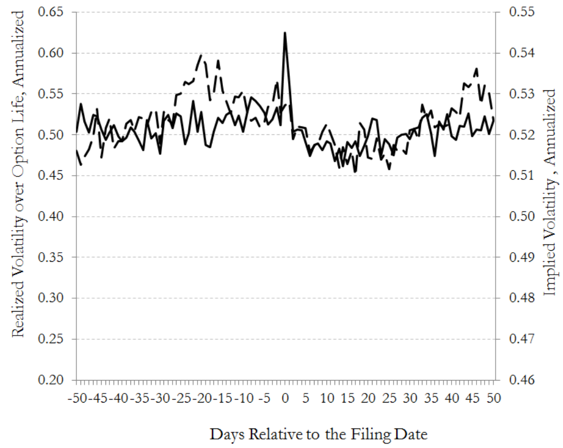


(d) Call options implied volatility skew

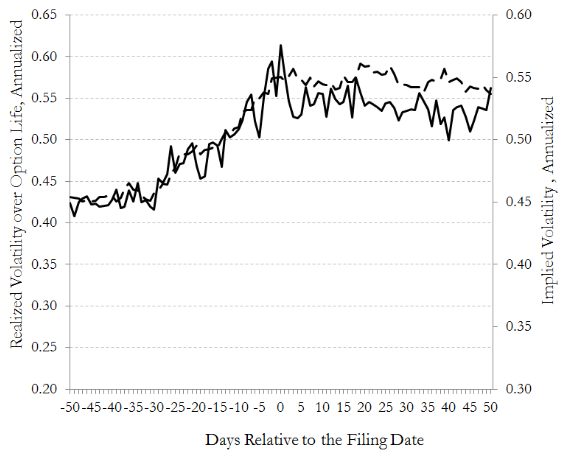
Figure 3
Option implied volatility. In panel A the dark line plots the average realized volatility over the next month from 50 days before the filing date to 50 days after. The dashed line plots implied volatilities of at-the-money options with one month until expiration. In panel B the dark (gray) line plots the time slope for the sample event (matched) stocks from 50 days before the filing date to 50 days after. In panels C and D the dark (gray) line plots put and call skew for the sample event (matched) stocks from 50 days before the filing date to 50 days after. All outcome variables are defined in table A1. The sample covers 580 Schedule 13D filings in which there are listed options on target firms. Matched stocks are assigned based on the same industry, market cap, and previous year volatility.



(a) Events with large drop in realized volatility.

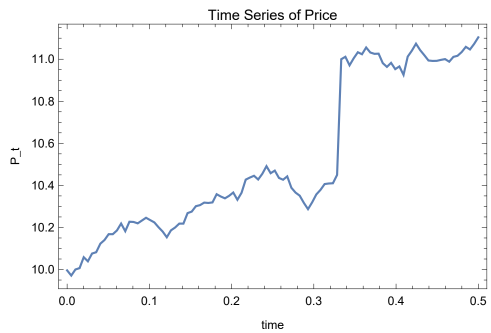


(b) Events with small change in realized volatility.

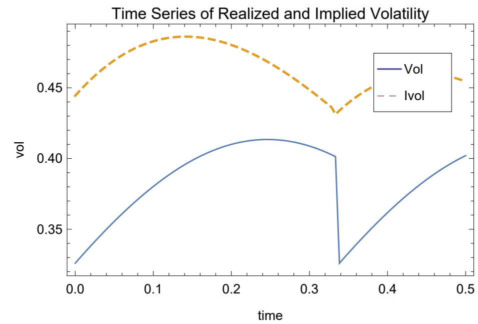


(c) Events with an increase in realized volatility.

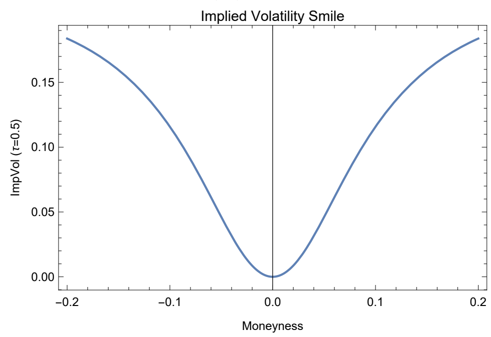
Figure 4
Implied and future realized volatilities: conditional results. The dark lines plot the average realized volatility over the next month from 50 days before the filing date to 50 days after. The dashed lines plot implied volatilities of at-the-money options with one month until expiration. In panel A the sample is restricted to events with large drops in realized volatility around the filing date. In panel B the sample is restricted to events with small changes in realized volatility around the filing date. In panel C the sample is restricted to events with increases in realized volatility around the filing date. All outcome variables are defined in table A1. The sample covers 580 Schedule 13D filings in which there are listed options on target firms.



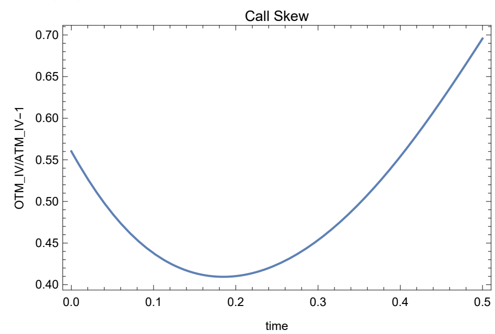
(a) Price path



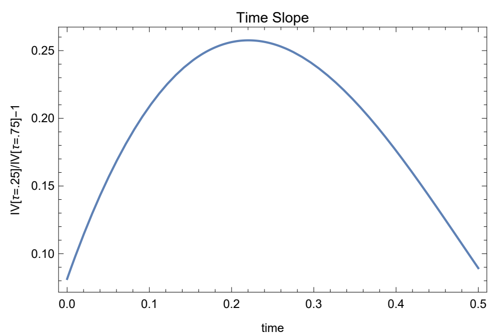
(b) Realized and Implied volatility path



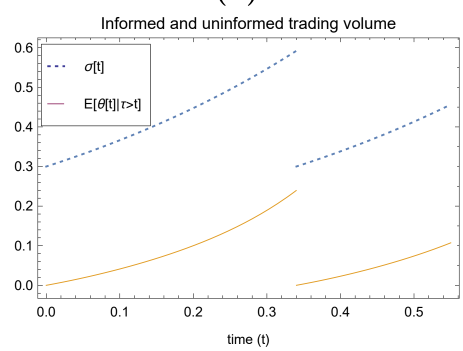
(c) Implied volatility smile.



(d) Call skew



(e) Time slope



(f) Volume

Figure 5

Model implied prices and volatilities. Parameter values used for the simulation are $\forall i = 0, 1, 2$: $\sigma^i = 0.3$, $m^i = 2$, $r_0^i = 0.01$, $r_1^i = 8$, $\Sigma^i = .3^2$, and $v_0 = 10$, $v_1 = v_2 = 1$. The corresponding expected announcement date is $\mathrm{E}[\tau_1] = 0.44$, and for the particular path of noise-trader shock simulated to generate the figures in panels (a) and (b) the actual announcement occurs at $\tau = 0.32$. Panel (a) plots a price path with a positive jump on announcement date $\tau = 0.32$. Panel (b) plots the corresponding path of instantaneous (realized) price volatility and at-the-money implied option volatility. Panel (c) plots the call-option implied volatility smile at date $t = 0.25$, two months prior to the expected announcement date. Panel (d) plots the path over time (and conditional on there being no announcement) of the call skew defined as the ratio of the 15% out-of-the-money call to the at-the-money call implied volatility minus 1. Panel (e) plots the path over time (and conditional on there being no announcement) of the time slope defined as the ratio of the 3-month to the 1-year at-the-money call-option implied volatility minus 1. Panel (f) plots the expected trading rate of the informed trader in his filtration ($\mathrm{E}[\theta_t \,|\, \tau > t, \mathcal{F}_t^Y, v]$) and the noise-trader volatility σ_t for a sample path where $\tau_1 = 0.32$.

Table I

Realized volatility and stock volume around the filing date. In this table we report the results of a comparison of the level of annualized realized volatility and (log) stock volume before and after the filing date. All variables are defined in table A1. The sample covers 580 Schedule 13D filings in which there are listed options on target firms. In column (1) we report the average level of realized volatility and stock volume for 50 days that precede the filing date. In column (2) we report the average level of realized volatility and stock volume for 50 days after the filing date. In column (3) we report the average change in realized volatility and stock volume around the filing date and the *t*-stat of the difference. In columns (4) through (6) we repeat the results of the analysis for the sample of matched stocks. Matched stocks are assigned based on the same industry, market cap, and previous year volatility. In column (7) we report the average difference-in-differences in realized volatility and stock volume and the *t*-stat of these differences. *** indicates statistical significance at the 1% level.

	Event stocks			Matched stocks			
	Before (1)	After (2)	Difference (3)	Before (4)	After (5)	Difference (6)	Diff-in-diff (7)
Realized volatility	0.4075***	0.3687***	-0.0388***	0.4281***	0.4353***	0.0072	-0.0460***
(daily)			[-3.75]			[0.88]	[-3.49]
Realized volatility	0.4700***	0.4328***	-0.0372***	0.4961***	0.5022***	0.0061	-0.0433**
(intra-day)			[-2.70]			[0.51]	[-2.37]
Stock Volume	13.1179***	13.0171***	-0.1008**	12.9643***	12.9699***	0.0056	-0.1064*
(log)			[-2.13]			[0.14]	[-1.71]

Table II

Does volatility information flow into prices? Difference-in-differences estimates. In this table we report the results of analyses of differences in changes in outcome variables between event and matched stocks during the (t-1,t-30) and (t-31,t-60) periods before the filing date. Matched stocks are assigned based on the same industry, market cap, and previous year volatility. All outcome variables are defined in table A1. In column (1) we report the estimated difference-in-differences coefficients. In column (2) we report the corresponding t-statistics. The sample covers 580 Schedule 13D filings in which there are listed options on target firms. The sample covers the 60-day disclosure period only. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	Diff – event (1)	Diff – control (2)	Diff-in-diff (3)	t-stat (4)
Panel A: Option market				
IV Call	-0.0153	0.0064	-0.0217***	-3.10
IV Put	-0.0146	0.0046	-0.0192***	-2.79
Put skew	0.0170	-0.0032	0.0202***	3.99
Call skew	0.0157	-0.0004	0.0161***	4.26
Time slope	0.1050	0.0111	0.0938***	6.91
Panel B: Stock market				
Excess Return	0.0008	-0.0002	0.0010**	2.21
Volume (log)	0.1913	0.0264	0.1649***	7.32

Table III

How do activists use derivatives? The results reported in this table indicate how activists use derivatives. In column (1) we report results for all Schedule 13D filing with information on derivatives (66 events). In column (2) we report results for a sub-sample with available listed options (58 events; see section IV for a description of the "options available" criteria). In column (3) we report results for a sub-sample with over-the-counter derivatives being used by activists (28 events).

Sample type: Sample size:	Full sample 66 events (1)	Listed options 58 events (2)	Over-the-counter 28 events (3)
Types of derivatives			
Long Call	0.848	0.828	0.964
Short Put	0.364	0.396	0.429
Long Call and Short Put	0.242	0.259	0.428
Long Equity Swap	0.106	0.121	0.107
Short Call	0.054	0.054	0.000
Long Put	0.000	0.000	0.000
No Long Exposure	0.015	0.017	0.000
Ownership structure			
Beneficial ownership - derivatives	2.3%	2.1%	4.0%
Beneficial ownership - common stock	6.4%	6.3%	5.4%
Sample type			
Options Available	0.879	1.000	0.714
Over-the-counter	0.424	0.345	1.000

Table IV

The flow of information into prices and informed trading: No derivatives are used. We use this table to compare the results pertaining to the outcome variables on days when Schedule 13D filers trade and on days when Schedule 13D filers do not trade. All outcome variables are defined in table A1. In the table we report estimates of γ_1 from regression (19): $y_{it} = \gamma_1 itrade_{it} + \eta_i + X_t'\gamma_3 + \epsilon_{it}$, where y_{it} is a measure of trading activity for company i on day t minus a measure of trading activity for the matched stock, *itrade* indicates days on which Schedule 13D filers trade on the stock market, X is a vector of control variables (four Fama-French factors and VIX), and η_i are event fixed effects. Matched stocks are assigned based on the same industry, market cap, and previous year volatility. The sample covers 522 Schedule 13D filings in which there are listed options on target firms but Schedule 13D filers do not use any type of derivatives and covers the (t-1,t-60) period before the filing date. Heteroskedasticity-robust standard errors are clustered at the event level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	itrade (1)	t-stat (2)	N (3)
Panel A: Implied volatility			
IV Call	-0.0341***	-4.98	35,699
IV Put	-0.0308***	-4.46	35,699
Panel B: Measures based on implied volatility			
Put skew	0.0275***	4.64	35,699
Call skew	0.0203***	3.90	35,699
Time slope	0.1125***	6.44	35,699
Panel C: Bid-Ask spread			
All options	0.0032***	3.42	29,345
Call options	0.0029***	3.03	27,870
Put options	0.0030***	2.79	27,122
Panel D: Trading activity			
Option-to-stock volume ratio	-1.8677***	-3.40	35,560
Option Volume (log)	-0.0217	-0.25	35,560
Put volume (log)	0.2636***	2.76	35,560
ATM put volume (log)	0.2820**	2.54	30,256
OTM put volume (log)	0.3129***	3.19	35,101
Call volume (log)	-0.1356	-1.43	35,560
ATM put volume (log)	0.0865	0.74	30,256
OTM put volume (log)	-0.1001	-0.96	35,101
Put-to-call volume ratio	0.0239***	2.72	35,560
Panel E: Order Imbalance			
All trades	-0.0120	-0.82	10,338
Open trades	-0.0118	-0.72	10,338
Put options, all trades	0.0239	1.58	10,338
Put options, open trades	0.0260	1.45	10,338
Call options, all trades	0.0132	0.86	10,338
Call options, open trades	0.0098	0.56	10,338
Panel F: Stock market			
Excess Return	0.0019***	4.00	35,800
Bid-ask Spread	-0.0005***	-3.53	34,249
Volatility	0.0004	0.94	35,800
Volume (log)	0.3527***	13.10	35,800

Table V

Cross-section variation tests. This table presents cross-sectional variations in the changes in key outcome variables reported in table IV. Odd columns report estimates of γ_1 from regression (19): $y_{it} = \gamma_1 itrade_{it} + \eta_i + X_t'\gamma_3 + \epsilon_{it}$, where y_{it} is the option bid-ask spread for company i on day t minus the option bid-ask spread for the matched stock, $itrade$ indicates days on which Schedule 13D filers trade on the stock market, X is a vector of control variables, and η_i are event fixed effects. Matched stocks are assigned based on the same industry, market cap, and previous year volatility. In even columns we report the corresponding t-statistics, calculated using heteroskedasticity-robust standard errors clustered at the event level. To obtain the results reported in panel A we split the sample based on CAR, which 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. To obtain the results reported in panel B we split the sample based on volatility drop, which is the difference in realized volatility during (t+2,t+6) and the remaining sample period. To obtain the results reported in panel C we split the sample based on the level of integration between stock and option markets. We use the absolute difference between implied volatility for calls and puts during (t-90,t-60) as a proxy for integration between the stock and option markets. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Dependent variable:	IV, Calls		IV Skew		IV Time Slope		Option bid-ask spread		Stock volume (log)		Option volume (log)	
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Sort on CAR around Schedule 13D filing date												
Large CAR	-0.0608***	-6.18	0.0311***	3.77	0.1650***	6.46	0.0040***	3.29	0.4294***	13.14	-0.0126	-0.13
Small CAR	0.0021	0.30	0.0009	0.13	0.0300**	2.23	0.0027***	2.98	0.3327***	11.13	0.0050	0.05
Difference	-0.0628***	-5.24	0.0302***	2.77	0.1350***	4.68	0.0013	0.89	0.0967**	2.19	-0.0176	-0.13
Panel B: Sort on volatility drop around Schedule 13D filing date												
Large volatility drop	-0.0798***	-8.07	0.0351***	3.54	0.1780***	6.62	0.0058***	3.99	0.4695***	12.87	-0.1450	-1.42
Small volatility drop	0.0186***	3.03	-0.0017	-0.35	0.0232**	2.03	0.0015**	2.04	0.2993***	12.27	0.1439*	1.72
Difference	-0.0985***	-8.46	0.0368***	3.35	0.1548***	5.31	0.0043***	2.63	0.1702***	3.88	-0.2889**	-2.19
Panel C: Sort on the level of integration between stock and option markets												
High integration	-0.0419***	-4.89	0.0302***	3.88	0.1311***	5.46	0.0057***	5.00	0.3794***	11.99	-0.0574	-0.69
Low integration	-0.0183**	-2.01	0.0016	0.20	0.0671***	3.83	0.0007	0.71	0.3855***	12.10	0.0562	0.53
Difference	-0.0237*	-1.89	0.0286***	2.59	0.0640**	2.16	0.0050***	3.38	-0.0061	-0.14	-0.1136	-0.85

Table VI

Do observable characteristics explain changes in outcome variables? We use this table to compare the results for key outcome variables on days when Schedule 13D filers trade and on days when Schedule 13D filers do not trade, while expanding the list of control variables. All variables are defined in table A1. In the table we report estimates of γ_1 from regression (19): $y_{it} = \gamma_1 itrade_{it} + \eta_i + X_t'\gamma_3 + \epsilon_{it}$, where y_{it} is an outcome variable for company i on day t minus the outcome variable for the matched stock, *itrade* indicates days on which Schedule 13D filers trade in stock market, X is a vector of control variables, and η_i are event fixed effects. Matched stocks are assigned based on the same industry, market cap, and previous year volatility. In each panel, we report the difference between the coefficients listed in columns (4) and (1) and the corresponding χ^2-statistics. The sample covers 522 Schedule 13D filings in which there are listed options on target firms but Schedule 13D filers do not use derivatives of any type and also covers the (t-1,t-60) period before the filing date. Heteroskedasticity-robust standard errors are clustered at the event level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)
Panel A: Implied volatility				
itrade	-0.0341***	-0.0304***	-0.0314***	-0.0213***
	[-4.98]	[-4.61]	[-5.05]	[-4.23]
Difference with column (1)				0.0128***
χ^2-stat				18.78
Panel B: Implied volatility skew				
itrade	0.0275***	0.0275***	0.0273***	0.0243***
	[4.64]	[4.61]	[4.77]	[4.49]
Difference with column (1)				-0.0032**
χ^2-stat				4.06
Panel C: Implied volatility time slope				
itrade	0.1125***	0.1065***	0.0881***	0.0785***
	[6.44]	[6.34]	[5.76]	[5.68]
Difference with column (1)				-0.0340***
χ^2-stat				35.67
Panel D: Option bid-ask spread				
itrade	0.0032***	0.0032***	0.0031***	0.0030***
	[3.42]	[3.29]	[3.22]	[3.21]
Difference with column (1)				-0.0002
χ^2-stat				1.19
Controls:				
Event fixed effects	Yes	Yes	Yes	Yes
Four Fama-French factors and VIX	Yes	Yes	Yes	Yes
Stock bid-ask spread	No	Yes	Yes	Yes
Stock volume (log)	No	No	Yes	Yes
Realized volatility	No	No	No	Yes

Table VII

Outcome variables before and after days when Schedule 13D filers trade. We use this table to compare the results for outcome variables on days before and after days when Schedule 13D filers trade. All variables are defined in table A1. In the table we report estimates of γ_τ from regression (20): $y_{it} = \sum_{\tau=-2}^{\tau=2} \gamma_\tau itrade_{it-\tau} + \eta_i + X_t'\beta + \epsilon_{it}$, where y_{it} is an outcome variable for company i on day t minus the outcome variable for the matched stock, $itrade_{it-\tau}$ indicates days before and after days on which Schedule 13D filers trade in stock market, X is a vector of control variables, and η_i are event fixed effects. Matched stocks are assigned based on the same industry, market cap, and previous year volatility. The sample covers 522 Schedule 13D filings in which there are listed options on target firms but Schedule 13D filers do not use derivatives of any type and also covers the (t-1,t-60) period before the filing date. Heteroskedasticity-robust standard errors are clustered at the event level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Dependent variable:	Implied volatility		Implied volatility Skew		Implied volatility Time Slope		Option Bid Ask spread		Option Volume (log)		Put volume (log)		Call volume (log)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
itrade (t+2)		-0.0159***		0.0195***		0.0509***		0.0012*		-0.0969		-0.1688		-0.1242
		[-3.38]		[3.94]		[4.73]		[1.72]		[-0.94]		[-1.36]		[-1.18]
itrade (t+1)		-0.0159***		0.0053		0.0350***		0.0006		-0.0224		0.1361		-0.1093
		[-3.75]		[1.36]		[3.72]		[0.89]		[-0.22]		[1.11]		[-0.97]
itrade	-0.0341***	-0.0372***	0.0275***	0.0315***	0.1125***	0.1277***	0.0032***	0.0036***	-0.0217	-0.0303	0.2636***	0.2599**	-0.1356	-0.1449
	[-4.98]	[-4.80]	[4.64]	[4.75]	[6.44]	[6.57]	[3.42]	[3.41]	[-0.25]	[-0.31]	[2.76]	[2.46]	[-1.43]	[-1.37]
itrade (t-1)		-0.0059*		0.0088**		0.0338***		0.0016**		0.0348		-0.0276		0.1193
		[-1.70]		[2.57]		[5.31]		[2.28]		[0.36]		[-0.25]		[1.16]
itrade (t-2)		0.0026		0.0083**		0.0388***		0.0001		-0.0076		0.0311		0.0040
		[0.72]		[2.24]		[5.40]		[0.12]		[-0.08]		[0.29]		[0.04]
R^2	1.60%	1.90%	0.70%	0.90%	2.70%	3.60%	0.30%	0.40%	0.00%	0.00%	0.10%	0.10%	0.00%	0.00%
N	35,699	35,699	35,699	35,699	35,699	35,699	29,345	29,345	35,560	35,560	35,560	35,560	35,560	35,560

Appendix A. The model

On the last announcement date, the price jumps to $v_0 + v_1 + v_2$ and stays constant as there is no more trading. At $\tau_i < \tau_2$, the price jumps to $\sum_{j=0}^{i} v_j$ and the insider becomes privy to the next announcement value v_{i+1}. Her trades carry only information about this next announcement value. From the structure of the model, it is thus clear that we can solve for the equilibrium by 'backward induction,' as a sequence of one random-announcement model with dynamic trading. This is similar to the Admati and Pfleiderer (1988) model, which is essentially a stringed together sequence of one-period myopic Kyle (1985) models, except our model strings together a sequence of random announcement models with continuous time trading prior to each announcement. The one announcement case has been solved in Collin-Dufresne and Fos (2016a). Their model allows for stochastic arrival intensity and stochastic volatility of noise trading, and thus has a more complicated solution. Since we focus on the case where the intensity and the volatility of noise trading are deterministic between announcements, the solution is somewhat simpler. So we present the derivation for completeness (but the equilibrium can be obtained as a special case of their theorem 1).

A. The case with one random announcement

Let's suppose there is only one random announcement time $\tau > 0$ which has a deterministic intensity $\rho_t > 0$. At τ the liquidation value of the firm v will be announced. v is known only to the insider, but has a prior distribution perceived by the market maker of $v \sim N(v_0, \Sigma_0)$.

The insider accumulates a total number of shares X_t by choosing an admissible trading rate $\theta_t \in \mathcal{A}$ with $dX_t = \theta_t dt$ on $t < \tau$, so as to maximize the expected value of her trading profits:[31]

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

We define the set of admissible trading strategies $\mathcal{A} = \{\theta_t \ s.t. \ \mathrm{E}[(e^{-\int_0^T \rho_s ds} p_T)^2] \leq \infty \ \forall T]\}$.[32] The equilibrium price P_t is set by the competitive risk-neutral market maker so as to break-even on average. Specifically, the zero-profit condition for the market maker implies that

$$P_t = p_t \mathbf{1}_{\{\tau > t\}} + v \mathbf{1}_{\{\tau \leq t\}}, \tag{A.2}$$

that is the price jumps on the announcement date to the value v from the the *pre-announcement* price p_t given by:

$$p_t = \mathrm{E}[v | \mathcal{F}_t^y, \tau > t] \tag{A.3}$$

where we denote by $\mathcal{F}_t^y$ the filtration of the market maker generated on $\tau > t$ by observing the cumulative order flow y_t, which is the sum of the informed order flow and noise trading:

$$dy_t = \theta_t dt + \sigma_t dZ_t \tag{A.4}$$

The cumulative order flow of noise traders is driven by a Brownian motion Z_t with determinstic intensity $\sigma_t < \infty$.

[31] As standard in these continuous time Kyle-type model is actually optimal for the insider to trade in an absolutely continuous time fashion prior to the announcement. see Back (1993).

[32] This technical condition is sufficient to insure that the wealth process of the insider is well-behaved and, in particular, to rule out 'doubling-strategies' as discussed in Dybvig and Huang (1988).

Thus an equilibrium is defined by a pre-anouncement price process p_t and an admissible trading strategy θ_t, that maximizes the profits of the insider in equation (A.1), while satisfying the market-maker break-even condition equation (A.3).

To solve the pre-announcement equilibrium, we first conjecture that the trading strategy of the insider (on $\{\tau > t\}$) is of the form:

$$\theta_t = \beta_t(v - p_t) \tag{A.5}$$

for some deterministic trading speed β_t. Given this conjecture the market maker's filtering problem is a standard conditionally Gaussian problem on the set $\{\tau > t\}$:

$$\begin{aligned} dp_t &= \lambda_t dY_t && \text{(A.6)} \\ \lambda_t &= \frac{\beta_t \Sigma_t}{\sigma_t^2} && \text{(A.7)} \\ d\Sigma_t &= -\lambda_t^2 \sigma_t^2 dt && \text{(A.8)} \end{aligned}$$

where $\Sigma_t = \mathrm{E}[(v - p_t)^2 \,|\, \mathcal{F}_t^y]$ 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., $p_t = \mathrm{E}[v \,|\, \mathcal{F}_t^y, \tau > t] = \mathrm{E}[v \,|\, \mathcal{F}_t^y]$.

Note that given our conjecture on θ_t, price impact λ_t is itself deterministic. Given the price dynamics in (A.6) we turn to solving the insider's optimization problem. First, note that his value function can be rewritten as (on the set $\tau > t$):

$$J(t, p, v) = \max_{\theta_s \in \mathcal{A}} E\left[\int_t^\infty e^{-\int_s^t \rho_u du}(v - p_s)\theta_s ds \mid \mathcal{F}_t^y, v\right] \tag{A.9}$$

The HJB equation is:

$$\max_\theta \left\{ J_t + \frac{1}{2} J_{pp} \lambda_t^2 \sigma_t^2 + J_p \lambda_t \theta - \rho_t J + (v - p_t)\theta \right\} = 0. \tag{A.10}$$

It follows that the first order condition is:

$$J_p \lambda_t + (v - p_t) = 0. \tag{A.11}$$

We thus guess a quadratic form:

$$J(t, p, v) = \frac{(v-p)^2}{2\lambda_t} + f(t) \tag{A.12}$$

Using this guess in the HJB equation we find

$$f' - (v-p)^2 \frac{\lambda_t'}{2\lambda_t^2} + \frac{1}{2}\lambda_t \sigma_t^2 - \rho_t \left(\frac{(v-p)^2}{2\lambda_t} + f(t) \right) = 0 \tag{A.13}$$

Thus the guess is consistent if:

$$0 = f' + \frac{1}{2}\lambda_t \sigma_t^2 - \rho_t f(t) \tag{A.14}$$

$$\frac{\lambda_t'}{\lambda_t} = -\rho_t \tag{A.15}$$

Solving the equation for λ we obtain:

$$\lambda_t = \lambda_0 e^{-\int_0^t \rho_u du} \tag{A.16}$$

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

$$f(t) = \lambda_t \int_t^\infty e^{-2\int_t^s \rho_u du} \frac{1}{2} \sigma_s^2 ds \tag{A.17}$$

$$= \frac{\Sigma_t - \Sigma_\infty}{2\lambda_t} \tag{A.18}$$

Solving for the posterior variance we find:

$$\Sigma_t = \Sigma_0 - \int_0^t \lambda_s^2 \sigma_s^2 ds \tag{A.19}$$

We can then show the following:

Theorem 2. *If we can find a constant* λ_0 *such that* $\lim_{t\to\infty} \Sigma_t = 0$ *where* λ_t, Σ_t *are given in equations (A.16) and (A.19), then there exists an equilibrium where the price process follows:*

$$dP_t = \kappa_t(v - P_t)dt + \lambda_t \sigma_t dZ_t + (v - P_t)d\mathbf{1}_{\{\tau \le t\}} \tag{A.20}$$

$$\kappa_t = \frac{\lambda_t^2 \sigma_t^2}{\Sigma_t} \tag{A.21}$$

In that equilibrium the informed investor trades as in equation (A.5) with $\beta_t = \frac{\lambda_t \sigma_t^2}{\Sigma_t}$*. The expected trading rate of the informed investor in her own filtration is:*

$$\mathrm{E}[\theta_t \,|\, \tau > t, v, F_t^Y] = (v - p_0)\frac{\lambda_0 \sigma_0^2}{\Sigma_0} e^{-\int_0^t \kappa_s ds} \tag{A.22}$$

Proof. Proof in online appendix A.1 □

Now, we consider the model proposed in the main text, where both noise trading volatility and announcement intensity are deterministic increasing functions of time:

$$\sigma_t = \sigma_0 e^{mt} \tag{A.23}$$

$$\rho_t = r_0 + r_1 t \tag{A.24}$$

with $m, r_0, r_1 \ge 0$. Under these conditions we can show that an equilibrium exists under some conditions on the parameters. Indeed, we find

Corollary 1. *If the noise trading volatility and event intensity are given by equations (A.23) and (A.24) above then an equilibrium exists if either (PA):* $\{r_1 > 0\}$ *or (PB):* $\{r_1 = 0 \;\; and \;\; m < r_0\}$*.*

Under (PA) we have:

$$\lambda_0 = \frac{\sqrt{2\Sigma_0(r_0 - m)}}{\sigma_0} \tag{A.25}$$

$$\Sigma_t = \Sigma_0 e^{-2(r_0-m)t} \tag{A.26}$$

$$\lambda_t = \lambda_0 e^{-r_0 t} \tag{A.27}$$

Under (PB) we have:

$$\lambda_0 = \sqrt{\frac{\Sigma_0\sqrt{r_1}e^{-\frac{(m-r_0)^2}{r_1}}}{\sqrt{\pi}\sigma_0^2 N[\frac{m-r_0}{\sqrt{r_1/2}}]}} \tag{A.28}$$

$$\Sigma_t = \Sigma_0 \frac{\mathbf{N}[\frac{m-r_0-r_1 t}{\sqrt{r_1/2}}]}{\mathbf{N}[\frac{m-r_0}{\sqrt{r_1/2}}]} \tag{A.29}$$

$$\lambda_t = \lambda_0 e^{-r_0 t - \frac{r_1}{2}t^2} \tag{A.30}$$

where $\mathbf{N}[\cdot]$ *is the cumulative normal distribution function. In both cases the equilibrium stock price follows a mean-reverting process given by:*

$$dP_t = \kappa_t(v - P_t)dt + \lambda_0\sigma_0 e^{(m-r_0)t - r_1\frac{t^2}{2}} dZ_t + (v - P_t)d\mathbf{1}_{\{\tau \le t\}} \tag{A.31}$$

where the mean-reversion rate is given by:

$$\kappa_t = \frac{\lambda_t^2\sigma_t^2}{\Sigma_t} \tag{A.32}$$

Proof. If the parameter conditions are not satisfied then the solution for Σ_t diverges when $t \to \infty$. Thus there does not exist a value λ_0 satisfying the requirements of theorem 2. Instead, if either condition (PA) or (PB) are satisfied we can find the constant λ_0 such that $\lim_{t\to\infty} \Sigma_t = 0$ and the corresponding solution for the posterior variance and the price impact functions are as given in the corollary. □

A special case of this corollary is the case when $m = r_1 = 0$ where volatility and intensity are constant for all times and we have $\sigma_t = \sigma_0$ and $\rho_t = \rho_0 \ \forall t$. In that case, the equilibrium price P_t follows a standard Ornstein-Uhlenbeck process with a constant rate of mean-reversion $\kappa_t = 2\rho_0 \ \forall t$. This interesting special case is further discussed in the online appendix A.2.

The extension to n announcement dates is straightforward given the recursive structure of the model as discussed in the introduction to the appendix.

B. Computing option prices

Suppose the price has dynamics given in Theorem 1. Then, in the filtration of the market maker, we can rewrite it as:

$$dP_t = \sigma_P(t, N_{t^-}, \tau_{N_{t^-}}) d\hat{Z}_t + J(t, N_{t^-}, \tau_{N_{t^-}}) dN_t \tag{A.33}$$

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.[33] That is conditionning on the number of jumps that occur between t and T, the price change $P_T - P_t$ is normally distributed with deterministic mean and variance, which are readily calculated. We use this feature in online appendix A.3 to derive the closed-form solutions for option prices in our model.

[33]Note that the jump compensator is zero because the jump has zero mean.

Internet Appendix for
"Informed Trading in the Stock Market and Option Price Discovery"

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Internet Appendix: Additional results

A. Model Proofs

A.1. Proof of Theorem 2

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 (A.3). 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 (A.9) on $\tau > t$.

To that effect, consider an arbitrary admissible trading strategy $\theta_t \in \mathcal{A}$ and apply Itô's lemma to the candidate quadratic value function (A.12):

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

Taking expectation we find that for any admissible trading strategies:[34]

$$J(0, p_0, v) = \mathrm{E}\left[e^{-\int_0^T \rho_s ds} J(T, p_t, v) + \int_0^T e^{-\int_0^t \rho_s ds} (v - p_t) \theta_t dt \right] \tag{.1}$$

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

$$J(0, p_0, v) \geq \mathrm{E}\left[\int_0^T e^{-\int_0^t \rho_s ds} (v - p_t) \theta_t dt \right] \tag{.2}$$

[34] The fact that the strategy is admissible guarantees that the stochastic integral is a martingale, since $\mathrm{E}[\int_0^T e^{-\int_0^t 2\rho_s ds} (v - p_t)^2 \sigma_t^2 dt] < \infty$ for any $\theta_t \in \mathcal{A}$.

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

$$J(0, p_0, v) \geq \mathrm{E}\left[\int_0^{\infty} e^{-\int_0^t \rho_s ds}(v - p_t)\theta_t dt\right] \tag{.3}$$

Further, if we can find an admissible trading strategy such that $\lim_{T\to\infty} \mathrm{E}\left[e^{-\int_0^T \rho_s ds} J(T, p_T, v)\right] = 0$ then we obtain an equality in equation (.3) which proves the optimality of the strategy. Now, note that

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

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

A.2. Constant intensity and noise trading volatility

Here we explicitly compute the equilibrium when σ, ρ are both constant in theorem 2 (which corresponds to $m = r_1 = 0$ in corollary 1).

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

$$\Sigma(t) = \frac{\lambda_0^2 \sigma^2}{2\rho} e^{-2\rho t} \tag{.4}$$

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:

$$\lambda_0 = \frac{\sqrt{2\rho\Sigma_0}}{\sigma} \tag{.5}$$

and the corresponding posterior variance is:

$$\Sigma(t) = \Sigma_0 e^{-2\rho t} \tag{.6}$$

Further, we can compute the equilibrium trading strategy:

$$\theta_t = \frac{2\rho e^{\rho t}}{\lambda_0}(v - p_t) \tag{.7}$$

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

$$dP_t = 2\rho(v - P_t)dt + \sqrt{2\rho\Sigma_0}e^{-\rho t}dZ_t + (v - P_t)d\mathbf{1}_{\{\tau \leq t\}} \tag{.8}$$

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:

$$\mathrm{E}_t[p_T - v|v, \tau > T] = e^{-2\rho(T-t)}(p_t - v) \tag{.9}$$

$$V_t[p_T - v|v, \tau > T] = e^{-2\rho T}(1 - e^{-2\rho(T-t)})\Sigma_0 \tag{.10}$$

And we see that p_t converges in L^2 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.3. Closed-form Option prices

The market maker sets call option prices prior to the first announcement (i.e., on $t < \tau_1$) such that:

$$\begin{aligned} C(P_t, K, t, T) &= \mathrm{E}[|P_T - K|^+ \,|\, \mathcal{F}_t^Y, \tau_1 > t] \\ &= S^0_{t,0,T}\mathrm{E}_t[|P_T - K|^+|\tau_1 > T] + \int_t^T \delta S^0_{t,0,s}\Big\{ S^1_{s,s,T}\mathrm{E}_t[|P_T - K|^+|\tau_1 = s, \tau_2 > T] \\ &\quad + \int_s^T \delta S^1_{s,s,u}\mathrm{E}_t[|P_T - K|^+|\tau_1 = s, \tau_2 = u]\Big\} \end{aligned}$$

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 $\tau \leq t$:

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

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 $\delta_u S^j_{t,u,\tau} = S^j_{t,u,\tau}\rho(u, j, \tau)du$ 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.

$$\begin{aligned}\mathrm{E}[|P_T - K|^+ \,|\, \mathcal{F}_t^Y, \tau_1 > t] &= \mathrm{E}[|P_t + \int_t^T \sigma_P(s,0,0) d\hat{Z}_s - K|^+ \,|\, \mathcal{F}_t^Y, \tau_1 > t] \\ &= NC(P_t - K, \int_t^T \sigma_P(s,0,0)^2 ds)\end{aligned}$$

where we define the function:

$$\begin{aligned}NC(k,\Sigma) &= \mathrm{E}[|\epsilon\sqrt{\Sigma} + k|^+] \\ &= \int_{-k/\sqrt{\Sigma}}^{\infty} (x\sqrt{\Sigma} + k)\mathbf{n}(x)dx \\ &= k\mathbf{N}(k/\sqrt{\Sigma}) + \sqrt{\Sigma}\mathbf{n}(k/\sqrt{\Sigma})\end{aligned}$$

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:

$$\begin{aligned}\mathrm{E}_t[|P_T - K|^+ | \tau_1 = s, \tau_2 > T] = &\mathrm{E}_t[|P_t + \int_t^s \sigma_P(u,0,0) d\hat{Z}_u \\ &+ \int_s^T \sigma_P(u,1,s) d\hat{Z}_u + J(s,0,0) - K|^+ | \tau_1 = s, \tau_2 > T] \\ &= NC(P_t - K, \int_s^T \sigma_P(u,1,s)^2 du + \Sigma(t,0,0))\end{aligned}$$

We note a useful relation which we use to simplify slightly the solution for any $\tau_i \leq t < s \leq \tau_{i+1}$ we have:

$$\Sigma(t,i,\tau_i) = \int_t^s \sigma_P(u,i,\tau_i)^2 du + \Sigma(s,i,\tau_i)$$

which can be interpreted as the total uncertainty remaining at time t about the next announcement τ_{i+1} will be disclosed to the market through diffusion risk and the variance of the jump at the time of the next announcement s.

$$\begin{aligned}\mathrm{E}_t[|P_T - K|^+|\tau_1 = s, \tau_2 = u] =& \mathrm{E}_t[|P_t + \int_t^s \sigma_P(v,0,0)d\hat{Z}_v + \int_s^u \sigma_P(v,1,s)d\hat{Z}_v \\ &+ J(s,0,0) + J(u,1,s) - K|^+|\tau_1 = s, \tau_2 = u] \\ =& NC(P_t - K, \Sigma(t,0,0) + \Sigma_0^2)\end{aligned}$$

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 $\tau_1 < t < \tau_2$:

$$\begin{aligned}C(P_t, K, t, T) &= \mathrm{E}[|P_T - K|^+ \,|\, \mathcal{F}_t^Y, \tau_2 > t > \tau_1] \\ &= S^1_{t,\tau_1,T}\mathrm{E}_t[|P_T - K|^+|\tau_2 > T] + \int_t^T \delta S^1_{t,\tau_1,s}\mathrm{E}_t[|P_T - K|^+|\tau_2 = s] \\ &= S^1_{t,\tau_1,T} NC(P_t - K, \int_t^T \sigma_P(s,1,\tau_1)^2 ds) + \int_t^T \delta S^1_{t,s,\tau_1} NC(P_t - K, \Sigma(t,1,\tau_1))\end{aligned}$$

B. How Do Activists Use Derivatives?

Schedule 13D filers disclosed the usage of derivatives in 66 cases. Schedule 13D filers could use derivatives to either increase their exposure to the underlying, to hedge their exposure to the underlying, or to benefit from volatility information. Indeed, whereas informed traders can potentially trade on directional information in either stock or option markets, they can only trade on volatility information in non-linear securities such as options. Table III characterizes the usage of derivatives in the full sample (column (1)), in the sample with listed options (column (2)), and in the sample of events in which activists indicated the usage of OTC derivatives (column (3)).

[Insert table III here]

Full-sample results reveal that activists seek a 'long' stock price exposure in most of events. Specifically, activists hold long call (short put) positions in 84.8% (36.4%) of events. The activists have both long call and short put positions in 24.2% of events. Further, the activists have long equity swap positions in 10.6% of events. Either short call positions or long put positions are rare. In less than 2% 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. This result is not consistent with the notion that Schedule 13D filers use derivatives to decouple economic and voting exposure to their targets (Hu and Black, 2007).

When we consider what fraction of activists' beneficial ownership is in derivatives, we find that activists who use derivatives hold on average 6.4% of outstanding common stock in direct stock ownership. In addition, these activists hold 2.3% of outstanding common stock through derivatives positions. Thus, activists who decide to use derivatives achieve more than 25% of the economic exposure through derivatives. We also find that when activists use derivatives, 87.9% of targets have listed stock options and in 42.4% of events activists use over-the-counter derivatives, suggesting that exchange-listed options are not necessary for the activists to achieve exposure through 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, activists hold 7.5% of outstanding shares when no information on derivatives is disclosed (see Collin-Dufresne and Fos, 2015), which is lower than 8.7% reported in the sample of events with information on derivatives (6.4% in direct stock ownership plus 2.3% 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 little difference in 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 2.3% in the full sample to 4.0% 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.

Overall, the evidence suggests that activist rarely use derivatives, in 66 out of 2,905 events. When the do so, they seek long stock price exposure. In less than 2% of 66 events activists had no long exposure through positions in derivatives.

C. When do activists use derivatives?

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 A5. Consistent with the previous result, the evidence in columns (1) to (4) shows that activists are more likely to use derivatives when targets have exchange-traded options: when activists (do not) use derivatives, 84% (21%) of targets (do not) have exchange-traded options.

[Insert table A5 here]

Activists are also more likely to use derivatives when the targets' market capitalization is larger (on average it is three 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.[35] If a notification 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."[36]

Derivative contracts can mitigate the cost of this filing. 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

[35] A 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 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 the activist's purchase of a 5% toehold triggers HSR filing requirement, the activist is required to notify the company about the intended transaction.

[36] Allergan, 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.

the HSR filing until after the Schedule 13D filing is made. This way the notification is sent to all relevant parties after the activist's 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 A5 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, 66% (18%) of targets have a 5% toehold that meets (does not meet) the "Size-of-Transaction Test" specified by the HSR Act. The 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 (5) to (8) of table A5. Consistent 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, four 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 11.75 (9.44). This difference corresponds to 25% increase in the number of analysts covering the target. Similarly, the average market cap is $1,073m ($690m) when activists do (do not) use derivatives.

We next consider option-market variables. Panel B in table A5 reports the results. We find that activists are more likely to use derivatives when option markets are more liquid (bid-ask spreads are narrower). Moreover, we find that a higher put-to-call volume ratio is also positively associated with the usage of derivatives.

To conclude the analysis of firm characteristics that are associated with the usage of derivatives and, in particular to account for the fact that many significant variables uncovered above are likely to be correlated, we estimate a multivariate linear probability model to predict 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 A6.

[Insert table A6 here]

We find that the availability of listed options, the HSR indicator, and activist ownership continue to be positively 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. The Role of Informed Trading - Additional results

In this section we investigate the role of informed trading in price discovery, while considering events with information on trades in derivatives. As we discussed in Section I, whereas Schedule 13D filers have to disclose whether they have used derivatives, the precision of the disclosed information is vaguely specified if derivatives are not the subject security. For example, Schedule 13D filers do not have to disclose on what days they traded derivatives. The reader should therefore exercise caution in interpreting the results on changes in outcome variables on days when Schedule 13D filers trade options.

We estimate the following regression:

$$y_{it} = \gamma_1 itrade_{it} + \gamma_2 itrade\_opt_{it} + \gamma_3 itrade_{it} * itrade\_opt_{it} + \eta_i + X_t' \gamma_4 + \epsilon_{it}, \qquad (.11)$$

where y_{it} is a measure of trading activity for company i on day t minus a measure of trading activity for a matched stock, *itrade* indicates days on which Schedule 13D filers trade the stock, *itrade_opt* indicates days on which Schedule 13D filers trade options, X is a vector of control variables (four Fama-French factors and VIX), and η_i are event fixed effects. The interaction term captures days when Schedule 13D filers trade in stock and derivatives markets. While *itrade* is comprehensive in the sense that every stock trade by activists has to be reported and is therefore in our sample, *itrade_opt* is voluntary. That is, since activists are not required to report transactions in derivatives we will know about their trades only when they choose to include their brokerage trade-reports in the filing. The results are reported in table A7.

[Insert table A7 here]

First, we compare implied volatility measures on days when Schedule 13D filers trade stocks and on days when Schedule 13D filers do not trade stocks (*itrade*). The results are reported in panels A and B of table A7 and suggest that changes in outcome variables are larger on days when Schedule 13D filers trade stocks than on days when Schedule 13D filers do not trade stocks. Specifically, put and call implied volatility skew measures increase, time slope increases, and put and call implied volatilities decrease when Schedule 13D filers trade stocks. Thus, more information flows into *option* prices on days when Schedule 13D filers trade in the stock market. When we consider days when Schedule 13D filers trade in the option market (*itrade_opt*), we find no significant changes in implied volatility when Schedule 13D filers trade derivatives, which is consistent with the activists' trades in the option market not carrying incremental volatility information.

Interestingly, both put and call implied volatilities are higher on days when Schedule 13D filers trade stocks and options ($itrade * itrade\_opt$).

Next, we consider the relation between Schedule 13D filers' trades and option market bid-ask spreads. The results are reported in panel C of table A7. We find that option bid-ask spreads are wider when Schedule 13D filers trade in the underlying shares. In contrast, *itrade_opt* indicates that there are no significant changes in option market bid-ask spreads when Schedule 13D filers trade derivatives. The results are robust across different types of options and regression specifications. The positive relation between option market bid-ask spreads and trades by Schedule 13D filers in the stock market suggests that option market makers price the increase in adverse selection risk on days when Schedule 13D filers trade stocks.

To further understand how the information flows into option prices, we study trading activity in the option market. Specifically, we look at put and call volume, and option order imbalance measures. The results are reported in panels D and E of table A7. We find that put volume increases significantly on days when Schedule 13D filers trade in the stock market. But, call volume decreases (not statistically significantly) so that total option volume is not significantly different from zero. On the other hand, both put and call volume are significantly higher on days when Schedule 13D filers trade options.

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, 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.[37] We

[37] Order imbalance ranges 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. Muravyev (2015) describes the data and order imbalance measures in detail.

consider both the total order imbalance and the order imbalance for trades when a new option contract is opened.

Panel E shows that measures of order imbalance are significantly higher only on days when Schedule 13D filers trade both stocks and derivatives ($itrade * itrade\_opt$).

Finally, we describe the relation between Schedule 13D filers' trades in stock market ($itrade$) and stock market activity measures. We compare the market-adjusted returns, bid-ask spread, volatility, and trading volume on days when Schedule 13D filers trade and on days when Schedule 13D filers do not trade during the 60-day disclosure period. 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 0.18% 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. Even though they have significant private information (as evidenced by the abnormal profits they generate) we find that, on days when Schedule 13D traders trade stocks, bid-ask spreads are lower and trading volume is higher. These results are consistent with Collin-Dufresne and Fos (2016a), who predict that informed traders should select to trade when noise trading activity is large and when price impact is smaller. Finally, we find that the realized volatility is (insignificantly) higher on days when Schedule 13D filers trade, which is also consistent with more information being incorporated in prices on those days.

We next consider days when Schedule 13D filers trade derivatives ($itrade\_opt$). We find that the market-adjusted stock returns, volatility, and trading volume are higher on days when Schedule 13D filers trade options. For example, the market-adjusted returns are higher by 0.52% on days when Schedule 13D filers trade derivatives.

E. Leverage effect

In table A8 we investigate whether the relation between informed order flow and implied volatility measures is explained by the so-called 'leverage effect.' Specifically, we augment regression (19) with the current and lagged stock returns, the current and lagged absolute value of stock returns, as well as with the lagged change in implied volatility. The findings indicate that the coefficient of *itrade* remains almost unchanged when these control variables are added to the regression. For instance, the coefficient changes from -0.0341 to -0.0334 in the implied volatility regression. Thus, the leverage effect is not likely to drive the results.

[Insert table A8 here]

Internet Appendix: Figures and Tables

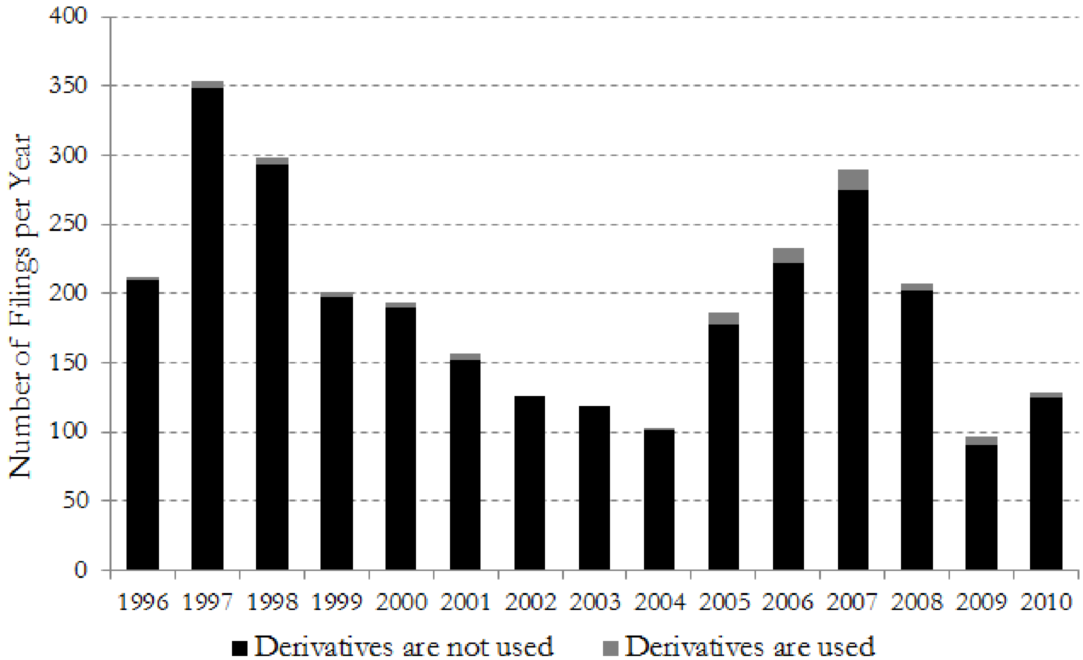
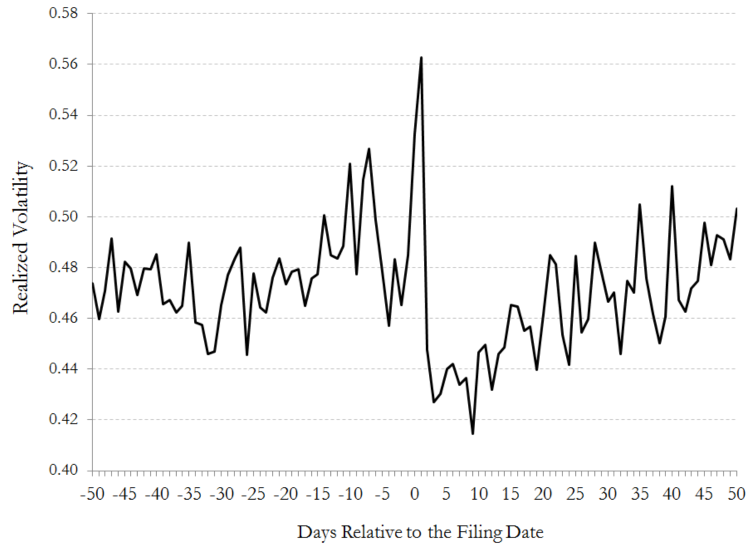
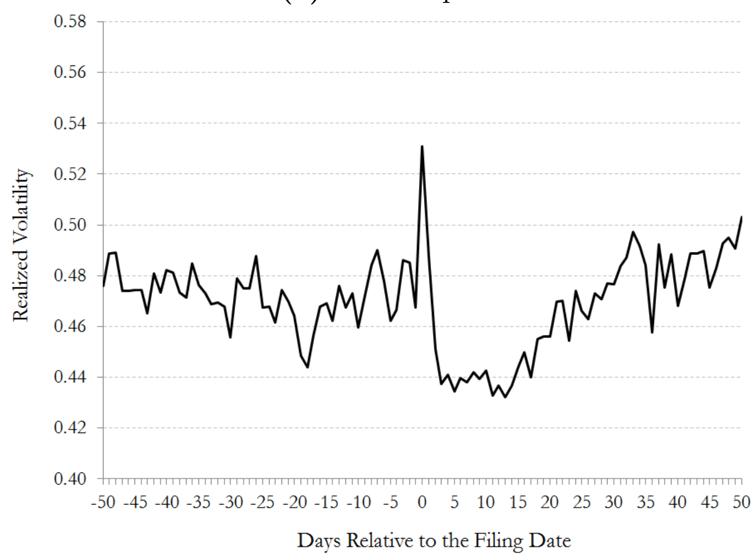


Figure A1
Time distribution of Schedule 13D filings. This chart plots the number of Schedule 13D filings that satisfy the criteria listed in Section I. The dark bars represent Schedule 13D filings with no information on derivatives. The gray bars represent Schedule 13D filings with information on derivatives.



(a) Full sample



(b) Sample with listed options

Figure A2

Realized volatility around filing date. Dark lines plot the realized volatility from 50 days before the filing date to 50 days after. The realized volatility is defined in table A1. The filing date is the day on which the Schedule 13D filing is submitted to the SEC. Panel A plots the realized volatility in the full sample of 2,905 Schedule 13D filings. Panel B plots the realized volatility in the sample of 580 Schedule 13D filings in which there are listed options on target firms.

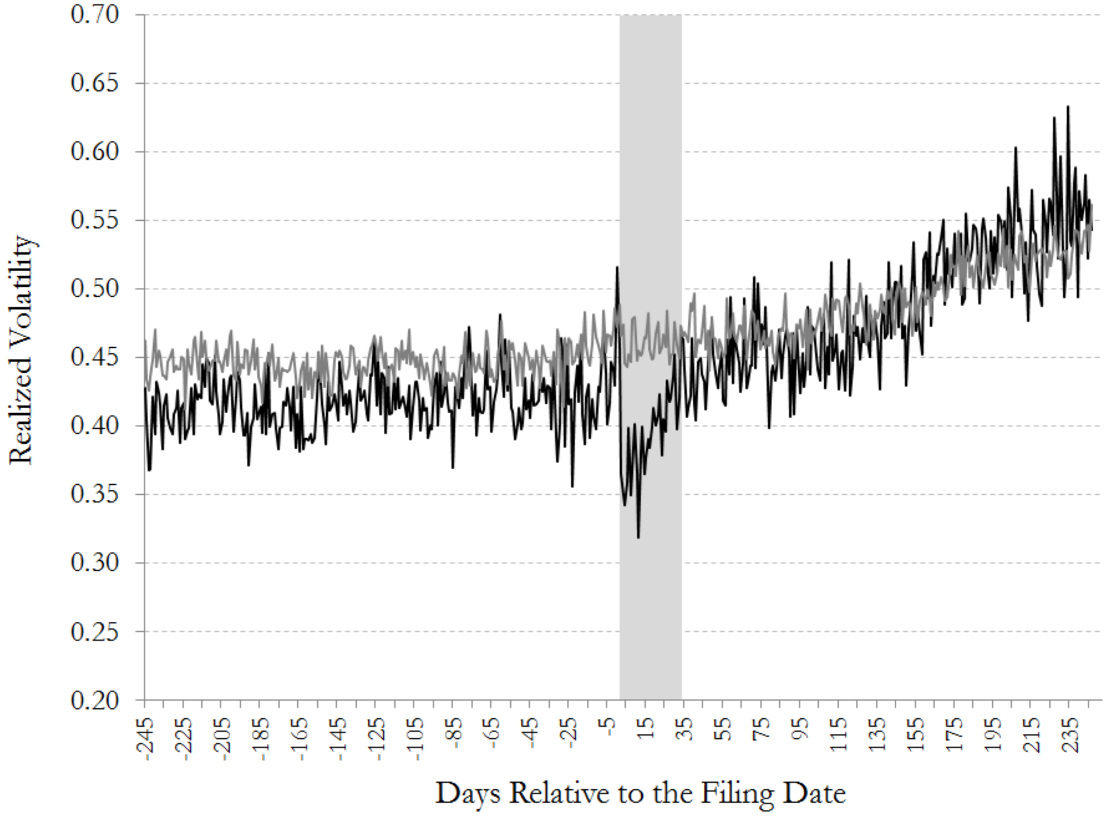


Figure A3
Volatility around the filing date – Long horizon. Dark (gray) line plots the realized volatility for the sample of event (matched) stocks from 250 days before the filing date to 250 days after. The realized volatility is defined in table A1. Matched stocks are assigned based on the same industry, market cap, and previous year volatility. The filing date is the day on which the Schedule 13D filing is submitted to the SEC. The sample covers 580 Schedule 13D filings in which there are listed options on target firms.

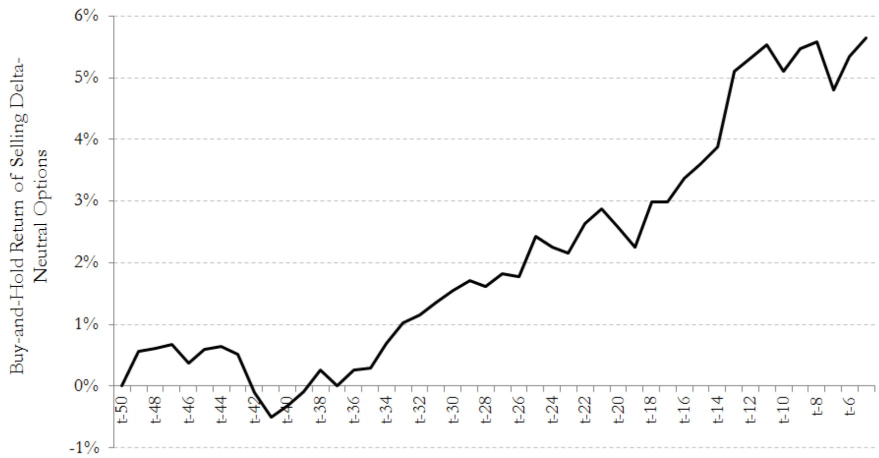


Figure A4
Buy-and-hold return on selling delta-neutral option strategies. The solid line plots the average buy-and-hold return on selling delta-neutral option strategies, in excess of the average buy-and-hold return on selling delta-neutral option strategies for matched stocks, from 50 days prior to 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 580 Schedule 13D filings in which there are listed options on target firms.

Table A1
Variable definitions.

Panel A. Stock market variables	
Excess Return	Stock return in excess of the CRSP value-weighted return.
Volatility	Volatility of daily stock returns.
Realized Vol	Realized volatility based on the absolute value of daily stock return.
Intraday Realized Vol	Computed from the sum of squared 5-minute returns over a trading day. The returns are computed from the TAQ trade transaction data.
Bid-Ask Spread	The percentage spread, calculated using daily close ask and bid.
Volume	Daily trading volume.
Panel B. Option market variables	
IV	Implied volatility provided by OptionMetrics; calculated based on 30 days to expiration.
Skew	The ratio of implied volatilities for out-of-the-money and at-the-money 30-day options, minus one. A put option is out-of-the-money (at-the-money) if delta is -0.3 (-0.5). A call option is out-of-the-money (at-the-money) if delta is 0.3 (0.5).
Time slope	The ratio of implied volatilities for call options with 30 days to expiration and call options with 365 days to expiration, minus one.
Spread, %	The percentage spread, calculated using daily close ask and bid.
Order Imbalance	The difference in the proportion of buy- and sell-initiated trades.
Panel C. Firm characteristics (firm-year level)	
Options available	Equals one if exchange traded options are available.
Market cap	Market capitalization.
Illiquidity	Amihud (2002) illiquidity measure, defined as the yearly average (using daily data) of $1000\sqrt{\frac{\lvert Return\rvert}{DollarTradingVolume}}$.
BM	The ratio of the book value of equity to the market value of equity.
Analyst	The number of analysts covering the stock.
Stock return	12-month buy-and-hold return.
INST	The proportion of shares held by institutions.
INST AHF	The proportion of shares held by activist hedge funds. Data on activist hedge funds are from Brav et al. (2008).
HSR	Equals one when a 5% toehold meets the "Size-of-Transaction Test" specified by the HSR Act.

Table A2

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
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
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
(log) 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
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 A3

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 580 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)	52,892	(2,224,586)
		[-0.09]	[0.16]	[-0.35]
Q2	438,976,302	1,011,851***	1,850,709***	25,966,410**
		[3.56]	[2.75]	[2.55]
Q3	873,588,004	1,758,625***	2,345,792**	39,050,138**
		[4.62]	[2.35]	[2.26]
Q4	1,760,772,119	1,999,809***	2,791,390**	57,376,458**
		[4.73]	[2.54]	[2.57]
Q5 - high	3,916,358,736	2,675,665***	3,720,508**	53,740,776*
		[4.95]	[2.52]	[1.87]

Table A4

Realized volatility and trading volume around filing date. The table reports estimates of γ_τ from the following regression: $y_{it} = \sum_{\tau=-3}^{\tau=5} \gamma_\tau fdate_{it-\tau} + \eta_i + X_t'\beta + \epsilon_{it}$, where y_{it} is a measure of volatility or trading activity for company i on day t, $fdate$ indicates Schedule 13D filing date, X is a vector of control variables (four Fama-French factors and VIX), and η_i are event fixed effects. The sample covers 522 Schedule 13D filings in which there are listed options on target firms and activist do not use derivatives and covers (t-10,t+5) period before the filing date. The coefficient correspond to the difference between the outcome variables on day $fdate_{it-\tau}$ and (t-10,t-4) period before the filing date. Heteroskedasticity-robust standard errors are clustered at the event level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Dependent variable:	Volume (log)	Volatility $\vert Ret \vert$	Volatility Intra-day
	(1)	(2)	(3)
$fdate_{it-3}$	-0.0246	0.0178	0.0128
	[-0.77]	[0.75]	[1.17]
$fdate_{it-2}$	-0.0262	0.0049	0.0057
	[-0.78]	[0.21]	[0.56]
$fdate_{it-1}$	-0.0517	0.0061	-0.0062
	[-1.49]	[0.27]	[-0.68]
$fdate_{it}$	0.0277	0.0626**	0.0450***
	[0.78]	[2.55]	[3.84]
$fdate_{it+1}$	-0.0218	0.0257	0.0082
	[-0.63]	[1.11]	[0.81]
$fdate_{it+2}$	-0.1145***	-0.0402*	-0.0208**
	[-3.40]	[-1.90]	[-2.21]
$fdate_{it+3}$	-0.1581***	-0.0703***	-0.0368***
	[-4.72]	[-3.69]	[-3.72]
$fdate_{it+4}$	-0.2367***	-0.0900***	-0.0360***
	[-7.28]	[-4.85]	[-3.71]
$fdate_{it+5}$	-0.2604***	-0.0601***	-0.0438***
	[-7.41]	[-3.17]	[-4.62]
R^2	0.027	0.013	0.043
N	7,579	7,579	7,579

Table A5

When do activists use derivatives? This table presents characteristics of targets when activist use and do not use derivatives. Columns (1) to (4) report results for all Schedule 13D filing with available data on firm characteristics (2,466 events). Columns (5) to (8) report results for sub-sample with available listed options (580 events; see Section IV for description of the "options available" criteria). Firm characteristics are measured at the end of the past fiscal year. Columns (1) and (5) report averages for targets when activist use derivatives. Columns (2) and (6) report averages for targets when activist do not use derivatives. Columns (3) and (7) report differences between (1) and (2) and (5) and (6) accordingly. Columns (4) and (8) report t-statistics of the differences. *, **, 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)	t-stat (4)	Use derivatives (5)	Do not use derivatives (6)	Diff (7)	t-stat (8)
Panel A: *Stock-market characteristics*								
Options Available	0.84	0.21	0.63***	11.98				
Market cap	906.88	211.23	695.65***	12.18	1073.08	689.54	383.54***	3.63
Illiquidity	0.1517	0.4859	-0.3341***	-4.35	0.0456	0.0584	-0.0128*	-1.81
BM	0.61	0.77	-0.16**	-2.07	0.57	0.48	0.10*	1.71
Analyst	10.15	3.81	6.34***	9.26	11.75	9.44	2.31**	2.22
Stock return	0.0105	0.0081	0.0025	0.43	0.0095	0.0122	-0.0027	-0.41
Volatility	0.5034	0.5532	-0.0498	-1.42	0.4755	0.4997	-0.0242	-0.72
INST	0.7093	0.4492	0.2601***	6.36	0.7630	0.7148	0.0482	1.29
INST AHF	0.0798	0.0597	0.0201**	2.11	0.0852	0.0574	0.0279***	2.72
HSR	0.6557	0.1847	0.471***	9.30	0.7647	0.5645	0.2002***	2.78
Panel B: *Option-market characteristics*								
IV					0.4828	0.4980	-0.0152	-0.46
Put skew					0.0525	0.0710	-0.0185	-0.89
Call skew					0.0053	0.0063	-0.001	-0.06
Time slope					0.1002	0.1623	-0.0621	-0.98
Bid-Ask spread					0.0676	0.0823	-0.0147***	-2.98
Bid-Ask spread - Call options					0.0734	0.0887	-0.0153***	-2.83
Bid-Ask spread - Put options					0.0604	0.0753	-0.0148***	-2.94
Put volume (log)					5.50	5.46	0.04	0.07
Call volume (log)					6.64	7.30	-0.66	-1.62
Put-to-Call volume					0.3364	0.2821	0.0543**	2.37

Table A6

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 2,021 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	0.0668***	0.0648***
	[4.47]	[4.38]
Market cap	0.0122**	0.0036
	[2.12]	[0.58]
Illiquidity	0.0131*	0.0060
	[1.68]	[0.71]
HSR		0.0326**
		[2.05]
BM	0.0079	0.0071
	[1.54]	[1.40]
Analyst	0.0024	0.0023
	[1.60]	[1.50]
Stock return	0.0289	0.0449
	[0.33]	[0.50]
Stock return vol	0.0126	0.0126
	[0.80]	[0.80]
INST	-0.0390*	-0.0295
	[-1.87]	[-1.37]
INST AHF	0.1703**	0.1773**
	[2.41]	[2.50]
Constant	-0.0653***	-0.0352
	[-2.66]	[-1.44]
R^2	0.074	0.077

Table A7

The flow of information into prices and informed trading. This table compares the outcome variables on days when Schedule 13D filers trade and on days when Schedule 13D filers do not trade. All outcome variables are defined in table A1. The table reports estimates of γ_1, γ_2, and γ_3 from regression (.11): $y_{it} = \gamma_1 itrade_{it} + \gamma_2 itrade\_opt_{it} + \gamma_3 itrade_{it} * itrade\_opt_{it} + \eta_i + X_t'\gamma_4 + \epsilon_{it}$, where y_{it} is a measure of trading activity for company i on day t minus a measure of trading activity for the matched stock, *itrade* indicates days on which Schedule 13D filers trade in stock market, *itrade_opt* indicates days on which Schedule 13D filers trade in option market, X is a vector of control variables (four Fama-French factors and VIX), and η_i are event fixed effects. Matched stocks are assigned based on the same industry, market cap, and previous year volatility. The sample covers 580 Schedule 13D filings in which there are listed options on target firms and covers (t-1,t-60) period before the filing date. Heteroskedasticity-robust standard errors are clustered at the event level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	itrade	*t*-stat	*itrade_opt*	*t*-stat	*itrade*∗ *itrade_opt*	*t*-stat	*N*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Implied volatility							
IV Call	-0.0320***	-4.91	0.0096	0.92	0.0461***	2.80	39,017
IV Put	-0.0282***	-4.28	0.0067	0.67	0.0678***	2.66	39,017
Panel B: Measures based on implied volatility							
Put skew	0.0269***	4.75	0.0128	1.37	0.0139	0.47	39,017
Call skew	0.0195***	3.91	0.0034	0.41	-0.0467	-1.28	39,017
Time slope	0.1068***	6.46	-0.0064	-0.35	0.2782	1.57	39,017
Panel C: Bid-Ask spread							
All options	0.0030***	3.28	0.0001	0.04	0.0001	0.02	32,221
Call options	0.0027***	2.89	-0.0013	-0.68	0.005	0.77	30,637
Put options	0.0027***	2.62	0.0017	0.92	-0.0065	-0.81	29,898
Panel D: Trading activity							
Option-to-stock volume ratio	-1.7421***	-3.33	0.3458*	1.74	1.3738***	2.94	38,856
Option Volume (log)	-0.0199	-0.24	0.7472***	4.60	-0.1776	-0.29	38,856
Put volume (log)	0.2546***	2.74	0.5645*	1.89	0.4314	0.63	38,856
ATM put volume (log)	0.2641**	2.46	0.8345**	2.34	1.5406*	1.65	33,158
OTM put volume (log)	0.2998***	3.16	0.4927*	1.69	0.5655	0.94	38,341
Call volume (log)	-0.1318	-1.43	0.7823***	5.14	-0.3219	-0.54	38,856
ATM call volume (log)	0.0727	0.65	0.7779***	3.24	0.5025	0.58	33,158
OTM call volume (log)	-0.0998	-1.01	0.5189**	2.31	0.4878	0.91	38,341
Put-to-call volume ratio	0.0231***	2.66	-0.0073	-0.14	0.0434	0.42	38,856
Panel E: Order Imbalance							
All options, all trades	-0.0060	-0.41	0.0343	0.87	0.0640*	1.75	11,816
All options, open trades	-0.0062	-0.39	0.0195	0.58	0.0776**	2.41	11,816
Put options, all trades	0.0201	1.36	-0.0272	-0.77	0.0156	0.48	11,816
Put options, open trades	0.0231	1.31	0.0072	0.17	0.1003***	2.62	11,816
Call options, all trades	0.0164	1.08	0.036	0.69	0.0741	1.53	11,816
Call options, open trades	0.0152	0.89	0.017	0.32	0.1541***	3.13	11,816
Panel F: Stock market							
Excess Return	0.0019***	3.91	0.0050**	2.10	-0.0034	-0.36	39,142
Bid-ask Spread	-0.0004***	-3.21	0.0001	0.48	0.0011	1.64	37,510
Volatility	0.0003	0.71	0.0048*	1.95	0.0126	1.13	39,142
Vol (log)	0.3468***	13.21	0.2836***	3.79	-0.0672	-0.34	39,142

Table A8

Robustness: Leverage effect. This table compares the outcome variables on days when Schedule 13D filers trade and on days when Schedule 13D filers do not trade. All outcome variables are defined in table A1. The table reports estimates of γ_1 from regression (19): $y_{it} = \gamma_1 itrade_{it} + \eta_i + X_t'\gamma_3 + \epsilon_{it}$, where y_{it} is a measure of trading activity for company i on day t minus a measure of trading activity for the matched stock, *itrade* indicates days on which Schedule 13D filers trade in stock market, X is a vector of control variables, and η_i are event fixed effects. Matched stocks are assigned based on the same industry, market cap, and previous year volatility. The sample covers 522 Schedule 13D filings in which there are listed options on target firms but Schedule 13D filers do not use any type of derivatives and covers (t-1,t-60) period before the filing date. The sample covers 522 Schedule 13D filings in which there are listed options on target firms but Schedule 13D filers do not use any type of derivatives and covers (t-1,t-60) period before the filing date. In columns (1) and (4), X includes four Fama-French factors and VIX. In other columns we extend the list of control variables and report estimated coefficients of these additional controls. Heteroskedasticity-robust standard errors are clustered at the event level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Dependent variable:	Implied volatility, Calls			Implied volatility skew			Implied volatility time slope			Option bid-ask spread		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
itrade	-0.0341***	-0.0337***	-0.0334***	0.0275***	0.0275***	0.0268***	0.1125***	0.1126***	0.1115***	0.0032***	0.0032***	0.0033***
	[-4.98]	[-4.92]	[-5.11]	[4.64]	[4.64]	[4.56]	[6.44]	[6.45]	[6.43]	[3.42]	[3.44]	[3.45]
stock return (t)		-0.2374***	-0.2894***		-0.0081	0.0063		-0.0492	-0.0518		-0.0185***	-0.0180***
		[-9.04]	[-11.36]		[-0.34]	[0.27]		[-1.11]	[-1.14]		[-3.63]	[-3.46]
stock return (t-1)			-0.0982***			-0.0016			0.2130***			-0.0063
			[-4.21]			[-0.08]			[4.53]			[-1.40]
change in implied vol (t-1)			0.2089***			-0.0289***			0.2996***			-0.0047*
			[17.54]			[-2.71]			[12.40]			[-1.85]
abs(stk return) (t)			0.6057***			-0.2174***			-0.1949*			-0.0199***
			[11.11]			[-5.97]			[-1.90]			[-2.96]
abs(stk return) (t-1)			0.5157***			-0.2053***			-0.1708*			-0.0196***
			[10.60]			[-5.81]			[-1.88]			[-2.81]
Constant	-0.0233*	-0.0236**	-0.0247**	0.0133	0.0133	0.0149	0.0708***	0.0708***	0.0733***	0.0069***	0.0069***	0.0070***
	[-1.96]	[-1.99]	[-2.18]	[1.33]	[1.33]	[1.52]	[3.00]	[3.00]	[3.08]	[4.16]	[4.15]	[4.15]
R^2	0.016	0.02	0.067	0.007	0.007	0.01	0.027	0.027	0.031	0.003	0.004	0.005
N	35,699	35,699	34,770	35,699	35,699	34,770	35,699	35,699	34,770	29,345	29,345	28,545

Table A9

Integration between stock and option markets: Additional robustness tests.

This table presents cross-sectional variations in the relations between changes in option market bid-ask spread and option market volume reported in table IV. Columns (1) and (3) report estimates of γ_1 from regression (19): $y_{it} = \gamma_1 itrade_{it} + \eta_i + X_t'\gamma_3 + \epsilon_{it}$, where y_{it} is option bid-ask spread for company i on day t minus option bid-ask spread for the matched stock, *itrade* indicates days on which Schedule 13D filers trade in stock market, X is a vector of control variables, and η_i are event fixed effects. Matched stocks are assigned based on the same industry, market cap, and previous year volatility. Columns (2) and (4) report the corresponding t-statistics, calculated using heteroskedasticity-robust standard errors clustered at the event level. In panel A we report results for our main measure of integration between stock and option markets: the absolute difference between implied volatility for calls and puts during (t-90,t-60). In panel B we use the difference between implied volatility for calls and puts during (t-90,t-60) as the measure of integration between stock and option markets. In panel C we use the negative option bid-ask spread during (t-90,t-60) as the measure of integration between stock and option markets. In panel D we use option volume during (t-90,t-60) as the measure of integration between stock and option markets. In panel E we use option open interest during (t-90,t-60) as the measure of integration between stock and option markets. In panel F co-movements of changes in IV of call and put options during (t-90,t-60) as the measure of integration between stock and option markets. For every trading date, co-movement is 1 if call and put IVs move in the same direction, and zero otherwise. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Dependent variable:	Option bid-ask spread		Option volume (log)	
	Coefficient	t-stat	Coefficient	t-stat
	(1)	(2)	(3)	(4)
Panel A: Sort on the absolute difference between implied volatility for call and put options				
High integration	0.0057***	5.00	-0.0574	-0.69
Low integration	0.0007	0.71	0.0562	0.53
Difference	0.0050***	3.38	-0.1136	-0.85
Panel B: Sort on the difference between implied volatility for call and put options				
High	0.0022**	1.97	-0.0241	-0.24
Low	0.0044***	4.21	0.0165	0.19
Difference	-0.0022	-1.47	-0.0406	-0.31
Panel C: Sort on the negative option bid-ask spread				
High integration	0.0051***	4.55	0.0649	0.84
Low integration	0.0015	1.54	-0.124	-1.17
Difference	0.0036**	2.41	0.1889	1.45
Panel D: Sort on the option volume				
High integration	0.0054***	4.51	0.0386	0.49
Low integration	0.0012	1.33	-0.0443	-0.42
Difference	0.0042***	2.79	0.0829	0.63
Panel E: Sort on the option open interest				
High integration	0.0051***	4.01	0.0143	0.18
Low integration	0.0017**	1.98	-0.0202	-0.19
Difference	0.0035**	2.28	0.0345	0.26
Panel F: Sort on co-movement of changes in call and put IV				
High integration	0.0045***	3.68	0.0083	0.09
Low integration	0.0023**	2.52	-0.0115	-0.12
Difference	0.0022	1.45	0.0198	0.15

Table A10

Call-Put Parity violations before and after days when Schedule 13D filers trade. This table compares the difference between implied volatilities of Call and Put options on days before and after days when Schedule 13D filers trade. All variables are defined in table A1. The table reports estimates of γ_τ from regression (20): $y_{it} = \sum_{\tau=-2}^{\tau=2} \gamma_\tau itrade_{it-\tau} + \eta_i + X_t'\beta + \epsilon_{it}$, where y_{it} is an outcome variable for company i on day t minus the outcome variable for the matched stock, $itrade_{it-\tau}$ indicates days before and after days on which Schedule 13D filers trade in stock market, X is a vector of control variables, and η_i are event fixed effects. Matched stocks are assigned based on the same industry, market cap, and previous year volatility. The sample covers 522 Schedule 13D filings in which there are listed options on target firms but Schedule 13D filers do not use any type of derivatives and covers (t-1,t-60) period before the filing date. Heteroskedasticity-robust standard errors are clustered at the event level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)
itrade (t+2)		-0.0036
		[-1.56]
itrade (t+1)		-0.0038
		[-1.62]
itrade	-0.0040**	-0.0045**
	[-2.44]	[-2.44]
itrade (t-1)		-0.0013
		[-0.67]
itrade (t-2)		0.0026
		[1.47]
R^2	0.10%	0.10%
N	35,681	35,681
N-clusters	487	487