Informed Options Trading prior to Takeover Announcements: Insider Trading?*

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Abstract

We quantify the pervasiveness of informed trading activity in target companies' equity options before M&A announcements. About 25% of takeovers have positive abnormal volumes, which are greater for short-dated out-of-the-money calls, consistent with bullish directional trading ahead of the announcement. Over half of this abnormal activity is unlikely to be explained by speculation, news and rumors, trading of corporate insiders, leakage in the stock market, deal predictability, or beneficial ownership filings by activist investors. Although the characteristics of a sample of illegal option trades prior to M&A announcements closely resemble the characteristics of abnormal option trades in our sample, the SEC litigates only about 8% of all deals in it. Hence, our findings flag abnormal options volume as a useful indicator for regulatory examination of potential insider trading.

Keywords: Asymmetric Information, Civil Litigations, Insider Trading, Mergers and Acquisitions, Market Microstructure, Equity Options, SEC

JEL Classification: C1, C4, G13, G14, G34, G38, K22, K41

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1 Introduction

Existing research documents abnormal trading activity in equity options prior to mergers and takeover announcements. Cao, Chen, and Griffin (2005) suggest that this activity may be informed, as directional trading activity positively foreshadows future price movements.[1] This finding raises questions about the nature of the observed run-up in option volumes and the distribution of informed trading across deals. Is the run-up driven by a few deals with significant volumes, or do all deals contribute to the options activity that is abnormal on average? Which information drives the individual run-ups in option volumes, and may they be explained by publicly available sources of information besides illegal insider trading? In this paper, we aim to characterize the pervasiveness of informed options trading around takeover announcements and improve our understanding of the nature and sources of the pre-announcement run-up in option volumes.

Our analysis encompasses three pillars. We first quantify the pervasiveness of informed trading in the equity options of target companies ahead of U.S. takeover announcements. To better understand the sources of informed trading, we examine in a second step a large number of channels that could plausibly explain the abnormal trading volumes in options based on correct anticipation of upcoming takeover activity. It is in particular the deal-by-deal examination of the pre-announcement activity that allows us to examine the overlaps in explanations across deals, and to flag those deals with abnormal options activity that are the most unlikely to be anticipated. Third, we also verify whether the run-up may be explained by illegal insider trades reported by the Securities and Exchange Commission (SEC), and compare the characteristics of all option trades litigated for alleged illegal insider trading to those of the pre-announcement options activity. This comparison strengthens the assessment of the nature and sources of the pre-announcement run-up in option volumes.

In a sample of 1,859 U.S. takeover transactions between January 1996 and December 2012, we document that about a quarter of all deals, i.e., 25% (467 deals), have abnormal volumes in equity options, over the 30 days preceding the formal announcements of acquisitions, that are statistically significant at the 5% level. The proportion of cases with abnormal volumes is relatively higher

[1] We discuss other references on informed options trading prior to takeover announcements in Section 2 and summarize them in Table 1: Jayaraman, Mandelker, and Shastri (1991), Levy and Yoder (1993), Jayaraman, Frye, and Sabherwal (2001), Arnold, Erwin, Nail, and Nixon (2006), Acharya and Johnson (2010), Clements and Singh (2011), Spyrou, Tsekrekos, and Siougle (2011), Shafer (2012), Klapper (2013), Wang (2013), Liu, Lung, and Lallemand (2015), Podolski, Truong, and Veeraraghavan (2013), Chan, Ge, and Lin (2015), Ordu and Schweizer (2015), Huang and Tung (2016), Lowry, Rossi, and Zhu (2016).

for call options than for put options. Stratifying the results by "moneyness," we find that there is significantly higher abnormal trading volume in OTM call options compared to at-the-money (ATM) and in-the-money (ITM) calls.[2]

An examination of the characteristics of cumulative abnormal volume shows that informed trading is more pervasive for larger deals, those for which informed investors may potentially have less uncertainty about the final takeover price, and in cases of target firms receiving cash offers. We study the trading volume, implied volatility, and bid-ask spreads of equity options, and consider a number of robustness tests, which support the evidence of informed investors trading directionally in anticipation of a jump in the price of the target company's stock. It is the deal-by-deal examination of the pre-announcement activity that may help us appreciate the pervasiveness of informed trading in takeover transactions.

In a second step, we explore whether the takeover announcements could have been anticipated based on public sources of information known to us. We first show that the run-up in options volume is unlikely to be explained by speculative trading activity in response to observable trading activity in the underlying shares or industry and firm characteristics. We compare the options activity in the takeover sample to several control samples that are matched either on the activity in the underlying stock market, or on industry and firm characteristics. Similar findings of informed trading activity in options ahead of takeover announcements are absent from these control groups.

In addition, we find it unlikely that the entire amount of informed options activity could be explained by news and rumors. To identify rumors and news about upcoming takeovers, we use RavenPack News Analytics, a database that is constructed from textual information in major newspaper outlets, public relation feeds, and over 19,000 other traditional and social media sites. We associate news with 170 takeover transactions, and with only 40 of the 467 deals that exhibit informed options activity (9%). We find no statistically significant difference in the average cumulative abnormal options trading volumes between the samples with and without news. We further check whether the option trades originate from the accounts of corporate insiders. Corporate officers, directors, or large block-holders are legally required to disclose security transactions in their company's options.

[2]We also find that ITM puts trade in abnormally larger volumes than ATM puts. This indicates that informed traders may possibly also engage in ITM put transactions, or that the call trading generates arbitrage-based put trading activity. We explicitly consider synthetic options strategies and show in an Online Appendix (Section A-I) that a wide variety of strategies for exploiting private information about an acquisition result in the trading of OTM calls or ITM puts.

An analysis of the derivative transactions and holdings information in the Thomson Reuters insider filings reveals that not a single options transaction was executed by registered insiders within the thirty pre-announcement days.

We also consider the possibility that astute option traders trade on information leakage in the stock market. However, our analysis suggests that option volume leads stock volume, and that past stock volume and return performance is not significantly related to future abnormal options activity. In addition, we find that only 7% of all deals in our sample exhibit abnormal stock returns in the pre-announcement period, while about 44% of all deals exhibit excess implied volatility. Although 19% of all takeover transactions exhibit statistically significant abnormal stock volume, a frequency somewhat lower than in the options market, the economic magnitude is substantially smaller. Thus, quantifying how many deals are subject to informed trading may also be informative about whether informed trading is more prevalent in the options or in the stock market.

Next, we show that it is difficult to predict takeover announcements based on publicly available information. Thus, the documented abnormal option trading volume is unlikely to be explained by traders' ability to time the market. However, we observe that most of the informed activity arises in the five to ten days before the information gets publicly released. Finally, we screen the 13D beneficial ownership reports, which need to be filed by registered active investment advisors no later than 10 days following the acquisition of beneficial ownership of more than 5% of any class of publicly traded securities. The trading by supposedly informed activist investors is unlikely to fully explain the abnormal options activity, as only 17 of these deals have a filing in the 30 days prior to the announcement date.

Out of the 467 deals with significant cumulative abnormal options volume, 236 deals, i.e., 13% of the sample, are unlikely to be associated with publicly available sources of information. Consider that in this sub-sample, we exclude those deals that exhibit statistically significant stock volume or returns, which appear to lag the option market in the pre-announcement period. An alternative to the run-up in options volume is illegal insider trading. To verify that hypothesis, we filter through more than 8,000 litigation records from the SEC to identify whether the takeover transactions in our sample were subject to a litigation for alleged insider trading. We find that the SEC litigates about 8% of takeovers in our sample for insider trading in options or stocks, but only 43 deals out of the 467 transactions that we associate with informed trading. Moreover, only 24 out of the 236 deals that we fail to associate with public sources of information are involved in a litigation. Thus, the number of civil lawsuits for insider trading appears modest in comparison to the pervasive informed trading activity reflected in one out of four takeover transactions.

Using the litigation records, we hand collect information on the size, timing and type of illegal trades, information we supplement with information in the criminal records from the U.S. Department of Justice (DoJ). The characteristics of the illegal option trades, i.e., short-dated OTM call options on target companies that are initiated, on average, 21 days before the announcement, closely resemble the characteristics and timing of the abnormal options activity in a representative sample of takeover transactions. This resemblance, coupled with the absence of public information sources that could have led to the anticipation of the takeover transaction, supports the assessment that the pervasive informed options activity may be illegal.

DeMarzo, Fishman, and Hagerty (1998) suggest that it may be optimal to prosecute insiders only after large price moves or after large volume transactions, and not to penalize small trades. We do find that the SEC is likely to examine cases in which the targets are large firms that experience substantial abnormal returns after the announcement, and in which the acquirers are headquartered outside the U.S. We do not find evidence that the probability of litigation is positively related to the pre-announcement abnormal options volume. In addition to the novel insights about the sources of informed trading, our analysis thus highlights that abnormal options activity may potentially be an overlooked metric by regulators and prosecutors trying to detect insider trading activity.

To summarize, we extend the current literature along three key dimensions. While prior research has highlighted the existence of informed options activity ahead of takeover announcements, our paper quantifies the prevalence of informed trading in the economy and documents that the informed options activity is driven by a quarter of all deals. Second, in contrast to previous work, we examine the sources of informed trading in the options market and show that for at least 13% of all deals, it is difficult to associate the abnormal options activity with public sources of information. Third, a unique feature of our research is that we study the characteristics of SEC-prosecuted cases related to insider trading in options prior to M&A announcements. This allows us to compare the nature of abnormal options activity to illegal option trades and examine how the SEC's litigation record relates to abnormal options trading around takeover announcements.

2 Literature Review and Contributions

The run-up in the stock prices of target companies before M&A announcements is a well-documented fact (Mandelker, 1974; Dodd, 1980; Jensen and Ruback, 1983; Asquith, 1983; Dennis and McConnell, 1986; Schwert, 1996). A long-standing debate relates to whether this run-up is due to public information such as, for example, media speculation (Jarrell and Poulsen, 1989), or whether it is the result of private information leakage and illegal insider trading (Keown and Pinkerton, 1981; Meulbroek, 1992; Sanders and Zdanowicz, 1992).

Abnormal options volume and price activity ahead of M&A announcements have been the subject of several papers, particularly in recent years. Table 1 summarizes this prior work in detail. Jayaraman, Mandelker, and Shastri (1991) are the first to document a pre-announcement increase in the option-implied volatilities of target companies, which precedes the increase in stock returns (Levy and Yoder, 1993). Jayaraman, Frye, and Sabherwal (2001) further document that the abnormal options volume is accompanied by abnormal open interest that is concentrated in short-term OTM options, that it leads abnormal stock volume, and that the increase in abnormal options volume is greater for call than for put options. Using signed volume, Cao, Chen, and Griffin (2005) support the presence of informed activity, since prior to takeover announcements, the option volume order imbalance contains information regarding subsequent stock price movements, greater call volume balances are associated with greater announcement returns, and the options market displaces the stock market for information-based trading (see also Arnold, Erwin, Nail, and Nixon (2006)). Acharya and Johnson (2010) show that a large number of equity participants in leveraged buyout syndicates is associated with greater levels of suspicious stock and options activity. Clements and Singh (2011) argue that pre-announcement options volume reflects both informed and "contraire" trading, while Shafer (2012) documents a positive correlation between the pre-announcement option-to-stock volume ratio and the probability of being a takeover target that becomes weaker after Regulation Fair Disclosure in 2000.

Many studies in more recent years have corroborated the existing evidence of abnormal pre-announcement option activity in target companies, in the U.S. and in the U.K. (Spyrou, Tsekrekos, and Siougle, 2011). The extant literature at times emphasizes different aspects of the pre-announcement activity, including abnormal changes in the IV skew, IV spread, and the option-to-stock volume ratio (Klapper, 2013), a positive correlation between pre-announcement run-up and abnormal options volume (Wang, 2013), an increasing importance of options' leading role for price discovery (Liu, Lung, and Lallemand, 2015), or a greater propensity of informed trading to occur in more liquid and higher leverage options (Podolski, Truong, and Veeraraghavan, 2013). Chan, Ge, and Lin (2015) show that the one-day pre-event implied volatility spread (the implied volatility skew), a proxy for informed option trading, is positively (negatively) associated with acquirer cumulative abnormal returns. Ordu and Schweizer (2015) associate greater abnormal volumes with greater CEO wealth-to-performance sensitivity for stock-financed takeovers, suggesting that informed managers hedge anticipated negative acquirer announcement returns. Focusing also on acquirers, Huang and Tung (2016) find a positive relation between announcement returns and pre-announcement option-to-stock volume ratios, which are positively related to idiosyncratic stock volatility. Chesney, Crameri, and Mancini (2015) (not tabulated) propose a method for detecting abnormal options activity and relate six unusual transactions to M&A announcements. Kedia and Zhou (2014) conclude in favor of pre-announcement informed trading in target bonds. Poteshman (2006) concludes that informed investors traded put options ahead of the 9/11 terrorist attack.

Table 1 emphasizes the distinction between this study and prior work. Apart from Spyrou, Tsekrekos, and Siougle (2011), who examine U.K. data, most studies are not informative about the distribution of informed options trading in the economy. For a sample of up to 33 firms that is not representative of option trading over the last two decades, Jayaraman, Mandelker, and Shastri (1991); Jayaraman, Frye, and Sabherwal (2001) count positive changes in implied volatilities, without offering any indication of statistical significance. In contrast, we examine deals, case by case, and emphasize how and where insiders trade in the options market, as they engage in directional strategies for targets, which are reflected in more pronounced abnormal activity in OTM calls and cash-financed takeovers. In addition, we explicitly consider synthetic option strategies that lead to long bullish or short bearish exposures for targets, and review earlier evidence as the findings appear to be inconsistent across studies.[3]

Importantly, there is only scarce information on the sources of informed options trading in the options of target firms. Klapper (2013) and Wang (2013) examine media speculation/rumors, but

[3]For instance, Cao, Chen, and Griffin (2005) (Chesney, Crameri, and Mancini (2015),Wang (2013)) document greater abnormal options activity in short-term OTM (put, ATM call) options.

their results are inconsistent with each other.[4] Liu, Lung, and Lallemand (2015) provide some evidence against the leakage hypothesis, but do not explain whether abnormal options activity for a given deal might be the result of abnormal stock activity. In contemporaneous work, Lowry, Rossi, and Zhu (2016) indicate that trading desks connected to M&A advisory desks take abnormal call option positions in the target companies during the one to seven pre-announcement quarters. Ordu and Schweizer (2015) examine the sources of informed trading (managers), but focus on options of the acquirers. Our focus here is on documenting the abnormal options activity for the target firms and identifying the specific types of options traded ahead of the announcement.

Some authors incorporate information on the existence of deals detected by the SEC for illegal insider trading (Jayaraman, Frye, and Sabherwal, 2001; Podolski, Truong, and Veeraraghavan, 2013) or study the predictability of prosecutions (Wang, 2013). Using a proprietary sample of illegal trades prosecuted by the SEC, Meulbroek (1992) and Meulbroek and Hart (1997) document that insider trades have an immediate effect on stock prices, that half of the pre-announcement run-up occurs on insider trading days, and that the announcement returns are a third larger when insider trading is detected. Frino, Satchell, Wong, and Zheng (2013) study hand-collected SEC litigations and find that illegal stock trades are positively associated with subsequent price changes, but negatively with the size of the penalties and the stock's liquidity. However, there exists no information on the characteristics of option trades prosecuted for illegal insider trading, nor on how prosecution relates to the degree of abnormal options activity. Our examination relates our results to the prior literature associated with illegal insider trading in stocks.

Cornell and Sirri (1992) and Chakravarty and McConnell (1999, 1997) conduct clinical studies of illegal stock trades ahead of the 1982 takeover of Campbell Taggart by Anheuser-Busch and the 1984 takeover of Carnation by Nestlé. Both studies find positive price impacts, and either a positive or no effect on bid-ask spreads or depth. Fishe and Robe (2004) find that trading by brokers, who illegally had advance access to news information on 116 *stocks* negatively impacted market depth. Guercio, Odders-White, and Ready (2015) argue that illegal insider trading has decreased in response to more aggressive enforcement. Ahern (2017) examines insider trading networks from civil and criminal prosecutions initiated by the SEC and the DoJ, while Kacperczyk and Pagnotta

[4] Wang (2013) finds no significant difference in abnormal options volume for samples with and without media coverage. Klapper (2013) finds a greater stock price run-up for rumored deals. Again, in contrast we use a novel high frequency news data base to revisit the evidence, and quantify the fraction of rumored deals.

(2016) study price impact of illegal trading using SEC litigation files. Heitzman and Klasa (2016) study informed stock trading around non-public merger negotiations. Bhattacharya (2014) provides a comprehensive literature review. For a discussion on the legal aspects of insider trading, see for example Crimmins (2013) and Arshadi (1998).

Our focus differs from the literature that examines informed stock trading by corporate insiders. For example, Cohen, Malloy, and Pomorski (2012) show that only opportunistic, but not routine, transactions have predictive content for stock prices. Agrawal and Nasser (2012) discuss widespread "passive" insider trading on targets, whereby registered insiders increase their net exposure through reduced stock selling. These studies generally focus on stock trades only, and provide no evidence on option activity.

Our work relates broadly to the vast literature, studying when and how informed agents choose to trade in the options market in the presence of asymmetric information (Easley, O'Hara, and Srinivas, 1998), differences in opinion (Cao and Ou-Yang, 2009), short-sale constraints (Johnson and So, 2012), or margin requirements and wealth constraints (John, Koticha, Narayanan, and Subrahmanyam, 2003), and on the predictability of option-implied measures for stock returns (Easley, O'Hara, and Srinivas, 1998; Pan and Poteshman, 2006; Xing, Zhang, and Zhao, 2010; Cremers and Weinbaum, 2010; Johnson and So, 2011; Tse-Chun and Xiaolong, 2015; Jin, Livnat, and Zhang, 2012; Hu, 2014). Several other papers are peripherally related to the specific issue studied in this paper. Roll, Schwartz, and Subrahmanyam (2010) study the relationship between the option-to-stock trading volume and post-earnings announcement returns. Bester, Martinez, and Rosu (2011) and Subramanian (2004) develop theoretical option pricing models for the target in the case of cash and stock-for-stock mergers respectively.

3 Data Selection and M&A Deal Characteristics

The data for our study come from three primary sources: the Thomson Reuters Securities Data Company Platinum Database (SDC), the Center for Research in Securities Prices (CRSP) Database and the OptionMetrics Database. We start our sample selection with the full domestic M&A dataset for U.S. target firms from SDC Platinum over the time period from January 1996, the starting date for available option information in OptionMetrics, through December 2012. Our final sample consists of 1,859 transactions for which we were able to identify matching stock and option information for the target. These deals were undertaken by 1,279 unique acquirers on 1,669 unique targets.[5]

Starting from an initial sample of 185,419 transactions, we restrict the study to deals aimed at affecting a change of control, where the acquirer owned less than 50% of the target's stock before, and was seeking to own more than 50% of it after the transaction. Hence, our sample includes only M&As of majority interest, excluding all deals that were acquisitions of remaining or partial interest (minority stake purchases), acquisitions of assets, recapitalizations, buybacks/repurchases/self-tender and exchange offers. In addition, we exclude deals with pending or unknown status, i.e., we only include completed, tentative or withdrawn deals. These restrictions reduce the sample size to 34,350 deals. Next, we require information to be available on the deal value, and eliminate deals with a transaction value below 1 million USD, which reduces the sample further to 19,064 transactions. Finally, we match the information from SDC with price and volume information in both CRSP and OptionMetrics. We require a minimum of 90 days of valid stock and option price and volume information on the target prior to, and including, the announcement date, which results in the final sample of 1,859 takeover announcements. All matches between SDC and CRSP/OptionMetrics are manually checked for consistency based on the company name.

Panel A in Table 2 reports the basic deal characteristics for the full sample. Pure cash offers make up 48.6% of the sample, followed by hybrid financing offers with 22.3%, and share offers with 21.7%. 82.9% of all transactions are completed, and mergers tend to be mostly within the same industry, with 53.4% of all deals being undertaken with a company in the same industry based on the two-digit SIC code. 90.2% of all deals are considered to be friendly and only 3.4% are hostile, while 11.6% of all transactions are challenged. For only 6.5% of the sample do the contracts contain a collar structure, 76.5% of all deals involve a termination fee, and in only 3.5% of the transactions does the bidder already have a toehold in the target company. Panel B shows that the average deal size is 3.8 billion USD, with cash-only deals being, on average, smaller (2.2 billion USD) than stock-only transactions (5.4 billion USD). The average one-day offer premium, defined as the excess of the offer price relative to the target's closing stock price, one day before the announcement date, is 31%.

[5]Thus, 190 of the targets were involved in an unsuccessful merger or acquisition that was ultimately withdrawn. However, we include these cases in our sample, since the withdrawal occurred *after* the takeover announcement.

4 Informed Options Activity prior to Takeovers

The first objective of our empirical analysis is to quantify the prevalence of informed trading using options volume. For that purpose, we review and confirm much of the evidence from the prior literature described in Table 1. A takeover announcement is generally associated with a significant stock price increase for the target, as noted by (Andrade, Mitchell, and Stafford, 2001); the average one-day offer premium is 31% in our sample. Investors intending to trade on private information about the anticipated announcement return trade off the options' market leverage (Black, 1975) against the greater liquidity in the stock market, perhaps also associated with a lower probability of detection. In the presence of asymmetric information (Easley, O'Hara, and Srinivas, 1998), wealth constraints (John, Koticha, Narayanan, and Subrahmanyam, 2003), short-sale constraints (Johnson and So, 2012), or disagreement (Cao and Ou-Yang, 2009), some investors will migrate towards the option market as a venue for informed trading. We emphasize that an informed trader would pursue directional strategies for the target, as the stock price almost always goes up after an announcement. A necessary condition for informed pre-announcement activity is, therefore, the detection of abnormal options volume, as stated in the first hypothesis H1.

- H1: *There is evidence of positive abnormal trading volume in the equity options of target firms prior to takeover announcements.*

In the presence of superior information, a trading strategy involving the purchase of OTM call options should generate a significantly higher abnormal return, as a consequence of the higher leverage ("more bang for the buck"). Hence, we expect a larger increase in abnormal trading volume for OTM calls relative to ATM and ITM calls. Moreover, an informed investor, taking advantage of his privileged knowledge of the future direction of the target's stock price evolution, may also increase the trading volume through the sale of ITM puts, as these will become less valuable with the increase in the target's stock price upon announcement. An alternative, and more cash-intensive, strategy would be to mimic the strategy of buying OTM calls, by buying ITM puts coupled with the underlying stock, financed by borrowing. Thus, an abnormally high volume in ITM puts may result from either the strategy of mimicking the purchase of OTM calls, or the strategy of taking a synthetic long position in the stock (buying a call and selling a put with the same strike price). An informed trader may possibly engage in more complicated trading strategies to hide his intentions. Irrespective of which alternative strategy is employed, we should observe abnormal trading volume in OTM call and/or ITM put options, if investors with precise information exploit option leverage. This leads to a sharper prediction stated in hypothesis H2.

- H2: *The ratios of the abnormal trading volumes in (a) OTM call options to ATM and ITM call options, and (b) ITM put options to ATM and OTM put options, written on the target firms, are higher prior to takeover announcements.*

To test hypotheses H1 and H2, we examine the deal-by-deal trading volume in equity options written on target firms during the 30 days preceding takeover announcements. In a nutshell, we find that approximately 25% of all deals in our sample exhibit statistically significant abnormal options activity (at the 5% level) in the pre-announcement period. In the U.K., Spyrou, Tsekrekos, and Siougle (2011) also document abnormal pre-announcement options volume for one out of four deals. The magnitude of abnormal volume is greater for OTM call options than for ATM and ITM calls in our sample, confirming the results of Cao, Chen, and Griffin (2005). Our analysis suggests that the odds of abnormal volumes being greater in a sample with randomized announcement dates are at most one in a million.

4.1 Identifying Abnormal Trading Volumes

We test hypothesis H1 by applying event study methodology to trading volumes. To compute the abnormal trading volume, we use, as a conservative benchmark, a market model for volume (*MMV* model), which accounts for the market volume in options (median trading volume across all options in the OptionMetrics database), the Chicago Board of Options Exchange (CBOE) Volatility Index (VIX), as well as the contemporaneous return of the underlying stock and the market, proxied by the return on the S&P500 index. In addition, we control for lagged values of the dependent and all the independent variables. The estimation window starts 90 days before the announcement date and finishes 30 days before the announcement date. As we are interested in the abnormal trading volume in anticipation of the event, our event window stretches from 30 days before to one day before the announcement date. To account for the possibility of clustered event dates, we correct standard errors in aggregate tests for cross-sectional dependence.

Table 3 shows that the average cumulative abnormal trading volume for target firms is positive and statistically significant. The magnitude of the average cumulative abnormal volume over the 30 pre-event days is estimated to be 8,946 contracts for call options. For put options on the target, the average cumulative abnormal volume is also positive, but, over the 30 pre-event days, it is much smaller, at 1,559 contracts, and not statistically significant. The evolution of the average abnormal and cumulative abnormal trading volume for the targets is illustrated in Figure 1. It is apparent that the average cumulative abnormal trading volume in put options is quantitatively less important than that in call options, which primarily drives the results for the overall sample. The daily average abnormal volume for call options is positive and steadily increasing to a level of approximately 1,500 contracts the day before the announcement. Individually, the number of deals with positive abnormal trading volumes, at the 5% significance level, ranges from 467 for calls, to 304 for puts, corresponding to approximately 25% and 16% of the entire sample, respectively.[6] Thus, approximately one out of four deals exhibits statistically significant cumulative abnormal options trading volume.[7]

We further stratify our sample by moneyness, and conduct an event study for each category, using only options expiring after the announcement date. We find that there is significantly higher abnormal trading volume for the targets in OTM call options, compared to ATM and ITM calls, both in terms of volume levels and frequencies. Table 3 shows that the average cumulative abnormal volume is 3,380 (1,417) contracts for OTM calls (puts) and 1,540 (984) contracts for ITM calls (puts), while it is 1,156 (457) for ATM calls (puts). These values correspond to 408 (343, 482) deals, or 22% (18%, 26%) of the sample for OTM (ATM, ITM) calls, and 451 (362, 396) deals or 24% (19%, 21%), for OTM (ATM, ITM) puts, respectively.

In Panel B, we report results from paired t-tests for the differences in the means of the cumulative average abnormal volumes across different categories. Consistent with hypothesis H2, these results emphasize that there is higher abnormal trading volume for OTM call options than for ATM or ITM calls. The differences in the means for OTM calls relative to ATM and ITM calls, are 2,224 and 1,840, respectively, which are positive and statistically different from zero. On the other hand, the

[6]Unreported results indicate that, at the 1% significance level, the number of deals with positive abnormal trading volumes in the entire sample ranges from 275 for calls to 179 for puts, corresponding to frequencies of 15% and 10%, respectively.

[7]For statistical inference, we follow Kothari and Warner (2007) and Campbell, Lo, and MacKinlay (1996). We note that the predictive volume models account for lagged values of both dependent and independent variables in order to purge serial correlation in the residuals at the firm level. Moreover, we show in the Online Appendix that the documented effects for option volumes do not arise in samples matched on randomized announcement dates, on industry and firm characteristics, as well as on takeover propensity scores. We also account for false positives in multiple hypothesis testing, following the methodology in Barras, Scaillet, and Wermers (2010). The frequency of mergers with statistically significant abnormal call option volume is still 24%, even though we fail to adjust for false negatives, i.e., the fact that we fail to reject the null hypothesis simply by chance, which leads to a downward bias in the proportion of anomalous trading we observe.

difference in the means between ATM and ITM calls is slightly negative (-384), but not statistically different from zero. The average cumulative abnormal volume for ITM put options is higher than for ATM put options, which provides some evidence that informed traders may not only engage in OTM call transactions but may also sell ITM puts.[8]

To summarize, the evidence supports the conclusion of positive abnormal pre-announcement volumes in target equity options in a quarter of all takeover transactions. The abnormal trading volume is significantly larger in OTM call options than in ATM or ITM call options. The evidence that informed traders may also engage in writing ITM put options is weaker. One reason for this discrepancy may be that writing naked (especially ITM) puts is risky, as the failure of deal negotiations could lead to a sharp stock price drop. Selling naked puts also requires large margins, which may impose binding capital constraints on traders.

We verify our results using a plethora of alternative tests and robustness checks for option volumes to ensure that our findings do not arise by pure chance. The results of all additional tests overwhelmingly agree with the previous findings, yielding either similar or stronger results, both qualitatively and quantitatively. In order not to distract the reader from the second key objective of our analysis, i.e., the assessment of the likelihood that the observed informed trading activity is illegal, we discuss the details of these additional tests in the Online Appendix Section A-II.

4.2 Characteristics of Abnormal Volume

We next examine whether certain target companies are more likely than others to exhibit unusual trading volumes. We investigate several takeover deal characteristics that may imply a higher likelihood of informed trading, as they are associated with greater announcement returns. Hence, we regress the cumulative abnormal log trading volume in call and put options over the 30 pre-announcement days on a set of categorical variables reflecting deal characteristics and market activity variables. We first test the following model:

$$\begin{aligned} CABVOL = \beta_0 + \beta_1 SIZE + \beta_2 CASH + \beta_3 TOE + \beta_4 PRIVATE + \beta_5 COLLAR \\ + \beta_6 TERM + \beta_7 FRIENDLY + \beta_8 US + \gamma_t + \varepsilon, \end{aligned} \tag{1}$$

[8]The expected cumulative abnormal volume for OTM put options is slightly higher than that for ITM put options. The difference of 433 contracts is, nevertheless, small in unit terms, given that it is a cumulative measure taken over 30 days.

where $CABVOL$ denotes the cumulative abnormal trading volume in call or put options respectively, which we scale for each target by the average predicted volume in the event window.[9] All specifications contain year fixed effects γ_t, and standard errors are clustered by announcement day.

Our strongest prior is that cumulative abnormal volume should be higher for cash-financed deals, given that cash-financed deals are known to have higher abnormal announcement returns (Andrade, Mitchell, and Stafford, 2001) and are more likely to be completed (Fishman, 1989). Thus, we expect that an informed trader will benefit more from trading in such deals if he anticipates a higher abnormal return and is more certain that he will earn it. We test for this by including a dummy variable $CASH$ that takes the value one for purely cash-financed deals. In addition, traders with private information may prefer opening positions for larger companies, whose stocks (and, therefore, their options) tend to be more liquid, and hence less likely to reveal unusual, informed trading. Thus, we expect cumulative abnormal volume to be higher for larger deals, measured by $SIZE$, a dummy variable that takes the value one, if the deal is above the median transaction value, and zero otherwise. According to Acharya and Johnson (2010), firm size may also proxy for the number of insiders to the deal and, thus, the probability of information leakage. A bidder who has a toehold in the company (TOE) could also be likely to gather and trade on private information about a future takeover. Alternatively, a toehold investor with privileged information may refrain from trading as he would be among the first suspects in any investigation. The existence of a foothold may also be interpreted as publicly observable information (Jarrell and Poulsen, 1989). We also control for other deal characteristics, such as whether the target is taken private post-takeover ($PRIVATE$), whether the deal has a collar structure ($COLLAR$), whether it involves a termination fee upon the failure of deal negotiations ($TERM$), whether the deal attitude is considered to be friendly ($FRIENDLY$), and whether the bidder is a U.S.-headquartered company (US).

The results for the benchmark regressions of cumulative abnormal volume in the target call options are reported in column (1) of Table 4. Firm size is a significant positive predictor of abnormal options volume. This evidence is consistent with the view that informed trading in target call options is greater for larger, more liquid companies, for which it is easier to hide informed trading, and when there is a greater probability of information leakage (Acharya and Johnson, 2010). Our results are similar if we proxy firm size using company sales. We have also examined the number of target and

[9] This analysis is based on a natural log transformation of volume. Hence, scaled cumulative abnormal log volume is comparable across companies, and interpretable as a percentage relative to predicted volume.

acquirer advisors as a proxy for information leakage, but the results are not statistically significant, similar to the findings of Heitzman and Klasa (2016). This may be due to insufficient variation in the number of advisors for publicly traded firms (91.2% of the sample has less than 5 advisors, and the median is 2), whereas Acharya and Johnson (2010) examine a sample of private equity buyouts, which typically feature a higher number of equity participants. Quantitatively, a target deal above the median transaction value has, on average, 3.32% greater cumulative abnormal call trading volume relative to its normal volume than a target below the median deal size.

Abnormal options volume is also significantly greater for cash-financed deals, which are expected to have higher abnormal announcement returns. Cash-financed deals have, on average, 6.37% greater cumulative abnormal volume than non-cash-financed deals. Given that the average cumulative abnormal volume is approximately 10,000 contracts, the typical cash-financed deal has about 637 more contracts traded during the 30 days before an announcement. The cash indicator is consistently robust across all specifications, with similar economic magnitudes.

If the bidder already has a toehold in the company, cumulative abnormal volume is about 5.6% smaller. The negative coefficient supports the interpretation that investors with a toehold may make more of an attempt to keep their intentions secret, as they would be natural suspects in the case of insider trading. The coefficient of TOE, however, looses its significance in other specifications with additional control variables. Deals that embed a collar structure and a termination fee in their negotiations are also more likely to exhibit higher cumulative abnormal volume, by about 7.23% and 5.65%, on average. A collar structure implicitly defines a target price range for the takeover agreement. Moreover, a termination fee makes it more likely that a negotiation will be concluded. Thus, both variables are associated with greater certainty about the magnitude of the target's stock price increase, conditional on an announcement being made. This is consistent with a greater likelihood of informed trading in the presence of greater price certainty. All other variables are statistically insignificant. The adjusted R^2 of the regression, 6%, is reasonable, given the likely idiosyncratic nature of the derived statistic for cumulative abnormal trading volume.

We next examine whether market activity variables have an impact on the pre-announcement cumulative abnormal call volume. We include $TRUNUP$, the pre-announcement cumulative abnormal stock return for the target, $TANNRET$, the target's announcement-day abnormal return, $TTPRET1$, the target's post-announcement cumulative abnormal return, and $ARUNUP$, the abnormal stock return for the acquirer before the announcement day. $MKTVOL$ denotes the market volume on the day before the announcement day. These results are reported in column (2). The pre-announcement run-up in the target's stock price is strongly positively related to the cumulative abnormal volume, consistent with Acharya and Johnson (2010) and Wang (2013). This finding may suggest that abnormal options trading activity on the target firm may be instigated by the target's firm positive stock price momentum. We examine this possibility in section 5. On the other hand, the target's cumulative abnormal announcement return is negatively associated with the cumulative abnormal trading volume for call options. All other variables are statistically insignificant. The coefficients remain robust for large deals that are cash-financed, that have a collar structure, and that have a termination fee. In this final regression specification, the explanatory power increases to 12%. In unreported results, we repeat the analysis for cumulative abnormal volume in put options. While the results are qualitatively similar, the magnitudes of the coefficients are typically smaller.

The insignificant (negative) relation between abnormal call options volume and the abnormal announcement (post-announcement cumulative) return may appear at odds with the notion that the abnormal options activity is informed. The results are nevertheless consistent with the findings in Jayaraman, Frye, and Sabherwal (2001), Klapper (2013), Spyrou, Tsekrekos, and Siougle (2011), and Podolski, Truong, and Veeraraghavan (2013). Cao, Chen, and Griffin (2005) rely on signed volume to show that buy minus sell call volume order imbalance in the pre-announcement period positively predicts two-day abnormal announcement returns. In unreported regressions, we use signed options volume data, taken from the International Securities Exchange for a subsample of approximately 400 takeovers from 2006 onwards, and confirm the positive relationship between pre-announcement call option order imbalance and announcement returns. As we use unsigned volume, the relation is not as straightforward. If much of the insider information gets incorporated into prices in the pre-announcement period (Meulbroek, 1992), one may expect a negative relation between the volume run-up and the announcement return, as the stock price run-up and the announcement effect are negatively correlated for a given offer premium (-14% in our sample). A priori, the relation between an unsigned volume metric measured over thirty days and the announcement effect is unclear. Rather, we would expect a positive relation between the magnitude of the abnormal pre-announcement options volume and the total premium paid by the bidder, which corresponds to the sum of the pre-announcement run-up ($TRUNP$), the announcement effect ($TANNRET$), and the post-announcement return ($TTPRET1$). Thus, we replace these three variables in column (3) with the total premium ($TOT\_PREMIUM$) and find a significantly positive relation, consistent with the interpretation that the options activity is informed.

In columns (4) and (5), we corroborate the previous findings using a logistic regression for which the dependent variable is an indicator variable that takes on the value one, if a deal has cumulative abnormal call options trading volume at the 5% significance level, and zero otherwise. Overall, the evidence supports a positive relation between the abnormal options activity in the pre-announcement period and variables that are positively correlated with a higher probability of informed trading.

5 Informed vs. Insider Trading

It has been a long-standing debate as to whether the stock price run-up before M&A announcements is rationally anticipated or whether it is the result of private information. The pre-announcement run-up in options volume may be due to rational anticipation of upcoming takeover announcements, arising through rumors about upcoming tender offers, speculation because of industry-specific merger waves, or simply because of the superior ability of certain types of investors to forecast deal activity. Alternatively, it could arise through trading on private information. In this section, we attempt to assess the likelihood of the informed options activity being illegal, in light of these alternative explanations. To this end, we examine deal-by-deal whether publicly available information may explain the pre-announcement run-up in options volume.

5.1 A Legal Definition of Insider Trading

In the United States, insider trading is regulated under the 1934 Securities Exchange Act ("Exchange Act") and the responsibility for enforcement lies with the SEC. More specifically, it is Section 10(b) of the Exchange Act and, in particular, Rule 10b-5, as well as Section 14(e) and Rule 14e-3 in the limited context of tender offers, that defines as illicit those trades that are based on material non-public information, and that are made in breach of fiduciary duty.[10]

Registered insiders – corporate officers, directors, or large block-holders with a stake of 10% or more in the company – are allowed to trade in their company's stock, or options written on

[10] For details on insider trading regulations, see Bainbridge (2007), Morrison-Foerster (2013), Crimmins (2013).

it, but are bound by rules relating to mandatory disclosure and timing, governed by Section 16a of the Exchange Act. Thus, their trades may be of a legal or illegal nature, depending on the circumstances of trading and disclosure. Such "insiders" are bound by the "classical" theory implicit in the antifraud provisions in the Exchange Act, which holds them liable if they have traded based on material non-public information from their company, and if they have violated their fiduciary duty to the company and its shareholders.[11]

In addition, there are traders who are not directly connected with the company. Such agents may analyze multiple pieces of immaterial non-public information to infer a material "mosaic" conclusion, allowing them to make educated guesses with superior forecasting ability. Informed trading based on the so-called "mosaic theory" may not necessarily be illegal. However, such informed traders are restricted by the "misappropriation" theory implicit in the antifraud provisions in the Exchange Act, which prohibits trading based on information that is misappropriated from a third party to whom the investor owes a fiduciary duty. Nevertheless, a trade initiated by a "tippee," who has received material non-public information from a "tipper," may not be liable for conviction if the person did not know that the information was obtained in breach of fiduciary duty, at least that was the case prior to 2012.[12] The boundaries of illegal insider trading are thus, at best, blurry. Naturally, a regulatory system dependent on common law is evolving and path dependent. Allegedly, it appears that the ability and willingness to convict anyone for illicit insider trading practices is more of an art than a science, and may be influenced by, among other things, the aggressiveness of the prosecutors and the prevailing public mood.[13]

Until proven otherwise, an accused investor remains innocent, and hence we are unable to draw a clear and precise distinction between a trade that is speculative, informed and legal, and one that is illegal, as defined by Rule 10b-5 of the Exchange Act. What we can do is focus our microscope on each deal, narrow down on the possibility that the unusual/abnormal pre-announcement options

[11]A recent decision by the Second Circuit in 'United States v. Newman, in December 2014, has raised the bar on identifying insider trading, ruling that it is necessary to show that (a) the trader knew that the information was confidential and illegal, and (b) that inside information was provided in exchange for something that benefited the provider. However, in December 2016, in Salman v. United States, the Supreme Court rejected the Second Circuit's requirement that the tipper should have received a benefit of a pecuniary or similarly valuable nature. Subsequently, other cases have relied on the new Supreme Court standard.

[12]"In 2012, a decision by the Second U.S. Circuit Court of Appeals in SEC v. Obus arguably expanded tippee/tipper liability - at least in SEC civil enforcement actions - to encompass cases where neither the tipper nor the tippee has actual knowledge that the inside information was disclosed in breach of a duty of confidentiality" (Morrison-Foerster, 2013).

[13]The wave of prosecutions initiated by Rudolph Giuliani in the 1980s, and by Preet Bharara in recent years, both U.S. Attorneys for the Southern District of New York, are indicative of such aggressiveness.

activity might be explained by publicly available information. If we fail to find a public source of information, we flag a deal as suspicious and indicative of illicit activity. In Section 6, we cross-check each flagged deal with the list of takeover announcements that were subject to SEC litigation for illegal insider trading. Comparing the characteristics of option trades that were investigated to flagged abnormal pre-announcement options activity complements the assessment of the likelihood that the informed options activity may be illegal.

5.2 Speculation

It is well known that merger activity is pro-cyclical and arrives in industry-specific waves (Andrade, Mitchell, and Stafford, 2001). The earlier findings for the sources of informed trading, namely that cumulative abnormal volumes are significantly related to the run-up in stock prices, may also suggest that the abnormal options activity may simply be the result of positive price momentum on the target's stock. Thus, speculation may explain the pre-announcement options activity. Such a selection bias would be consistent with the view that takeovers are anticipated.

We examine this possibility by constructing several control samples, matching them based on either on the activity in the underlying stock, or on firm characteristics.[14] In other words, for each takeover deal in our sample, we look for a similar firm with traded options that resembles the takeover firm either in terms of stock market activity measures for the underlying stock, or based on a number of selected firm characteristics. For the market-based control sample, we match firms based on three-month moving averages of a firm's stock return, stock return volatility using the exponential-weighted moving average model, stock trading volume, percentage bid-ask spread to capture illiquidity, and three-month cumulative stock returns to capture the momentum in a firm's stock. We match only targets for completed deals based on the month prior to the takeover announcement. We sample with replacement, and use the Mahalanobis distance metric to evaluate the "closeness" of the match.

The findings reported in Table 5 suggest that the run-up in options trading volume prior to the announcement is unlikely to be explained by investors speculating in the options market after having observed (perhaps) informed trading activity in the underlying shares. We report results for aggregate options volume, and separately for the aggregate call and put volumes, using the MMV

[14] We explore different combinations of market variables and/or firm characteristics for the matching procedure, using both raw volume and natural log transformations of options volume. We have also implemented tests using takeover propensity score matched samples following the methodology in Roberts and Whited (2012). All robustness tests are quantitatively and qualitatively consistent with the reported evidence.

model, which controls for lagged values of both dependent and independent variables. About 25% of all deals have positive abnormal call options trading volume, with a lower frequency (16%) of unusual options activity for put options. The average cumulative abnormal total options and call volume is 10,768 and 11,145 contracts, respectively. Both values are statistically significant at the 1% level.

Panel B of Table 5 reports the results for the control groups using the first best (PS1) and two first best (PS2) matches. The frequency of deals with statistically significant cumulative abnormal volume at the 5% significance level is lower than in the treatment sample, ranging between 13% and 14%. Focusing on call options, the average cumulative abnormal volume is significantly lower than for the treatment group, i.e., 1,011 option contracts for the control sample using the first best match, compared to 11,145 for the treatment sample, and 764 option contracts for the control sample using the second best match. Importantly, none of the statistics is statistically significant.

In Panel C, we report the average treatment effects obtained from a regression of the cumulative abnormal options volume on an indicator variable that takes on the value one, if a target belongs to the treatment group, and zero otherwise. All the reported regressions control for the matching variables to account for residual differences between the treatment and control groups, year fixed effects, and standard errors are clustered by announcement date to account for cross-sectional correlation due to possible clustering of announcement dates. These difference-in-difference tests are akin to controlling for both the effects of market activity in the underlying or firm characteristics, and the effects of time. The difference in the average cumulative abnormal volume is 10,356 and 10,748 contracts for call options using the first or two first best matches, respectively, and ranges between 11,516 and 12,043 contracts for the aggregated options volume. For put options, the difference for the two sets of matches tends to be considerably smaller, at 1,687 or 768 contracts, respectively, and is not significant. In contrast, the difference is statistically significant at the 1% significance level for call options and the aggregated options volume.

Table A-6 in the Internet Appendix documents the matching quality for both control samples. While most variables are statistically indistinguishable between the treatment and control groups, while those that are resemble each other closely in terms of economic magnitude. The significant differences in options activity across the two groups are visually depicted in Figure 2, which reports the average abnormal volume and average cumulative abnormal volumes in both the treatment and the control group using the first best match. Clearly, the average abnormal options volume rises significantly ahead of the announcement for the takeover sample (dashed lines), while it fluctuates randomly for the control groups (solid lines).

We further match targets based on firm characteristics, and report results for a control sample matched on size, measured by the natural logarithm of total assets; industry takeover activity, captured by an indicator variable that equals one, if a takeover attempt occurred in the same 4-digit SIC code in the previous calendar year; the presence of at least one institutional block-holder with a minimum 5% equity stake; firm leverage measured as the ratio of total liabilities over total assets; and the natural logarithm of the average stock trading volume in the previous calendar year. Although we do require firms eligible to be included in the control groups to have traded options, not all of these firms have continuous option price and volume information available over the 90 days preceding the announcement dates. We, therefore, lose some additional control firms from our sample. While the treatment group has 1,346 firms, the control group, using the first (and second) best match, has 1,059 (2,097) firms.

Results for the sample matched based on firm characteristics are qualitatively and quantitatively similar. Because of space constraints, we only report the summary statistics for matching variables between the treatment and control groups in Table A-6 of the Internet Appendix to underscore the quality of the match. We do the same with the graph for the average and average cumulative abnormal volumes in both the treatment and the control groups, using the first and two first best matches, in Figure A-5. Finally, we also perform a robustness test by matching on size (natural logarithm of firm assets), market-to-book ratios, and momentum (either the 12-month cumulative return over the previous calendar year or the past 3-month cumulative stock return in the month prior to the takeover). Numerical results are available in Table A-7 of the Internet Appendix. Overall, these findings suggest that the unusual options activity is significantly larger in the sample of firms that were takeover targets than in the sample of firms that were not, but closely resemble the takeover targets based on observable industry and firm characteristics.

5.3 Buying the Rumor

Jarrell and Poulsen (1989) find that the run-up in stock prices before a sample of 172 tender offers is mostly associated with observable and legal factors. Thus, run-ups in trading activity could reflect the market's correct anticipation of future takeover activity based on information "heard on the street." We test this hypothesis using RavenPack News Analytics, a leading global news database widely used in quantitative and algorithmic trading, which contains detailed real-time information on news and rumors about M&A activity.

RavenPack extracts textual information from major news outlets and publishers, such as Dow Jones Newswires, the Wall Street Journal, Barron's, regulatory and public relation feeds and over 19,000 other traditional and social media sites. The company transforms this information into a structured data feed that can be used in quantitative analysis.[15] The database starts in January 2000, and we have access to it for the period up to August 2012, which slightly reduces the takeover sample. Previous finance studies that have used this information database include, among others, Kolasinski, Reed, and Ringgenberg (2013), Dang, Moshirian, and Zhang (2015), and Schroff, Verdi, and Yu (2014).

We rely on the information category "acquisitions-mergers." There are, in total, 88,103 observations for 6,913 different entities (CUSIP identifiers), coming from news sources classified as full articles, hot news flashes, news flashes, press releases, and tabular material. The bulk of the information on tender offers comes from news flashes, which make up 60.39% of the sample. The two other important categories are full articles and press releases, representing 17.37% and 19.85% of the information, respectively, while hot news flashes and tabular material contribute only marginally to the structured information.

We flag each deal with an indicator that equals one if there exists any rumor about a deal in RavenPack during the pre-announcement period, and zero if not. We find a rumor or news story on 5,195 different deal-days, corresponding to 877 unique deals from our sample. Most of the news and rumor information appears on the announcement day itself, as can be seen in Table 6, which illustrates the total number of observations and unique deals in different sample windows. Rumors or news stories exist in the 30-day pre-announcement period for only 170 firms, which corresponds to approximately 9% of our sample, or 13.72% on a proportional basis, given that 1,239 takeovers were announced between January 2000 and August 2012. Most importantly, out of the 467 takeover announcements with significant informed options trading, i.e., statistically significant cumulative abnormal options volume at the 5% significance level, we associate only 40 deals, i.e., 8.57% of the

[15]We are grateful to Bohui Zhang for pointing us towards this news database.

informed trading sample, with news or rumors captured by RavenPack.

It is possible that rumored firms drive the unusual trading activity we document ahead of the announcements. Thus, we investigate whether there is more abnormal volume in options for those firms that have rumors compared to a control group of targets without rumors. Figures 2c and 2d visually report the differences in average and average cumulative abnormal option trading volumes for the sub-samples with and without rumors in the 30-day pre-announcement period. These tests are based on a natural log transformation of volume. The two sub-samples are statistically indistinguishable from each other, and the average abnormal trading volume is as unusual in the sub-sample with news "heard on the street," as in the sample without. The same results hold if we screen the sample for news and rumors in the 90-day pre-announcement period.[16]

We provide a visual overview of the sub-sample overlaps using a Venn diagram embedded in Table 7. The large square defines the full sample of 1,859 takeovers, which we label Ω. The informed trading sub-sample is characterized by the rectangle A, which indicates that 467 deals are flagged with statistically significant positive cumulative abnormal trading volume at the 5% significance level, corresponding to 25.12% of the entire sample. In the 30 pre-announcement days, we identify news for 170 deals. The news sample is depicted as the rectangle B, and accounts for 9.14% of the overall sample. Out of the 170 takeovers that are associated with news, 40 overlap with the 467 deals flagged for informed options trading, representing 8.57% of the informed trading sample. The remaining overlaps are described in the following subsections. We also find that tests based on a natural log transformation of volume indicate no statistically significant difference in abnormal trading volume between the sub-samples with and without news. Rumors and news about upcoming merger activities are thus unlikely to explain the full amount of directional trading volume on targets ahead of announcements that we document.

5.4 Legal Insider Trading

Registered corporate insiders have access to privileged information. As a result, the SEC imposes on them the strict legal requirement that they must file with the regulator whenever they trade in their

[16] Using the sentiment scores associated with Ravenpack news for the subsample of 170 deals with news and rumors, we confirm previous findings that sentiment explains abnormal volume (Han, 2008). We note that bullish signals lead to more abnormal trading in both calls and puts, while the strength of our previous findings of unusual options activity ahead of takeover announcements was primarily confined to calls. Thus, rumors and news trigger speculation and more trading activity overall, but not necessarily directional trading on the target.

company's securities and their derivatives.[17] Even though it is illegal for insiders to trade the target firm's securities prior to a takeover announcement, there exists some evidence of such activity in prior research. This could be explained through limited enforceability of insider trading laws, or a lack of prosecution (Arshadi and Eyssell, 1991; Bris, 2005). For example, in the U.S., Agrawal and Nasser (2012) document that insiders increase their net stock purchases prior to takeover announcements. As prior research has not reported on transactions by registered insiders in target firms' options, we examine the registered derivatives-trading activity, which is logged in Table 2 of the Thomson Reuters insider filing data feeds.[18]

We made an elaborate search of transactions by insiders for our 1,859 target firms and find not a single record of a transaction, purchase or sale, of a derivative security within the 30 days preceding the announcement. Nevertheless it is possible that the unusual options volume we document stems from tips originating with senior executives at target companies or from former school ties (Cohen, Frazzini, and Malloy, 2010). Indeed, Ahern (2017) reports that tips that lead to illegal insider trades often originate from corporate executives.

5.5 Leakage

Evidence in Roll, Schwartz, and Subrahmanyam (2010) and Johnson and So (2012) suggests that option volume tends to rise in response to positive stock returns. Thus, the abnormal volume effects observed in the options market could be driven by pre-announcement leakage or informed trading in stock markets. We test this conjecture in several ways.

First, in all abnormal volume tests, we systematically control for both contemporaneous and lagged stock returns of the target companies and the overall market. This does not affect the evidence of abnormal options activity in the pre-announcement period. Second, we conduct an event study for abnormal stock returns, and find that only 7.26% (135 deals) of all takeovers in our sample exhibit abnormal stock returns at the 5% statistical significance level. Out of the 467 deals that

[17] Corporate insiders are defined broadly as people who have "access to non-public, material, insider information." They are required to file SEC Forms 3, 4 and 5, and under certain circumstances, Form 144, whenever they trade or intend to trade in their company's securities.

[18] We screen all open market derivative transactions as well as information on the exercise, award, and expiration of stock options, based on the Form 4 filings, which document a change in an insider's ownership position. We examine options, calls and puts, warrants, employee stock options, and group derivative security types with option-embedded features, such as convertibles. We ignore option expirations and swap transactions, and we drop all records that are flagged with the cleansing codes S or A, indicating inaccuracies in the data that are impossible to validate or are missing.

we associate with informed options trading, only 45 events exhibit abnormal stock returns, as is illustrated by the overlaps of the informed option trading subsample A and the subsample with abnormal stock returns D in the Venn diagram illustrated in Table 7.

Third, although we do find that about 18.93% of all deals have abnormal stock volumes at the 5% level, the expected cumulative abnormal log volume for stocks is 1.64, which is about a fifth of what we find in the options market, i.e., 8.59 in terms of logs.[19] Even though stock volume is not directly comparable to (unadjusted) options volume, the net effect from multiplying the options volume by the hedge ratio, i.e., the delta, and the size of 100 shares specified in the standard options contract, would make this difference even wider. This further shows that the magnitude of abnormal volumes in the options market is greater than in the stock market. Most importantly, out of the 467 takeover announcements with abnormal options trading volume, only 181 deals are associated with abnormal stock trading volume (subsample C in the Venn diagram illustrated in Table 7). Overall, the abnormal options trading volume for 262 deals (14.09% of the sample) is unlikely to be explained by activity in the stock market.

Fourth, we have examined the entire distribution of the option-to-stock volume ratios (see Figure A-4 in the Internet Appendix). We find a significant increase in the ratios of the call-to-stock and the call-to-put volumes, in particular at the right tail of the distribution, but only a modest increase in the ratio of the put-to-stock volume. Dividing the raw trading volume in stocks by 100 to make it comparable to the volume in options markets (since each option contract is based on 100 shares), we find that the average (median, 90th percentile) call-to-stock volume ratio increases from 7% to 11% (1% to 4%, 15% to 29%) in the pre-announcement period. Similarly, the call-to-put volume ratio increases from 16.83% to 30.72% at the 90th percentile of the distribution, while the put-to-stock volume increases by a more modest amount from 6% to 8% over the 30 pre-announcement days.

Finally, we have studied the lead-lag relationship between options and stock volume in the 30 pre-announcement days. While options and stock volumes are positively related in contemporaneous regressions, options volume predicts stock volume, but stock volume does not predict options volume. Thus, if anything, the activity in the stock market responds to the activity in the options market, and not the other way round. These findings are consistent with Cao, Chen, and Griffin (2005)

[19]We find that about 24% of all deals have abnormal stock volumes at the 5% level, if we use a natural log transformation of stock volume, which we compare to 33% of all deals that have cumulative abnormal options volume using a natural log transformation. As the relative difference between deals with abnormal stock and options volume is smaller for results using raw volume, we consider these magnitudes to be on the conservative side.

and Liu, Lung, and Lallemand (2015), among others, who find that the options market displaces the stock market for information-based trading during the periods immediately preceding takeover announcements, but not in normal times.

5.6 Other Explanations - Deal Predictability, Activist Investors, M&A Advisors

We assess the ability of traders to predict merger activity using publicly observable information. Consistent with previous literature (Palepu, 1986; Ambrose and Megginson, 1992; Cremers, Nair, and John, 2009; Billett and Xue, 2007), we find that it is difficult to correctly predict, using publicly available information, whether a company is subject to a future takeover threat.[20] Takeover propensity scores are low, about 4% on average, and the explanatory power of the predictability models is not much higher than 5%. Even if some investors have superior ability to process information (Solomo and Scholtes, 2015), it is much less conceivable that they could correctly predict the exact timing of a deal. Thus, it seems unlikely that the abnormal options volume, which is most pronounced in the ten days preceding the public announcement, is due to investors correctly predicting future announcement dates.

Another source of information comes from registered active investment advisors, who need to file 13D schedules no later than 10 days following the acquisition of beneficial ownership of more than 5% of any class of publicly traded securities. While Ravenpack generally captures news associated with 13D filings, not all filings necessarily trigger news and, hence, may be missing in that database. Thus, we need to examine whether any such filings occurred within the 90 days prior to the announcement, using the comprehensive SEC EDGAR database on beneficial ownership reports.[21] In total, we identify 181 13D filings during the 90 pre-announcement days, of which 74 schedules are filed within 30 days before the public announcement of a takeover, relating to 161 and 70 unique deals, respectively. Out of the 467 deals identified with informed trading, only 17 coincide with the filing of beneficial ownership report in the 30 pre-announcement days.[22] These results are consistent with Collin-Dufresne, Fos, and Muravyev (2015), who find little evidence of derivatives trading by activist

[20]We report details on the takeover predictability model in the Internet Appendix.

[21]We are indebted to Jan Schnitzler and Ulf Von-Lilienfeld-Toal for sharing this data with us.

[22]If we consider filings within 90 days before the announcement, 43 deals have both abnormal options trading volume and 13D filings. We note that any options activity in response to such a filing during the 90 to 30 days before the announcement would introduce a bias against finding evidence of informed options trading, as this would increase the predicted normal volume during the event window. Thus, we are primarily concerned with filings that occur during the 30 days preceding the formal announcement.

investors, and no difference in call volumes on days when Schedule 13D filers trade, and on days when they do not trade. Abnormal pre-announcement options activity is thus unlikely driven by information derived from 13D filings.

Some authors, using quarterly data, argue that investment banks advising bidders take equity or options stakes in the target companies during the window between seven and one quarters before the announcement (Bodnaruk, Massa, and Simonov, 2009; Lowry, Rossi, and Zhu, 2016). However, using more granular high-frequency data on broker level transactions and connections, Griffin, Shu, and Topaloglu (2012) find that such institutional investors do not engage in trading on inside information during the two to twenty days before takeover announcements.

5.7 Bottom Line

Abnormal options activity is pervasive ahead of M&A announcements, and reflected in 467 takeover deals, corresponding to 25.12% of our sample. We have shown that it is difficult to predict the exact timing of merger announcements and that speculation is unlikely to be driving our results, as similar findings are absent from control samples matched on stock market activity and firm characteristics. In addition, news and rumors are unlikely to explain the full extent of informed options activity, nor is it likely that leakage of information leads people to trade in the stock market, which is picked up by astute traders who then exploit their information in the options market.

The four-dimensional Venn diagram in the top left figure illustrated in Table 7 lays out all different sample cuts in the study. For 236 deals, i.e., 13% of the total sample, we find it challenging to associate the abnormal option market activity with public sources of information. In fact, the 236 deals represent a lower bound, as 404 deals (21.73%) have abnormal volume in both the stock and options market, and we confirm prior results showing that the options volume leads stock volume in the pre-announcement period.

Proving illegal insider trading is tremendously challenging. A civil or criminal conviction often requires wire taps or other hard legal evidence, typically gathered with the help of the Federal Bureau of Investigation or other federal agencies. We nevertheless aim to further understand the sources of informed options trading and better assess the likelihood that this activity is illegal. Thus, we tie in Section 6 the statistical evidence of informed trading to the civil litigations initiated by the SEC for instances of illegal security trading around M&A announcements. We compare the characteristics of option trades that were investigated to the flagged abnormal options activity and cross-check the deals with statistically significant abnormal options volume with the litigation record of the SEC.

6 SEC Litigation Reports

We now verify whether there is any relationship between the abnormal options activity we document and the insider trading cases that we know, with the benefit of hindsight, to have been prosecuted. To do so, we scan more than 8,000 litigation releases concerning civil lawsuits brought by the SEC in federal court.[23] We extract all cases from the SEC files that encompass trading in stock options around M&A and takeover announcements, i.e., civil complaints against illegal insider trading in options, or, in both stocks and options. We complement missing information in the civil complaint files with information from the criminal complaint files, accessible through the Public Access to Court Electronic Records (PACER) from the U.S. Department of Justice (DoJ). A summary overview of the trades and their characteristics is reported in Table 8, and more detailed case-specific information is available upon request. We find that the characteristics of prosecuted trades closely resemble the characteristics of those options that exhibit unusual option volumes and prices, which we find to be pervasive prior to takeover announcements.

6.1 The Characteristics of Insider Trading

In total, we identify 408 M&A transactions involved in insider trading litigations between January 1990 and December 2013. Among these M&A transactions, 258 are investigated due to insider trading in stocks only, and 150 deals involve insider trading in options. About one third of these cases (47 deals) cite insider trading in options only, while the remaining 103 cases involve illicit trading in both options and stocks. The large number of investigations for stock trades relative to those for option trades stands in contrast to our finding of pervasive abnormal call option trading volumes that are greater than abnormal stock volumes.[24]

Out of the 150 SEC cases with illegal option trades, 131 correspond to our sample period, which

[23] We are grateful to Kenneth Ahern for valuable discussions on this data. The litigation reports are publicly available on the SEC's website, https://www.sec.gov/litigation/litreleases.shtml.

[24] An interesting case is the takeover of Nexen by CNOOC, which was involved in a SEC lawsuit because of insider trading in stocks, while the newspapers broadly discussed unusual option trades. Also note that the litigation files contain only five instances of insider trading involving options written on the acquirer, among which three are within the bounds of our sample period.

stretches from January 1996 to December 2012. Several of the litigated cases do not appear in our sample, one reason being sample selection criteria for our study. On the other hand, some prominent cases of insider trading, such as the 2004 JPM Chase-Bank One merger, in which one investor was alleged to have bought deep out-of-the-money (DOTM) calls just (hours) before the announcement, do not appear in the SEC database. We have three potential explanations for these discrepancies.

First, the SEC only reports civil litigations. If a case is deemed criminal, then the DoJ will handle it and it will usually not appear in the SEC records. We believe this reason to be an unlikely cause, given that a case typically does not come under criminal investigation without being investigated in the first instance by the SEC. Our intepretation is based on several discussions with securities law firms and prosecutors. It is also corroborated by Ahern (2017), who identifies only two cases among all (not just for M&As) the DoJ criminal complaints for insider trading that do not appear among the SEC civil litigation records. Second, the SEC may refrain from divulging the details of a case to protect the identity of a whistleblower. In these instances, if the case is settled out of court, it will not appear in the public record. Third, the SEC is unlikely to litigate if there is little chance of indictment. This could depend on the availability of clear legal evidence of insider activity or the involvement of a foreign national (entity). In spite of these biases, 90 of the SEC litigation cases with illegal option trades are covered by our study, and 154, if we include those litigations of takeovers that feature only illegal stock trades. Assuming that the publicly disclosed deals represent all litigated cases, the public records suggest that the SEC engaged in litigation in about 8.28% of the 1,859 takeover deals included in our sample (see the informed trading subsample E in Table A-9). The four-dimensional Venn diagram on the top right figure of Table A-9 in the external appendix illustrates visually that, out of the 467 deals with informed options trading activity, 43 deals (9.21% of the subsample of informed trading) are litigated by the SEC/DoJ. Note also that SEC/DOJ initiated a litigation for only 24 deals out of the 236 transactions with informed options activity that is unlikely explained based on public sources of information.

We next describe the characteristics of those option trades available in the SEC litigation reports.[25] 59.33% of all cases are cash-financed transactions. Unreported statistics suggest that only

[25] The SEC likely has access to much more granular information on these cases, but we are not aware of any study that describes the characteristics of illegal option trades. Meulbroek (1992) and Frino, Satchell, Wong, and Zheng (2013) describe the characteristics of illegal stock trades. Ahern (2017) analyzes the same data, but he focuses on insider networks and does not report any information on inside trades. Kacperczyk and Pagnotta (2016) study price impact of illegal trading using the SEC litigation files.

23.33% are purely stock-financed, while hybrid financing structures account for 12% of the litigation sample, and the financing structure is unknown for the remaining 5.33% of the sample. We would expect investors with private information to be less likely to trade on stock-financed announcements, as the announcement return is typically higher for cash deals. This is consistent with our finding of a greater cumulative abnormal call option volume for such transactions. The average profit reaped through "rogue trades" (in both options and stocks) during our sample period, is 1.084 million USD. Compare this to Meulbroek (1992) and Frino, Satchell, Wong, and Zheng (2013), who report median insider profits of 24,673 USD and 26,860 USD, respectively, for illegal trading in stocks. For trades on the target firms, this profit arises from transactions that are almost exclusively purchases of OTM call options, at a single or multiple strike prices.

The litigation reports reference put trades in only 6% of all cases. For 22 out of these 25 put trades, we can identify the trading direction, which suggests that these were all sales of put options, consistent with the hypothesis that insiders would buy OTM calls and/or sell ITM puts. Table 8 shows that the average ratio of the stock price to the strike price, in the case of call options purchased on the target, is 93%. Only 25 observations ($\approx$ 6%) have a moneyness ratio above 1.05, the cut-off level we defined for ATM options. Out of 25 put option trades on the targets, on the other hand, the average ratio of the stock price to the strike price is 97.29%, which is within our definition of ATM, but 12 of all these trades relate to sales of ITM put options with an average ratio of the stock price to the strike price above 105%.

Furthermore, the insider trades are primarily executed in short-dated options, with an average time to expiration of 1.87 months. We note that there is a large variation in the timing of trades, the average inside trader transacting 21 days before the announcement date. However, the median trade occurs 11 days prior to the announcement. In contrast, Frino, Satchell, Wong, and Zheng (2013) document that insiders trade in target firms' stocks on average 7 days before the announcement. This finding is supportive of the earlier results that options volume leads stock volume in the pre-announcement period. It takes the SEC, on average, 644 days to publicly announce its first litigation action in a given case. Thus, assuming that the litigation releases appear shortly after the actual initiation of investigations, it takes the SEC almost two years, on average, to prosecute a rogue trade.

The fines, including disgorged trading profits, prejudgment interest and civil penalty, if any, appear large enough to adequately recuperate illicit trading profits. The average fine is, at 1.889

million USD, about double the average rogue profit. This is, however, largely driven by cases related to 2007, which exhibit a ratio of the average fine to the average profit of about 4.39. Fines are also larger than those reported earlier for illegal trading in stocks. The median penalty reported by Meulbroek (1992) and Frino, Satchell, Wong, and Zheng (2013) is 21,000 USD and 67,511 USD, respectively. Finally, the typical insider trade involves more than one person, and is often a network, as documented in detail by Ahern (2017). We find that the average number of defendants is four.

To summarize, the bulk of the prosecuted trades relate to target companies and are purchases of plain-vanilla short-dated OTM call options that are approximately 7% OTM, occur within the 21 days prior to the announcement, and are more frequently related to cash-financed deals. There is some indicative evidence of sales of ITM put options on the target companies. These characteristics closely resemble those of the abnormal options volumes of the 467 deals in the sample that we flag for informed trading. These deals exhibit abnormal option trading volumes that are particularly pronounced for OTM and short-dated call options.

6.2 The Determinants of Insider Trading Litigation

We next examine the determinants of insider trading litigation, i.e., the characteristics of a case that tends to attract SEC action. One caveat is that we are unable to distinguish whether certain characteristics reflect deals that are more prone to insider trading, or whether certain company or market attributes more easily attract the attention of the SEC. For example, the SEC may be more attentive during specific market conditions and to a certain type of company.[26]

We examine the impact of takeover deal characteristics on the likelihood of SEC investigation using a logit model. We define the indicator variable SEC that takes the value one, if a deal has been litigated by the SEC, and zero otherwise, and estimate the following logit model as a benchmark:

$$\begin{gathered} Pr\left(SEC=1\right)=F\left(\beta_0+\beta_1 SIZE+\beta_2 CASH+\beta_3 CHALLENGE+\beta_4 COMPLETE\right. \\ \left.+\beta_5 TOE+\beta_6 PRIVATE+\beta_7 COLLAR+\beta_8 TERM+\beta_9 FRIENDLY+\beta_{10} US+\gamma_t\right), \end{gathered} \tag{2}$$

where $F(\cdot)$ defines the cumulative distribution of the logistic function, and all explanatory variables are categorical variables that take the value one if a condition is met, and zero otherwise. $SIZE$ takes

[26]We suspect that the second assumption may be true. Given our discussions with a senior former official at the regulator, the SEC operates under severely constrained resources. It is, therefore, more likely to litigate cases that have a greater chance of resulting in a conviction and that have generated substantial illicit trading profits. In addition, the recent emphasis on this issue with the creation of a Whistleblower Office, suggests that there is time variation, in particular, a recent increase, in the intensity of litigation activity.

the value one if the transaction is larger than the median M&A deal value. $CASH$ characterizes cash-financed takeovers. $CHALLENGE$ identifies deals that have been challenged by a second bidder. $COMPLETE$ identifies completed deals that were not withdrawn and did not fail. TOE indicates whether a bidder already had a toehold in the target firm. $PRIVATE$ equals one, if the acquirer privatized the target post-acquisition. $COLLAR$ identifies transactions with a collar structure. $TERM$ is one for deals that have a termination fee if takeover negotiations fail. $FRIENDLY$ refers to the deal attitude. US is one, if the bidder is a U.S.-based company. All specifications contain year fixed effects. We report the logit coefficients (and odds ratios in parentheses), using Firth's method for bias reduction in logistic regressions, in Table A-10 in the appendix.

The evidence in column (1) suggests that the likelihood of SEC litigation is higher for larger and completed deals that are initiated by foreign bidders. A transaction with a deal value greater than the median takeover deal value is 1.87 times more likely to be pursued. This evidence is consistent with Podolski, Truong, and Veeraraghavan (2013) and Wang (2013), who find size to be an important predictor of SEC litigation. The log-odds ratio suggests that an acquisition undertaken by a foreign bidder is roughly twice as likely to be prosecuted as an M&A transaction initiated by a U.S.-based bidder. Completed deals are positive predictors of options litigation, as a withdrawn or rumored deal is almost 3 times less likely to be investigated. The pseudo-R^2 of the regression is reasonable, with a value of 11%. We further test for the importance of the offer premium ($PREM1D$) and the offer price ($PRICE$) in affecting the probability of litigation. The results in column (2) indicate that both the offer premium and the offer price are positively related to the probability of SEC litigation, although the magnitudes of the odds ratios are just above one.

Next, we test whether we can predict the SEC litigations based on the stock price behavior of the parties involved in the transaction. In column (3), we estimate an augmented logit model and include $TRUNUP$, the target's pre-announcement cumulative abnormal stock return, $TANNRET$, the target's announcement-day abnormal return, $TTPRET1$, the target's post-announcement cumulative abnormal return, and $ARUNUP$, the acquirer's abnormal stock return before the announcement day. Only the target's post-announcement cumulative abnormal return is highly statistically significant. The coefficient of 2.10 suggests that a target with a 1% higher cumulative abnormal post-announcement return is approximately 8 times more likely to be investigated. This corresponds to a marginal effect of 4.8%, keeping all other variables at their median levels.

We also check whether the market environment in the period leading up to the announcement has predictive ability for the SEC litigations. Thus, in column (4), we augment the base model with $MKTVOL$, the market volume on the day before the announcement, and $ABNORMVOLC$, the target's total abnormal call trading volume during the 30 pre-announcement days. None of these variables exhibits statistical significance in explaining the SEC civil litigations. This is surprising, as we do find that a quarter of deals in our sample feature abnormal options volume that is difficult to associate with public sources of information, and many of these are not litigated.[27] Note that Wang (2013) reports a positive relation between pre-announcement call options volume and the probability of SEC litigation, without controlling for the influence of common variation. In unreported results, we similarly find a significant positive relation if we omit the year fixed effects. This supports the conjecture that there may be time variation in regulatory enforcement.

DeMarzo, Fishman, and Hagerty (1998) suggest that it may be optimal to prosecute insiders only after large price moves or after large volume transactions, and not to penalize small trades. Thus, from the perspective of the SEC, being resource-constrained, it could be efficient to pursue illicit transactions relating to securities of larger-sized firms that provide the biggest "bang for their buck" from a regulatory perspective. On the one hand, our results agree with DeMarzo, Fishman, and Hagerty (1998), given that SEC litigation is more likely for deals with large transaction values, higher bid prices and higher offer premiums. It is difficult, however, to differentiate whether insiders prefer to trade ahead of transactions involving larger companies, as such companies typically have more liquid options markets, which would allow insiders to better hide their trades, or whether the SEC is more likely to go after large-scale deals that are easier to detect and more broadly covered in the financial press. On the other hand, we do not find evidence that the odds of regulatory action are higher after observing large abnormal options volumes. This suggests that abnormal options volume could perhaps provide useful guidance for future regulatory pursuits. Finally, it is interesting to note that the odds of litigation are higher for deals that are initiated by foreign acquirers. This may indicate that rogue traders focus on foreign jurisdictions in order to gain and exploit their private information. Overall, the number of civil litigations initiated by the SEC because of illicit option trading ahead of M&As appears modest in light of the pervasiveness of abnormal options trading

[27] In unreported tests, we examine whether there is any fundamental difference between those SEC cases that were pursued because of alleged insider trading in options and those that were investigated because of allegedly illicit trading in stocks. Our previous conclusions remain largely unchanged.

that we documented for a quarter of all deals in our sample.

7 Conclusion

We quantify the prevalence of informed trading activity in target firms' options ahead of the unexpected takeover announcements in the U.S. from 1996 until 2012. We find that a quarter of all deals in our sample exhibit statistically significant abnormal trading volumes in options. The pre-announcement options activity appears to be informed. The evidence is consistent with directional trading strategies, and we see particularly pronounced effects for short-term OTM calls for targets, which almost always experience substantial positive announcement returns. Our key contribution is the deal-by-deal examination of the sources of informed trading to assess the likelihood of the informed options activity being illegal. We show that the magnitude of this abnormal activity is unlikely to have arisen out of speculation, superior predictive ability based on publicly observable information, through trading accounts of registered insiders, news and rumors, or trading in the stock market. It is difficult to associate the activity for at least 13% of all deals in our sample with public sources of information. Statistical tests suggest that the odds of the abnormal volume arising out of chance are, at best, one in a million.

The prevalence of informed trading appears more pervasive than would be expected based on the number of prosecutions, as the SEC litigates illegal stock and option trades for only 8.28% of takeovers, and for only 43 out of the 467 of the deals that display informed options activity. Yet, the characteristics of SEC-litigated insider trades in options ahead of M&A announcements closely resemble the characteristics of the (mostly unprosecuted) pre-announcement options activity that we flag as informed.

Guercio, Odders-White, and Ready (2015) argue that illegal insider trading in the stock market has decreased in response to more aggressive enforcement. Our work suggests that it may have moved to another location, the derivatives market. This is thought provoking, especially if there appears to be substantial insider trading in many countries with less sophisticated markets than the U.S. (Griffin, Hirschey, and Kelly, 2011), which is the focus in our study. The characterization of how and where informed investors trade is not only of interest to economists studying the information structure of asset markets around takeover announcements, but also to regulators and policy makers.

By shedding light on potential blind spots for the prosecution of rogue traders, these insights suggest that abnormal options volume may be a useful indicator for regulators looking for insider trading.

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Table 1: **Informed Trading Ahead of M&A Announcements.** In this table, we summarize the literature studying informed options activity in the pre-announcement period of mergers and takeovers, focusing on target options. We describe the paper's geographical focus (Country), whether the paper examines either stock or options activity, or both, whether the paper examines both target and acquirer options, and whether the paper quantifies the pervasiveness of informed options trading (Quantification). + indicates that the authors do not provide statistical significance for cases with increased options activity. For the data characteristics, we report the number of target deals, (* refers to acquirer deals), the subsample of deals with option data availability, and the study's time period. We indicate the sources of informed trading activity studied for abnormal activity in target options: rumors/news, speculation, options trading by registered insiders, stock market leakage, merger predictability, trading by activist investors, and trading by connected M&A advisory desks. We also indicate whether the study examines the occurrence of illegal insider trading litigations initiated by the SEC, and whether the study describes the nature and characteristics of option trades prosecuted by the SEC.

Study		Paper's Focus						Data Characteristics			Sources of Informed Trading on Targets								
Year	Authors	Country	Stocks	Options	Quantification	Target	Acquirer	# Target Deals	with Options	Time Period	Rumors/News	Speculation	Registered Insiders	Stock Market Leakage	Predictability/Anticipation	Activist Investors	M&A Advisors	SEC Litigation …	… Characteristics
1991	Jayaraman et al.	U.S.		✓	✓+	✓		27	27	75-84									
1993	Levy and Yoder	U.S.	✓	✓		✓	✓	21	21	82-85									
2001	Jayaraman et al.	U.S.	✓	✓	✓+	✓		33	33	86-96								✓*	
2005	Cao et al.	U.S.	✓	✓		✓		78	78	86-94									
2006	Arnold et al.	U.S.	✓	✓		✓		401	45	94-00									
2010	Acharya & Johnson	U.S.	✓	✓		✓		212	84	00-06									
2011	Spyrou et al.	U.K.	✓	✓	✓	✓	✓	3,875	1,812	87-06									
2011	Clements & Singh	U.S.	✓	✓		✓		393	59	01-06	✓								
2012	Shafer	U.S.	✓	✓		✓		824	824	96-10					✓				
2013	Klapper	U.S.		✓		✓		2,390	2,390	96-12	✓								
2013	Wang	U.S.	✓	✓		✓		3,124	3,124	96-08	✓							✓	
2013	Podolski et al.	U.S.		✓		✓		815	815	96-08								✓	
2015	Ordu & Schweizer	U.S.		✓			✓	5,986*	5,986*	96-08									
2015	Liu et al.	U.S.	✓	✓		✓		3,711	1,576	96-11				✓					
2015	Chan et al.	U.S.		✓		✓	✓	2,372	2,372	96-10									
2016	Huang and Tung	U.S.	✓	✓			✓	291	291	96-13									
2017	Lowry et al.	U.S.	✓	✓		✓		703	703	00-11							✓		
2017	The present study	U.S.	✓	✓	✓	✓		1,859	1,859	96-12	✓	✓	✓	✓	✓	✓		✓	✓

Table 2: Descriptive Overview of Takeover Sample

Panel A provides an overview of the M&A deal characteristics for all U.S. domestic M&As in the Thomson Reuters SDC Platinum database over the time period January 1996 through December 31, 2012, for which a matching stock and option price information were available for the target in the CRSP master file and OptionMetrics, respectively, based on the six-digit CUSIP. The sample excludes deals with an unknown or pending deal status, includes only those deals with available deal information, for which the deal value is above 1 million USD and in which an effective change of control was intended. In addition, we require valid price and volume information in both CRSP and OptionMetrics for the target for at least 90 days prior to and on the announcement day. We report the number of deals (No.) and the corresponding sample proportions (% of Tot.). In addition, we report how many of the deals are classified as completed, friendly, hostile, involving a target and acquirer in the same industry, challenged, or having a competing bidder, a collar structure, a termination fee or a bidder with a toehold in the target company. All characteristics are reported for the overall sample (column *Total*), as well as for different offer structures: cash-financed (*Cash Only*), stock-financed (*Shares*), a combination of cash and stock financing (*Hybrid*), other financing structures (*Other*), and unknown (*Unknown*). Panel B illustrates the financial statistics of the deals. We report the transaction value (*DVal*) in million USD and the offer premium, defined as the ratio of the offer price to the target's closing stock price. P1d (P1w, P4w) refers to the premium, one day (one week, four weeks) prior to the announcement date, in percentage terms. The deal value is the total value of the consideration paid by the acquirer, excluding fees and expenses. The dollar value includes the amount paid for all common stock, common stock equivalents, preferred stock, debt, options, assets, warrants, and stake purchases made within six months of the announcement date of the transaction. Any liabilities assumed are included in the value if they are publicly disclosed. Preferred stock is only included if it is being acquired as part of a 100% acquisition. If a portion of the consideration paid by the acquirer is common stock, the stock is valued using the closing price on the last full trading day prior to the announcement of the terms of the stock swap. If the exchange ratio of shares offered changes, the stock is valued based on its closing price on the last full trading date prior to the date of the exchange ratio change. For public-target 100% acquisitions, the number of shares at the date of announcement is used. Source: Thomson Reuters SDC Platinum.

Panel A: Deal Information												
Offer Structure	**Cash Only**		**Hybrid**		**Other**		**Shares**		**Unknown**		**Total**	
Description	No.	% of Tot.	No.	% of Tot.	No.	% of Tot.	No.	% of Tot.	No.	% of Tot.	No.	% of Tot.
No. of Deals	903	48.6%	415	22.3%	80	4.3%	403	21.7%	58	3.1%	1,859	100.0%
Completed Deals	746	40.1%	357	19.2%	67	3.6%	339	18.2%	33	1.8%	1,542	82.9%
Friendly Deals	805	43.3%	379	20.4%	69	3.7%	382	20.5%	42	2.3%	1,677	90.2%
Hostile Deals	35	1.9%	14	0.8%	3	0.2%	7	0.4%	4	0.2%	63	3.4%
Same-Industry Deals	379	42.0%	280	67.5%	39	48.8%	268	66.5%	27	46.6%	993	53.4%
Challenged Deals	111	6.0%	55	3.0%	7	0.4%	32	1.7%	11	0.6%	216	11.6%
Competing Bidder	83	4.5%	32	1.7%	3	0.2%	20	1.1%	4	0.2%	142	7.6%
Collar Deal	4	0.2%	54	2.9%	3	0.2%	52	2.8%	7	0.4%	120	6.5%
Termination Fee	698	37.5%	352	18.9%	51	2.7%	292	15.7%	29	1.6%	1,422	76.5%
Bidder has a Toehold	42	2.3%	11	0.6%	2	0.1%	7	0.4%	3	0.2%	65	3.5%

Panel B: Deal Financials												
Offer Structure	**Cash Only**		**Hybrid**		**Other**		**Shares**		**Unknown**		**Total**	
Description	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
DVal (mil)	$2,242.0	$4,147.2	$5,880.9	$10,071.5	$5,074.2	$10,387.7	$5,429.8	$15,158.5	$1,635.7	$2,503.7	$3,848.4	$9,401.3
P1d	33.6%	31.7%	28.5%	27.5%	25.1%	40.5%	28.3%	39.5%	33.3%	29.6%	31.0%	33.1%
P1w	36.6%	31.0%	32.4%	29.1%	29.5%	42.5%	33.6%	61.5%	33.4%	29.8%	34.7%	39.8%
P4w	41.1%	35.6%	35.0%	32.4%	31.2%	46.1%	36.7%	45.3%	38.0%	33.6%	38.3%	37.7%

Table 3: Positive Abnormal Options Trading Volume on Target Companies

Panel A reports the number (#) and frequency (freq.) of deals with statistically significant positive cumulative abnormal volume at the 5% significance level for the target companies, as well as the average cumulative abnormal volume ($E[CAV]$) and corresponding t-statistic ($t_{C\bar{A}V}$), computed using heteroscedasticity-robust standard errors. To calculate abnormal volume, we compute normal volume based on the market volume in options, the Chicago Board of Options Exchange VIX Volatility Index, and the contemporaneous return of the underlying stock and the market, proxied by the return on the S&P 500 index. For the market volume in options, we use the median trading volume across all, respectively call and put, options in the OptionMetrics database. We also use lagged values of the dependent and all independent variables. All results are reported separately for call options, put options, and for the aggregate option volume. Results stratified by moneyness are based only on those options expiring after the announcement date. The estimation window starts 90 days before the announcement date and runs until 30 days before the announcement date. The event window stretches from 30 days before until one day before the announcement date. Panel B reports the results of t-tests for the differences in the average cumulative abnormal volumes across moneyness categories: out-of-the-money (OTM), in-the-money (ITM), and at-the-money (ATM). We report the difference in average cumulative abnormal volume (Diff), the standard error (s.e.) and the p-value (p-val).

Panel A: **Magnitude and Frequency of Cum. Abnormal Volume Deals**

	All	Calls	Puts	All	Calls	Puts
	All Options - Target			**OTM Options - Target**		
Sign.t-stat 5% (#)	446	467	304	423	408	451
Sign.t-stat 5% (freq.)	0.24	0.25	0.16	0.23	0.22	0.24
$E[C\bar{A}V]$	10,385	8,946	1,559	5,071	3,380	1,417
$t_{C\bar{A}V}$	3.76	5.77	1.04	5.44	5.46	3.34
	ATM Options - Target			**ITM Options - Target**		
Sign.t-stat 5% (#)	341	343	362	393	482	396
Sign.t-stat 5% (freq.)	0.18	0.18	0.19	0.21	0.26	0.21
$E[C\bar{A}V]$	1,652	1,156	457	2,526	1,540	984
$t_{C\bar{A}V}$	2.84	2.65	1.98	4.71	6.40	2.42

Panel B: **Differences in Cum. Abnormal Volume across Moneyness**

	Diff	s.e.	p-val	Diff	s.e.	p-val
	All Options - Target			**Call Options - Target**		
OTM-ATM	3,419	722	0.00	2,224	531	0.00
OTM-ITM	2,544	669	0.00	1,840	561	0.00
ATM-ITM	-874	632	0.17	-384	444	0.39
	Put Options - Target					
OTM-ATM	960	450	0.03	–	–	–
OTM-ITM	433	367	0.24	–	–	–
ATM-ITM	-527	429	0.22	–	–	–

Table 4: Characteristics of Cumulative Abnormal Call Volume

Columns (1) and (2) in Table 4 report generalized least squares (GLS) regression results from the projection of cumulative abnormal call option log-volume ($CABVOL_C$) on a set of M&A characteristics and market activity measures. Cumulative abnormal volume is standardized by the average predicted volume during the event window. Columns (3) and (4) report logit coefficients (odds ratios in parentheses) from logistic regression results where the dependent variable takes on the value one if the cumulative abnormal call options trading volume during the 30 pre-announcement days is statistically significant at the 5% level, and zero otherwise. $SIZE$ quantifies the M&A deal value. $CASH$ is a categorical value taking the value one if the deal is a cash-financed takeover and zero otherwise, TOE has the value one if a bidder already has a toehold in the target company, $PRIVATE$ equals one if the acquirer privatizes the target post-acquisition, $COLLAR$ takes the value one for transactions with a collar structure, $TERM$ is one for deals that have a termination fee that applies if the takeover negotiations fail, $FRIENDLY$ has the value one if the deal attitude is considered to be friendly, and US is one if the bidder is a U.S.-based company, and zero otherwise. $TRUNUP$ denotes the pre-announcement cumulative abnormal stock return for the target, $TANNRET$ denotes the target's announcement abnormal return, $TTPRET1$ refers to the target's post-announcement cumulative abnormal return, and $ARUNUP$ is the abnormal stock return for the acquirer before the announcement day. $MKTVOL$ is the market volume on the day before the announcement day. Each regression contains year fixed effects (YEAR FE), and standard errors are clustered by announcement day. We report the number of observations (Observations) and the adjusted R-squared. ***, ** and * denote statistical significance at the 1%, 5% and 10% level, respectively. Source: Thomson Reuters SDC Platinum, CRSP, OptionMetrics.

	(1)	(2)	(3)	(4)	(5)
VARIABLES	$CABVOL_C$	$CABVOL_C$	$CABVOL_C$	$\mathcal{I}(CABVOL_C)$	$\mathcal{I}(CABVOL_C)$
SIZE	3.32**	2.44*	3.31**	0.23**	0.21*
	(1.34)	(1.29)	(1.33)	(1.26)	(1.24)
CASH	6.37***	5.49***	5.15***	0.42***	0.43***
	(1.53)	(1.54)	(1.59)	(1.52)	(1.53)
TOE	-5.58*	-3.38	-4.82*	-0.33	-0.27
	(2.94)	(2.71)	(2.92)	(0.72)	(0.76)
PRIVATE	0.12	0.06	0.88	-0.09	-0.13
	(1.97)	(1.91)	(2.00)	(0.91)	(0.88)
COLLAR	7.23**	6.47**	6.52**	0.41*	0.43**
	(2.94)	(2.85)	(2.95)	(1.50)	(1.54)
TERM	5.65***	4.57**	4.93***	0.20	0.21
	(1.83)	(1.80)	(1.83)	(1.22)	(1.23)
FRIENDLY	3.04	1.91	2.85	0.14	0.06
	(2.36)	(2.30)	(2.37)	(1.15)	(1.06)
US	-2.45	-1.71	-2.54	-0.35**	-0.31**
	(1.91)	(1.88)	(1.92)	(0.70)	(0.74)
TRUNUP		24.30***			1.01***
		(2.88)			(2.75)
TANNRET		0.57			0.74
		(4.56)			(2.10)
TTPRET1		-7.84*			-1.15**
		(4.08)			(0.32)
ARUNUP		-4.52	4.21		-0.97**
		(4.27)	(4.36)		(0.38)
MKTVOL		-3.85**	-1.91		-0.06
		(1.95)	(2.02)		(0.94)
TOT_PREMIUM			4.24**		
			(1.75)		
Constant	-1.37	15.25*	5.68	-0.82**	-0.62
	(2.79)	(8.66)	(9.01)	(0.44)	(0.54)
Observations	1,859	1,859	1,859	1,859	1,859
adj.R2/ ps.R2	0.056	0.123	0.060	0.035	0.054
YEAR FE	YES	YES	YES	YES	YES

Table 5: Positive Abnormal Trading Volume in Treatment and Control Groups

This table reports the number (#) and frequency (freq.) of deals with statistically significant positive cumulative abnormal volume at the 5% significance level, as well as the average cumulative abnormal volume ($E[CAV]$) and corresponding t-statistic ($t_{C\bar{A}V}$), computed using heteroscedasticity-robust standard errors. We use the MMV model to calculate abnormal volume. The MMV model accounts for the median of the total daily trading volume across all options, the VIX index and the contemporaneous return on the S&P500 market index and the underlying stock, as well as lagged variables of the dependent and all independent variables. All results are reported separately for call options, put options, and for the aggregate option volume. The estimation window starts 90 days before the announcement date and runs until 30 days before the announcement date. The event window stretches from 30 days before until one day before the announcement date. Panel A reports results for the treatment group, Panel B for the matched control groups using the first (and second) best matches. Targets are matched based on the return, bid-ask spread, stock volume, and stock volatility, using 3-month moving average values from the month prior to the announcement. Panel C reports the average treatment effects obtained from a regression of the cumulative abnormal options volume on an indicator variable that takes on the value one if a target belongs to the treatment group, and zero otherwise. All regressions control for the matching variables, year fixed effects, and standard errors are clustered by announcement date to account for cross-sectional correlation due to possible clustering of announcement dates. Source: Thomson Reuters SDC Platinum, CRSP, OptionMetrics.

Panel A:	**Magnitude and Frequency of Cum. Abnormal Volume Deals Treatment Group PS0 - Takeover Sample**		
	All	Call	Put
Sign.t-stat 5% (#)	296	321	220
Sign.t-stat 5% (freq.)	0.22	0.24	0.16
$E[CAV]$	10,768	11,145	746
$t_{C\bar{A}V}$	2.74	4.94	-0.12

Panel B:	**Magnitude and Frequency of Cum. Abnormal Volume Deals Control Group PS1 Best Match**			**Control Group PS2 Two Best Matches**		
	All	Call	Put	All	Call	Put
Sign.t-stat 5% (#)	161	158	167	326	329	319
Sign.t-stat 5% (freq.)	0.13	0.13	0.14	0.14	0.14	0.13
$E[CAV]$	872	1,011	467	990	764	419
$t_{C\bar{A}V}$	-0.01	0.54	-0.47	0.07	0.43	-0.33

Panel C:	**Differences in Cum. Abnormal Volume Deals across Treatment and Control Groups**					
Treatment1	12,043***	10,356***	1,687			
	(3,471)	(2,751)	(2,108)			
Treatment2				11,516***	10,748***	768
				(3,251)	(2,625)	(2,405)
CONTROLS	YES	YES	YES	YES	YES	YES
YEAR FE	YES	YES	YES	YES	YES	YES
CLUSTER	YES	YES	YES	YES	YES	YES

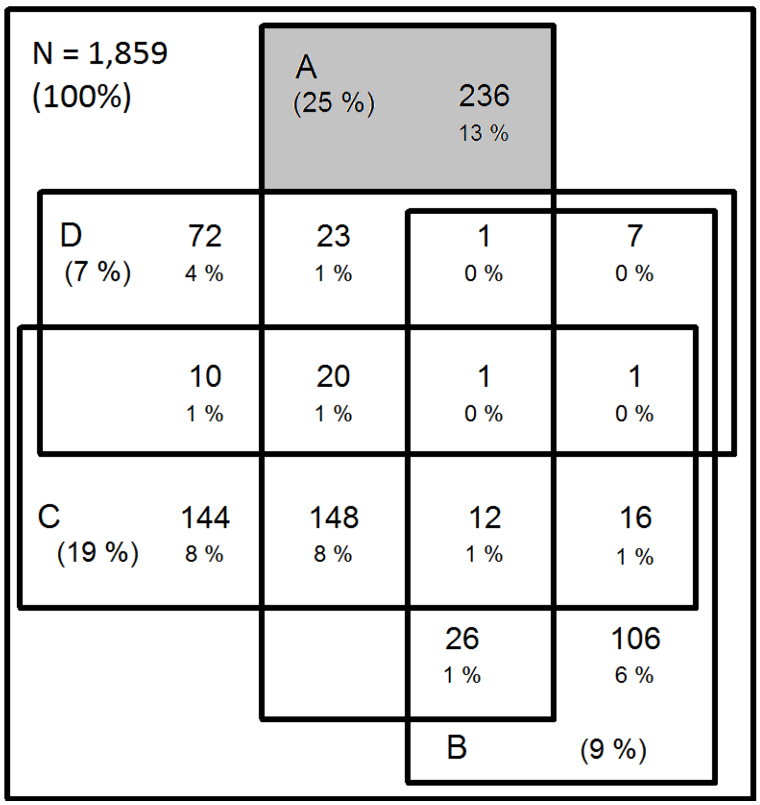
Table 6: Frequency of News around M&A Announcements

Table 6 reports the frequency of news around M&A Announcements. The information is based on RavenPack News Analytics, which extracts textual information from major publishers, such as Dow Jones Newswires, the Wall Street Journal, Barron's, regulatory and public relation feeds and over 19,000 other traditional and social media sites, and transforms it into a structured data feed that can be used in quantitative analysis. Using the data from January 2000 to August 2012, we report the number of news and rumor items (*Obs*) and the corresponding number of takeover deals (*Deals*) recorded during different time windows around the announcement day. The window titled "0" relates to news and rumors on the announcement day. All other columns refer to different time windows in the pre- or post-announcement period. Source: Thomson Reuters SDC Platinum, CRSP, OptionMetrics, Compustat, RavenPack News Analytics.

Time Window	[-150,-91]	[-90,-31]	[-30,-21]	[-20,-11]	[-10,-6]	[-5,-1]	[0]	[1,5]	[5,10]	[-150,-91]	[-30,-1]	[-90,-1]
Obs	258	290	67	67	31	74	660	252	140	1839	239	529
Deals	188	204	55	59	29	63	659	218	113	407	170	299

Table 7: Sources of Informed Options Trading

This table documents the sources of informed options trading for a sample of 1,859 takeovers from January 1996 to December 2012. Out of the 1,859 companies, 467 (25.12, subset A) have abnormal options trading volume at the 5% significance level over the 30 pre-announcement days. The sample of news and rumors amounts to 170 deals (9.14%, subset B). 352 of all deals (18.93%, subset C) have abnormal stock trading volume in the run-up to the announcement, while 135 deals (7.26%, subset D) have abnormal stock returns in the run-up to the announcement. In total, 427 of all deals (22.97%) have abnormal options trading volume ahead of the announcement, as well as abnormal returns and volume in the underlying stock, without any news or rumors. 236 of all deals (13%, grey shaded area) have only abnormal options trading volume and are difficult to associate with public sources of information.



Set	#	%	Cum%	A	B	C	D	Description
Ω	1,859	100.00	100.00	✓	✓	✓	✓	Takeover Sample
A	467	25.12	25.12	✓	✗	✗	✗	Abnormal Options Volume (A)
Ω\A	1,392	74.87	100.00	✗	✓	✓	✓	No Abnormal Options Volume
B	170	9.14	9.14	✗	✓	✗	✗	News & Rumors (B)
Ω\B	1,689	90.86	100.00	✓	✗	✓	✓	No News & Rumors
C	352	18.93	18.93	✗	✗	✓	✗	Abnormal Stock Volume (C)
Ω\C	1,507	81.07	100.00	✓	✓	✗	✓	No Abnormal Stock Volume
D	135	7.26	7.26	✗	✗	✗	✓	Abnormal Stock Returns (D)
Ω\D	1,724	92.74	100.00	✓	✓	✓	✗	No Abnormal Stock Returns
(A ∩ C ∩ D) \ B	427	22.97	22.97	✓	✗	✓	✓	A, C, D, No B
Ω\(A ∩ B ∩ C ∩ D)	1,036	55.73	55.73	✗	✗	✗	✗	No A, B, C, D
A\(B ∪ C ∪ D)	236	12.69	68.42	✓	✗	✗	✗	A, No B, C, D

Table 8: SEC Litigation Reports

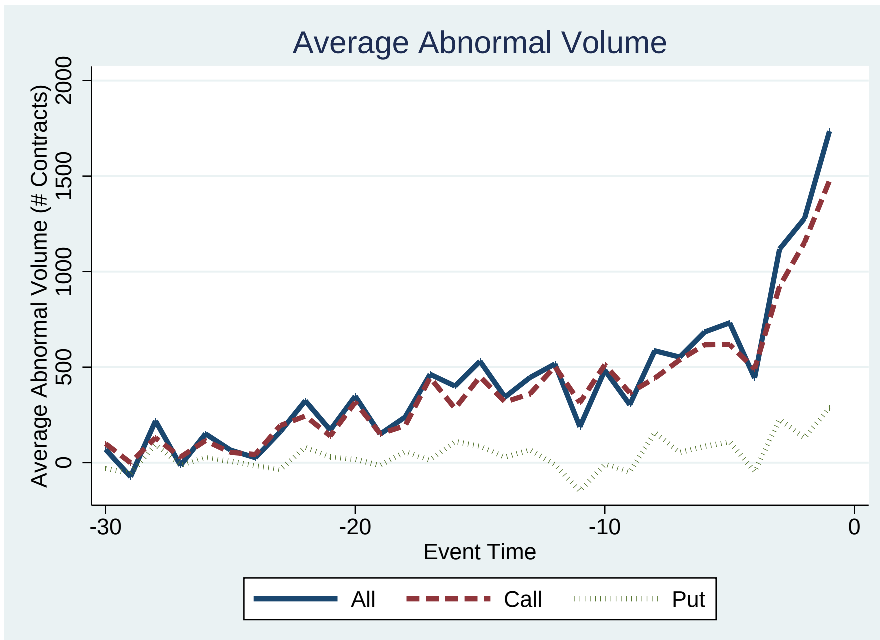
Table 8 provides summary statistics on a sub-sample of litigation releases concerning civil lawsuits brought by the Securities and Exchange Commission (SEC) in federal court. We extract and document all the litigations that encompass trading in stock options around M&A and takeover announcements. The column *SEC LRs* indicates the number of M&A deals in each calendar year (*Year*) that have been subject to litigation by the SEC. The column *Cash* indicates the number of litigated deals that are cash-financed (if the information is available). The column *ABS Sample* refers to our sample of M&A deals. The column *Illicit Profits* is the average number of illicit profits reaped in the litigated cases (from stocks and options) and the column *Fines* reports the average yearly fine imposed in the litigations (total amount including disgorged trading profits, prejudgment interest and civil penalty, if any). The column *Days to Lit.* denotes the average number of days between the announcement date and the first filed litigation report. The column *Moneyness* S/K provides information about the average moneyness of the prosecuted call option trades on the target. The column *Option Mat.* presents the average time to maturity (in months) of all options trades under litigation, and the column *Days to Ann.* reports the average number of days between the first unusual option trade and the announcement date. The last column, *Defend.*, shows the yearly average number of defendants. A * in the first column indicates years with M&As involved in a litigation for alleged illegal trading on the acquiring company. In total, there are only five cases involving the acquirer in a deal. The last two rows report the sample averages over the entire period for which we have information on SEC litigations, as well as over the shorter sample period, 1996 to 2012, that we cover in our analysis of unusual options trading. Source: Thomson Reuters SDC Platinum, Securities and Exchange Commission, Department of Justice, CRSP, Public Access to Court Electronic Records (PACER).

Year	**SEC LRs**	**Cash**	**ABS Sample**	**Illicit Profits**	**Fines**	**Days to Lit.**	**Moneyness S/K**	**Option Mat.**	**Days to Ann.**	**Defend.**
1990	1	0	.	650,000	.		.	.	.	17
1993	2	0	.	87,000	72,171	1,514	.	.	13	6
1994	5	2	.	156,690	281,480	883	0.88	1.00	4	3
1995*	4	2	.	400,319	650,060	1,026	0.93	2.78	26	14
1996	4	2	70	377,612	903,343	456	0.93	0.50	3	2
1997*	4	1	133	480,367	1,471,178	350	1.02	1.50	2	3
1998	8	3	175	1,443,723	648,023	369	0.89	1.20	8	8
1999	2	2	217	295,676	57,880	1,088	0.94	1.00	4	14
2000	8	4	164	221,340	192,995	915	1.09	1.00	4	2
2001	3	1	86	232,533	270,662	1,212	0.95	0.25	0	4
2002	1	0	36	250,000	61,714	933	.	.	72	4
2003	3	0	54	372,404	905,647	689	0.94	1.85	12	3
2004	2	2	72	1,242,665	1,743,741	438	0.98	1.38	3	.
2005	11	5	109	879,829	1,499,516	841	0.97	1.17	14	6
2006*	14	10	119	1,001,278	637,230	552	0.97	0.93	13	4
2007	24	17	159	1,396,619	6,132,891	874	0.90	1.83	25	3
2008	6	5	98	1,226,436	1,243,423	719	0.93	3.12	18	2
2009	6	3	74	2,684,571	827,898	634	0.89	2.63	43	2
2010*	20	15	93	604,633	1,993,138	489	0.94	1.33	17	2
2011	8	4	114	914,337	263,969	832	0.83	3.83	44	4
2012	7	6	86	2,762,365	352,327	211	0.93	1.11	15	7
2013	7	5	.	1,493,579	5,069,953	144	0.96	1.56	8	2
90-13	7	9	.	1,037,617	1,888,521	644	0.93	1.88	21	4
96-12	8	10	109	1,084,162	1,937,595	635	0.93	1.87	21	4

Figure 1: Abnormal Trading Volumes before Announcement Dates - Target

Figure (1a) plots the average abnormal trading volume for all equity options (solid line), call options (dashed line) and put options (dotted line), respectively, for the target companies, over the 30 pre-announcement days. Volume is defined as the number of option contracts. Figure (1b) reflects the average cumulative abnormal trading volume for all options (solid line), call options (dashed line) and put options (dotted line) over the same event period. Statistics are computed for a sample of 1,859 target companies over the time period January 1996 through December 31, 2012. Source: OptionMetrics.

(a)



(b)

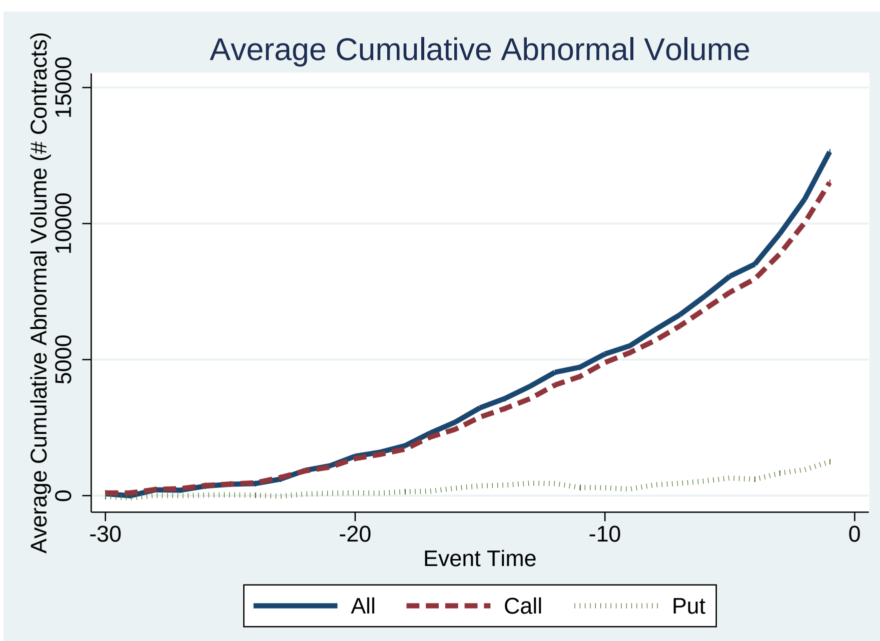
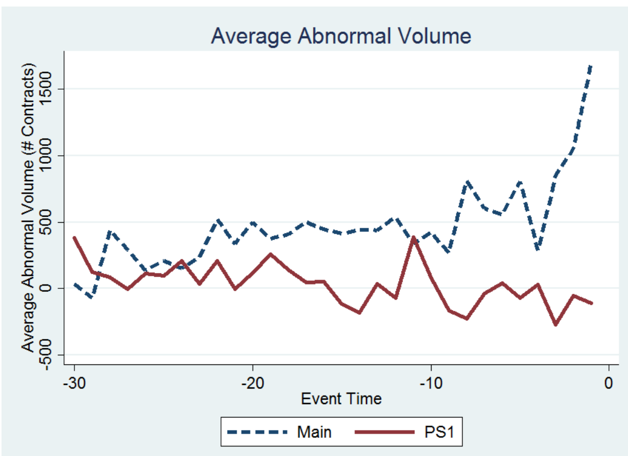


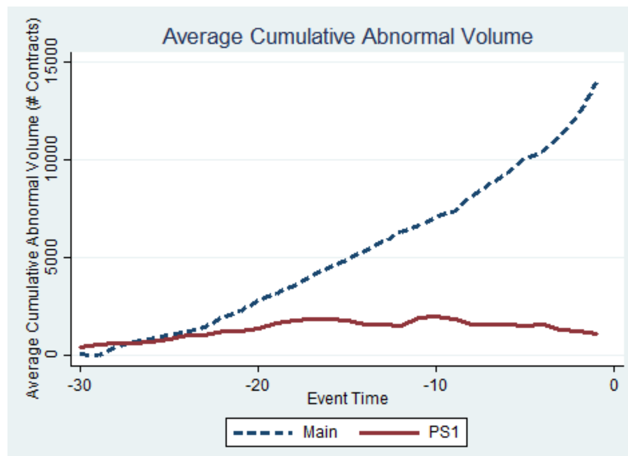
Figure 2: Abnormal Trading Volumes - Treatment and Matched Control Groups, News and Rumors

Figures (2a) and (2b) plot the average and average cumulative abnormal trading volume, respectively, for aggregate options volume in the treatment group (Main - dashed line) and the propensity-matched control group using the best match (PS1 - solid line), over the 30 days preceding the announcement date. Volume is defined as the number of option contracts, and abnormal volume is based on the market model for volume (MMV). Firms are matched based on 3-month moving average values in the month preceding the announcement for the target's stock return, its percentage bid-ask spread, the stock trading volume, and stock return volatility using an EWMA model with an autoregressive coefficient of 0.94. Figures (2c) and (2d) plot, respectively, the average and average cumulative abnormal trading volume for aggregate options volume in the sample with (No News – solid line) and without (News (30d) – dashed line) news or rumors about M&As in the 30 pre-announcement days. These results are based on a log-transformation of volume, defined as $logVolume = \ln(1 + Volume)$. All statistics are computed for a sample of 1,859 target companies over the time period January 1996 through December 31, 2012. Source: Thomson Reuters SDC Platinum, CRSP, OptionMetrics.

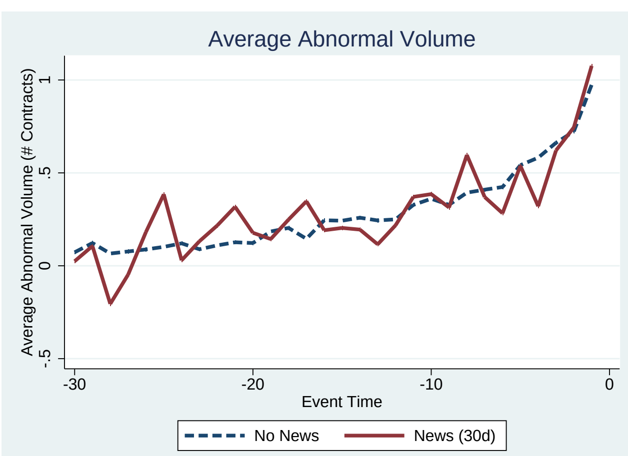
(a)



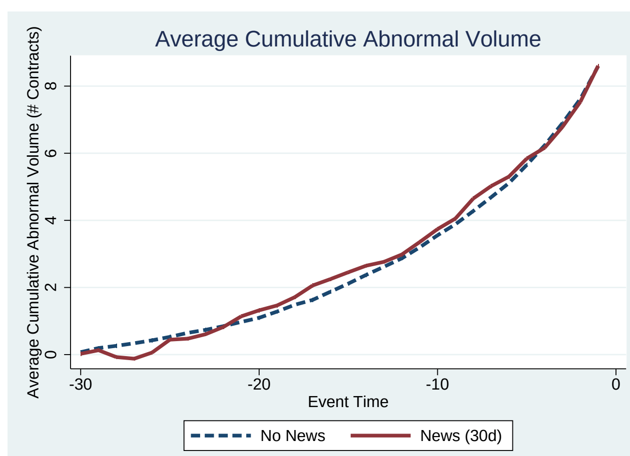
(b)



(c)



(d)



Online Appendix: Not for Publication

Informed Options Trading prior to Takeover Announcements: Insider Trading?

Abstract

We quantify the pervasiveness of informed trading activity in target companies' equity options before M&A announcements. About 25% of takeovers have positive abnormal volumes, which are greater for short-dated out-of-the-money calls, consistent with bullish directional trading ahead of the announcement. Over half of this abnormal activity is unlikely to be explained by speculation, news and rumors, trading of corporate insiders, leakage in the stock market, deal predictability, or beneficial ownership filings by activist investors. Although the characteristics of a sample of illegal option trades prior to M&A announcements closely resemble the characteristics of abnormal option trades in our sample, the SEC litigates only about 8% of all deals in it. Hence, our findings flag abnormal options volume as a useful indicator for regulatory examination of potential insider trading.

A-I A Taxonomy of Insider Trading Strategies

We describe a classification of potential insider trading strategies on the **target** companies. An investor trading illicitly, based on private information, would gain most from **bullish strategies** on the target company, or alternatively a replication of such a strategy carried out by **shorting bearish strategies**. Any replicating strategy that involves the underlying could also be created by investing in the futures contract on the underlying. In this section, we focus on options strategies and how they would impact options-to-stock volume ratios. We will not talk about the obvious strategy of investing directly in the stock only. The overall conclusion is that, irrespective of the strategy we consider, in the presence of insider information, there should be abnormal trading volumes in OTM call and/or ITM put options for target firms. Insider trading on targets is only profitable for long bullish strategies. These strategies can be replicated by shorting bearish strategies. We discuss each possibility one by one.

A-I.A Long Bullish Strategies

1. Long Call

   The simplest way to exploit inside information using options is to buy plain vanilla and short-dated deep OTM call options on the underlying stock, given that they provide the biggest leverage to the investor.[1] This implies that we should observe abnormal trading volumes in call options prior to M&A announcements. The abnormal trading volume should be relatively higher for OTM options in comparison to ATM and ITM options. Moreover, the call-to-stock volume ratios should increase ahead of the announcements. The cost of such a strategy will be equal to the option premium.

2. Long Call Ratio Backspread

   A call ratio backspread consists of selling a call option with strike K_1 and buying two call options with strike K_2, where $K_1 < K_2$. The advantage is that, by selling one call option for every two purchased, part of the strategy is self-financing. Similar to the simple long call strategy, the long call ratio backspread provides the most leverage if it is constructed using OTM options. Hence we would expect to see an abnormal trading volume in OTM call options in comparison to ATM and ITM options.[2] Moreover, the call-to-stock volume ratio should increase ahead of the announcement. The cost of this strategy will be equal to the option premium. (Note that this strategy could be replicated more cost efficiently by selling a put option with strike K_1, shorting the underlying, and buying two call options with strike K_2, where $K_1 < K_2$. Such a strategy would be more cost efficient as selling the ITM put and shorting the stock would bring in more money than selling the OTM call.)

3. Long Bull Call Spread

[1] Of course, the options should not be too far OTM, since the stock may not move that much, even after the announcement.

[2] The implication also applies to the relative volumes of deeper OTM to less deeply OTM calls.

An insider might be certain about the direction in which the stock price was going to move, but could also reasonably assume that it was going to move by no more than a certain percentage. In that case, he could engage in a long bull call spread. Such a strategy is constructed by buying a call option with strike K_1 and selling a call option with strike K_2, where $K_1 < K_2$. Similarly to the long call ratio backspread, this strategy would be partly self-financing. If we were to assume that leverage was optimized and the call options were OTM, then we would expect abnormal trading volumes in call options ahead of takeover announcements. Such abnormal trading volumes should be relatively higher for OTM options than ATM and ITM options. Moreover, the call-to-stock volume ratio should increase ahead of announcements. (Note that this strategy could be replicated more cost efficiently by selling a put option with strike K_2, shorting the underlying, and buying one call option with strike K_1, where $K_1 < K_2$. Such a strategy would be more cost efficient for a financially constrained investor as selling the ITM put and shorting the stock would bring in more money than selling the OTM call.)

4. Long Bull Put Spread

   A bull put spread can be implemented by buying a put option with strike K_1 and selling a put option with strike K_2, where $K_1 < K_2$. This would be most profitable if the investor transacted in ITM puts, thus creating the hypothesis that we ought to see an abnormal trading volume in ITM puts ahead of an announcement. Under this hypothesis, we should also see an increase in the put-to-stock trading volume ratio. The advantage of this strategy is that the purchase of an ITM put is financed with a relatively more ITM (and therefore more expensive) put. This strategy should therefore be entirely self-financing. (Note that this strategy can be replicated by buying a put option with strike K_1, selling a call option with strike K_2, where $K_1 < K_2$, and buying the underlying stock. In this case, we would also expect to see a higher abnormal trading volume in OTM call options and in ITM put options.)

A-I.B Short Bearish Strategies

1. Long Put + Stock

   According to put-call parity, a long call position can be replicated by a position in a put on the same underlying, with equal strike and equal time to maturity, combined with a position on the underlying stock. As the greatest leverage is obtained from OTM call options, this strategy can be replicated by buying ITM put options and matching them with the underlying stock. According to this hypothesis, we should observe abnormal trading volumes in both puts and stocks. Accordingly, the abnormal volume should be relatively higher for ITM put options than for ATM and OTM puts. In addition, the put-to-stock volume ratio should not be significantly affected. This strategy, however, would be significantly less attractive for a capital-constrained investor, relative to a simple OTM call transaction, as the ITM puts are comparatively more expensive and the stock is fully funded. The cost of this strategy will be determined by the put premium and the stock price.

2. Short Put

   If the investor is certain about the direction of the stock price movement, he can simply take advantage of his private information by selling ITM put options. When stock prices do shoot up after an announcement, the put options will expire worthless, whereas the writer of the options will have a profit equal to the put premium times the number of puts sold. This strategy could be replicated by taking a short position in matched-strike OTM call options together with a long position in the underlying stock (which would correspond to a covered call).

3. Sell Put Ratio Backspread

   A short put ratio backspread is implemented by selling two puts with strike K_1 and buying one put option with strike K_2, where $K_1 < K_2$. While this strategy suggests that there would be a range of contingent outcomes from which the insider could benefit, the strategy is much riskier than others as he could lose money if the prices rise more than a certain amount. While we expect such a strategy to be an unlikely choice for insider trading, it would generate abnormal trading volumes in ITM put options. (A replication strategy with two short puts at K_1, long a call at K_2 and short the stock would produce different predictions for the option-to-stock trading volume ratio, and would also suggest an abnormal trading volume in OTM calls.)

4. Sell Bear Call Spread

   The idea of selling a bear call spread is similar to the idea of selling ITM puts, except that the profit potential is diminished relative to simple ITM put options. This is thus another unlikely strategy, but a theoretically possible one. A short bear call spread is constructed by selling a call with strike K_2 and buying a call with strike K_1, where $K_1 < K_2$. In terms of expectations about trading volumes, such a strategy would raise the OTM call trading volume.

5. Sell Bear Put Spread

   Finally, a short bear put spread is very similar to the short bear call spread, except that it is constructed using puts rather than calls. The composition contains a short position in a put option with strike K_2 and a long position in a put option with strike K_1. As this strategy is also similar to the idea of selling ITM puts, except that the profit potential is diminished relative to simple ITM put options, we again find such a strategy unlikely but theoretically feasible. In any case, the prediction is that we should expect to see an increase in the abnormal volume for ITM put options.

A-I.C Conclusion

The insight from the exercise of classifying potential insider trading strategies for the target companies is the following: no matter which strategy we look at, the conclusion is that, in the presence of insider information, there should be abnormal trading volumes for the target companies in OTM call options and in ITM put options. Conditional on such findings, the ratios of call-to-stock, put-to-stock and call-to-put volumes may yield insights regarding which strategy has been implemented by the insider.

A-II Additional Results for Targets

A-II.A Summary of Robustness tests

We verify our results using a plethora of alternative tests and robustness checks for option volumes to ensure that our findings do not arise by pure chance. All additional tests agree with the previous findings, yielding either similar or stronger results, both qualitatively and quantitatively. We discuss the details of these additional tests in the following subsections, and briefly describe them in this subsection. We first verify that all results hold for a natural log transformation of volume. Second, we show, using an approximation to the bivariate Kolmogorov-Smirnov test, that the three-dimensional volume-moneyness distribution shifts significantly in both time and depth over the 30 days preceding the announcement day, with an increase in the OTM call volume relative to ATM and ITM calls as we approach the event day. Third, we show that the frequency of trading increases in the pre-announcement period and that it is greater compared to a matched sample with random announcement dates. The odds that the trading frequency observed during the five-day pre-announcement period is as high in a sample of randomly chosen announcement dates is at best one in a million. Fourth, we study specific trades that are most susceptible to insider trading, and compare them to a matched random sample. We compare the statistics from these most egregious trades to those from a randomly selected sample and compute a probability of three in a trillion that the pre-announcement trading volume happened by chance. Fifth, we show that the evidence of unusual options activity is the most striking for short term options expiring immediately after the announcement.

As a complement to the volume results, we further conduct an analysis of implied volatility, the summary statistic of the price behavior of options, over the 30 days preceding the takeover announcement date. We show that the pervasive evidence of informed trading on target companies is also reflected in positive excess implied volatility in the pre-event window, which is greatest for short-term options expiring *after* the announcement. Although higher abnormal volumes in OTM call options for the targets need not affect option prices, it could be argued that higher volume, initiated by the buy side, is executed more at the ask price which "translates," on average, into an increase of the implied volatility prior to the announcement day.[3] We also show that the percentage bid-ask spread for options on target firms rises from an average of 45% (35%) to 55% over the 30 (90) days preceding the announcement. This effect is significant for DOTM and OTM call options, as well as for short- to medium-dated options. It can be explained as a "hedge" against the risk of informed trading, manifested through an increase in options volume. Finally, informed trading has a greater impact on shorter-term equity option prices and, thus, leads to an attenuation of the slope of

[3]This argument is related to prior work on the inelasticity of the option supply curve, along the lines analyzed theoretically by Garleanu, Pedersen, and Poteshman (2009) and empirically by Bollen and Whaley (2004) and Deuskar, Gupta, and Subrahmanyam (2011).

the term structure of implied volatility for target firms. None of these effects on prices and liquidity arise in matched samples with randomized announcement dates.

A-II.B Shifts in the Option Trading Volume Density

The empirical section in the main text illustrated that the 30 days prior to takeover announcement dates should exhibit abnormal option volumes for target firms, particularly pronounced in respect to OTM call options. The question is whether there is a monotonic and statistically significant shift in the entire option trading volume *distribution* as the announcement date approaches. We formally test for a shift in the bivariate volume-moneyness distribution over time, in anticipation of the announcement dates.

Figure A-1 visually illustrates the shift in the volume distribution for calls and puts written on the target firms as we approach the announcement date. Each individual line reflects a local polynomial function fitted to the volume-moneyness pairs. It is striking to see how the volume distribution for call options shifts to the tails and increases the weights of the DITM and DOTM categories as we approach the announcement date. In addition, the volume keeps increasing, in particular in the event window $[-4, -1]$. The last event window $[0, 0]$ incorporates the announcement effect, whereby the overall average trading level is lifted upwards, and the distribution shifts to ITM call options and OTM puts, as would be expected as the merger has been announced. Another way to visualize the change in the distribution is shown in Figure A-2, although this graph is a univariate slice of the underlying bivariate distribution. The dashed blue line and the solid green line in each plot represent the 90th and 95th percentiles of the distribution, whereas the dotted red lines reflect the interquartile range. It is evident from the figure that the percentage increase in the percentiles of the volume distribution is very strong. For example, the interquartile range for target call options increases from a level below 50 contracts to approximately 2,000 contracts on the announcement day.

To summarize, there is a significant shift in both the mean and median trading volume for target firms in anticipation of takeover transactions. This shift is more pronounced for DOTM and OTM call options than for ITM and DITM options. This confirms Hypothesis H2 that there is a higher abnormal trading volume in DOTM call options than in ATM and ITM call options. In what follows, we apply a formal statistical test of the shift in the volume distribution.

In order to test whether the bivariate volume-moneyness distribution shifts over time prior to the announcement date, we use a two-sample bivariate Kolmogorov-Smirnov (KS) test. The two-sample KS test is a non-parametric test of the equality of two continuous distribution functions. Essentially, the KS-statistic quantifies the distance between the two empirical cumulative distribution functions. While the test statistic is straightforward to compute in the univariate setting with distribution-free properties, the computation in the multivariate setting can become burdensome, particularly when the sample size is large. The reason for this is that, in the univariate setting, the empirical cumulative distribution function diverges only at its observed points, while it diverges at an infinite number of points in the multivariate setting. To see this, remember that, in a multivariate setting, there is more than one definition of a cumulative distribution function. In particular, in the bivariate setting, the four *regions* of interest are

$$H^{(1)}(x,y) = P[X \leq x, Y \leq y], \qquad H^{(1)}(x,y) = P[X \leq x, Y \geq y] \tag{A-2}$$

$$H^{(1)}(x,y) = P[X \geq x, Y \leq y], \qquad H^{(1)}(x,y) = P[X \geq x, Y \geq y], \tag{A-3}$$

and we need to evaluate the empirical cumulative distribution function in all possible regions. To reduce computational complexity, we rely on the Fasano and Franceschini (FF) generalization of the two-sample bivariate KS test. Define the two sample sizes $\{\left(x_j^1, y_j^1\right) : 1 \leq j \leq n\}$ and $\{\left(x_j^2, y_j^2\right) : 1 \leq j \leq m\}$, with their corresponding empirical cumulative distribution functions $H_n^{(k)}$ and $H_m^{(k)}$, for regions $k = 1, 2, 3, 4$. The FF test statistic (Fasano and Franceschini, 1987) is then defined as

$$Z'_{n,m} = max\{T'^{(1)}_{n,m}, T'^{(2)}_{n,m}, T'^{(3)}_{n,m}, T'^{(4)}_{n,m}\}, \tag{A-4}$$

where

$$T'^{(k)}_{n,m} = sup_{(x,y)\in\mathcal{R}^2} \sqrt{\frac{nm}{n+m}} \left| H_n^{(k)}(x,y) - H_m^{(k)}(x,y) \right|. \tag{A-5}$$

Although the analytic distribution of the test statistic is unknown, its p-values can be estimated using an approximation, based on Press, Teukolsky, Vetterling, and Flannery (1992), to the FF Monte Carlo simulations.

Our prior is that the FF-statistic, which reflects the distance between the two bivariate empirical distribution functions (EDFs), should monotonically increase for the target firms as we get closer to the announcement date.[4] Essentially, the difference in EDFs should be larger between event windows $[-29, -25]$ and $[-24, -20]$, than between $[-29, -25]$ $[-19, -15]$, and so forth. In addition, the FF-statistics should increase relatively more for short-dated options, which mature closer to, but after, the announcement date. These predictions are clearly confirmed by the results in Table A-1. The FF test reveals statistically significant differences in the bivariate volume-moneyness distributions as we move closer to the announcement date. We compare the distributions in event-window blocks of five days. A glance at the table reveals that the test is statistically significant, at the 1% level, for almost all pair-wise comparisons. In addition, the magnitude of the statistic is monotonically increasing as we move from the left to the right, and as we move from the bottom to the top of the table.

Panels A and B in Table A-1 report the results for calls and puts, respectively. For example, the first row shows that the bivariate distribution shifts significantly from event window $[-29, -25]$ to $[-24, -20]$, with an FF-statistic of 0.0279. The test statistic increases to 0.1592 when we compare event windows $[-29, -25]$ and $[-4, -1]$, and to 0.4070 for event windows $[-29, -25]$ and $[0, 0]$. For short-dated options with a time to expiration of less than 30 days, the statistic for the difference in distributions for the shift from event window $[-29, -25]$ to $[-4, -1]$, *excluding the announcement effect*, has a value of 0.3388 (0.34) for call (put) options. This is *higher* than the announcement effect from event window $[-4, -1]$ to the announcement date. Changes in the bivariate distributions are statistically significant at the 1% level for almost all event windows. Overall, as expected, the largest

[4] One can think of the FF-statistic as a variation of the KS-statistic in the multivariate setting. The FF-statistic is computationally less intensive in the multivariate case, but is consistent and does not compromise power for large sample sizes. See Greenberg (2008).

test statistics seem to be associated with comparisons between the announcement date ($[0,0]$) and the event window immediately preceding it ($[-4,-1]$).

These formal statistical tests provide evidence that the two-dimensional volume-moneyness distribution shifts significantly in both time and depth over the 30 days preceding the announcement day. Hence, the level of the volume distribution increases, with a higher frequency of trades occurring in both OTM calls and ITM puts. These findings support the results of the event study and strengthen our conclusions in favor of Hypotheses H1 and H2.

A-II.C Zero-Volume Runs

As emphasized earlier, liquidity is low in equity options. Given the significant number of zero-volume observations that characterize the data for equity options, we compare the proportions of non-zero trading volume between the pre-announcement period and any randomly chosen period to supplement our forensic analysis of the behavior of option volume. We also investigate proportions of non-zero trading volume conditional on there being no trading volume for the preceding one to five days. Each observation corresponds to an option series characterized by its issuer, the type (put-call), strike and maturity.

First, Panel A in Table A-2 reports the volume proportions for a randomly chosen date, which turns out to be March 5, 2003. On that day, OptionMetrics contains a total of 103,496 observations, of which 28,402 are classified as DOTM and 28,404 are classified as DITM according to our definition of depth as the ratio of the stock price to the strike price. As expected, trading volume is generally low. Only 15% of all options were traded, about 3% were traded with more than 100 contracts, and only 0.42% were traded with more than 1,000 option contracts. The stratified proportions reveal that the proportion of observations with non-zero trading volume is largest in the ATM category, followed by the OTM category. We compare these proportions first to those from our overall sample, in Panel B. The proportions are very similar to those observed on March 5, 2003. This is confirmatory evidence that our sample is representative of a typical trading day. Panel C documents similar proportions for the five days preceding the announcement day.

These proportions are compared to a randomly chosen sample in Panel C, where for each takeover transaction we simulate a random pseudo-event date and look at the proportions of non-zero-volume observations in the five days leading up to the pseudo-event. Rather than reporting standard errors, we indicate how many standard deviations the proportion in the random sample lies from that actually observed.[5] The lowest difference between the proportions in the actual and random sample is four standard deviations. This value is obtained for the proportion of volumes above 1,000 contracts, for ATM options, conditional on there being no trading volume during the five preceding days. For all other comparisons, the difference corresponds to at least five standard deviations. A value of five standard deviations corresponds approximately to a chance of one in a million that the

[5] Note that each option volume observation follows a Bernoulli variable taking the value 1 if volume is positive (respectively larger than 100, 500 or 1,000 contracts) and 0 otherwise. Assuming independence, the sum of all observations follows a binomial distribution. The standard error of proportion p obtained from a random sample is given by $\sqrt{\frac{p(1-p)}{N}}$, where N is the number of observations.

randomly observed proportion would be larger than on the pre-announcement event date. As any other comparison leads to even larger differences, we believe the odds of one in a million to be a conservative estimate.

A-II.D Strongly Unusual Trading Volume and Matched Random Sample

Our primary goal is to distinguish informed trading from random speculative bets. Hence, we are looking for unusual trading patterns that are *clearly* different from the patterns exhibited by randomly selected samples, since evidence of non-random trading would point to the existence of informed trading. We analyze extreme cases that are potentially the *most likely* to reflect informed trading. In this spirit, we define as strongly unusual trading (SUT) observations (defined as the trading volume for an option-day pair, i.e., the end-of-day volume for a given option on the target) meeting the following four criteria for individual options: (1) The daily best recorded bid is zero. This corresponds implicitly to DOTM options where the market-maker, through his zero bid, signals his unwillingness to buy, but is willing to sell at a non-zero ask price. (2) The option expires on or after the announcement day, but is the first one to expire thereafter (the so-called front month option). Obviously, an insider would buy options that were going to expire soon after the announcement: in order to get the biggest "bang for their buck," he would try to buy the cheapest ones, these being the ones most likely to end up ITM. Short-dated OTM options tend to be cheaper and provide the greatest leverage. (3) The option has strictly positive trading volume. Since many individual equity options, especially those that are OTM, have zero trading volume (although all options have quotes in the market-making system), we focus on those that have positive volume, since a zero-volume trade is not unusual, by definition. (4) Finally, the transaction takes place within the 30 days preceding the event date, defined as the 0 date (i.e., between event dates -29 and 0). An informed trader faces a trade-off in that he must leverage on his private information prior to the event, while avoiding trading too close to the event, as that may entail a higher risk of alerting other market participants or triggering an investigation by the regulators.[6]

Table A-3 presents the sample statistics for the SUT sample. From the entire dataset, we identify 2,042 option-day observations, for the target firms, that meet our SUT selection criteria.[7] The share of calls is slightly more than half, with a total of 1,106 observations for target firms. The average trading volume is 124 option contracts, and the average trading volumes for calls and puts are, respectively, 137 and 108.[8] The median trading volume is somewhat more stable, with a value of 20 contracts for options written on the target.

We compare the statistics from the SUT sample with those from a randomly selected sample. The sampling procedure used to create the random sample is as follows: For each of the 1,859 events with options traded on the target firms, we randomly select a *pseudo-event* date. We treat the

[6]An additional aspect that we do not explicitly consider is the number of traders involved, and their connections with each other, which could reveal whether the information was shared by many players and potentially leaked to them. Presently, we do not have data on individual trades conducted in this period.

[7]Note that the full sample has approximately 12 million observations. For each event, the event time spans the period from one year before to one year after the announcement date.

[8]The average is taken across all observations satisfying the SUT selection criteria.

pseudo-event date as a hypothetical announcement date, chosen at random, and then apply the SUT selection criteria to it, i.e., we keep option-day observations with a zero bid price, with non-zero trading volume, that are within 30 days of the pseudo-event date, and that have an expiry date after the pseudo-event date.

The SUT sample statistics are compared to the random sample trading (RST) statistics in Panel B of Table A-3.[9] The number of observations, deals and options are somewhat higher in the RST sample than in the SUT sample, by a factor of between 1.4 and 1.8. However, the average and median trading volumes in the SUT sample are more than double those in the RST sample. The maximum observed trading volumes are significantly higher in the SUT sample than in the RST sample. However, the distributional statistics illustrate that this effect does not arise because of outliers. In the RST sample, from around the 50th percentile of the distribution upwards, volumes are consistently less than half the trading volumes observed in the SUT sample at comparable cut-offs of the volume distribution. Another interesting feature is that the distance between the median and the mean is roughly constant at around 100 traded contracts in the SUT sample. Statistics for the put options are statistically similar across both samples. For the entire sample, the difference between the average volume (124) before the deal announcement in the SUT sample, and the average volume (57) on a random date in the RST sample, is significantly different from zero. The one-sided t-statistic is -6.90, implying a probability of three in a trillion that the trading volume observed before the announcement happened by chance. Moreover, the volumes of the SUT sample are overwhelmingly higher for the percentiles over 30%, and about the same for those less than 30%.

We point out that the difference between the two samples is likely to be *understated* in our procedure compared to the procedure of choosing the random sample from the *entire* sample period. Specifically, in our case, for each event, we have a maximum of one year of data before and after the event, rather than the whole time-span of traded options from as far back as January 1996 until today. Using the whole time-span the difference would likely be even stronger. Hence, our statistical procedure is biased against failing to reject the null hypotheses.

To summarize, the entire distribution of trading volumes differs significantly between the SUT and RST samples for the target firms. In particular, we observe that an average trading volume above 100 contracts, with a mean-to-median distance of 100 contracts, can be considered strongly unusual and non-random when the transactions occur at a "zero-bid," within 30 days of the announcement date, on options expiring after the announcement. This test provides additional evidence in favor of Hypothesis H1, showing that there is a *non-random* increase in the trading volume for target firms prior to public takeover announcements, particularly if we restrict ourselves to the most illiquid and leveraged options in the SUT sample.

[9] Since our study is confined to a limited period, due to the fact that the variance may be large, and to address the possibility that the dates chosen at random may coincide with those of other announcements, we double-checked our results using 100 random samples of 1,859 pseudo-events for the target firms, in order to minimize the standard error of our estimates. As expected, the results from this robustness check were very similar to the original results.

A-II.E Excess Implied Volatility - Event Study

Informed traders with accurate information about the timing of an announcement and the offer price will tend to buy OTM calls *just prior* to the announcement (for example, as in the JPM-Bank One case). To obtain leverage, they will buy OTM calls that are likely to become ITM when the stock price reaches or exceeds the takeover offer price. If they are confident about their information, they will be willing to pay the offer price of the option market-maker, typically the seller of such options. Informed traders who anticipate a deal, but are uncertain of the offer price and the timing, will typically buy options that are closer to the money, and will also be willing to pay the offer price. Assuming that the equilibrium price of the option is, on average, between the bid and ask prices, buying at the ask price will result in higher excess implied volatility. The wider the bid-ask spread, the greater will be the measured excess volatility, due to the convexity of option prices. Thus, we anticipate excess implied volatility, albeit not especially large, for all options on the target.[10] More formally, we formulate the following hypothesis:

- H3: *There is positive excess implied volatility for equity options written on the target firms, prior to takeover announcements, provided informed traders primarily buy rather than sell options.*

To test this hypothesis, we conduct a forensic analysis of implied volatility, the summary statistic of the price behavior of options, over the 30 days preceding the takeover announcement date. As a complement to the volume results, we first conduct an event study to test for the presence of positive excess implied volatility relative to a market benchmark. We use the interpolated volatility surface in the OptionMetrics database, a three-dimensional function of the implied volatility in relation to the strike price and the time to expiration, for this exercise. To analyze the behavior of ATM implied volatility, we use the 50 delta (or a 0.50 hedge ratio) options in absolute value (for both calls and puts), and the 80 and 20 delta (or 0.80 and 0.20 hedge ratios) options in absolute value for the ITM and OTM options respectively. We test two different model specifications for our results: a simple constant mean volatility model and a market model, in which we use the S&P 500 VIX index as the market's benchmark for implied volatility. The estimation window runs from 90 to 31 days before the announcement date, while our event window relates to the 30 days before the event, excluding the announcement day itself. All standard errors are clustered by time to account for the bunching of events on a given day.

Panel A in Table A-4 documents that excess implied volatility is pervasive in our sample. At the 5% significance level, using the market model, there are about 812 cases (44% of the 1,859 deals) with positive excess implied volatility for ATM calls, and about 798 cases (43% of the 1,859 deals) with positive excess implied volatility for ATM puts. The frequencies are similar for OTM implied volatilities, and slightly lower for ITM implied volatilities, where positive excess implied volatility is documented for 39% (calls) and 41% (puts) of all cases. This study confirms the existence of

[10] This argument can be related to prior work on the inelasticity of the option supply curve, along the lines analyzed theoretically by Garleanu, Pedersen, and Poteshman (2009) and empirically by Bollen and Whaley (2004) and Deuskar, Gupta, and Subrahmanyam (2011).

positive excess implied volatility for the target companies, confirming Hyopthesis H3. These results are graphically presented in Figure A-3a for ATM implied volatilities. For targets, the daily average excess ATM implied volatility starts increasing about 18 days before the announcement date and rises to an excess of 5% the day before the announcement.

A-II.F Information Dispersion and the Determinants of Bid-ask Spreads

Similar to the rationale behind Hypothesis H3, there should be no clear pattern in the bid-ask spread for the options on the target firm as the announcement date approaches, in the absence of insider activity. An increase in the percentage bid-ask spread, conditional on abnormal trading volumes, would be a natural response of the market-makers to such asymmetric information. This would be indirect evidence that there were informed traders in this market prior to the announcement date, but not necessarily that the information about a potential merger had leaked to the whole market. Thus, we formulate the following additional hypothesis:

- H4 : *The percentage bid-ask spread for options written on target firms widens prior to takeover announcements.*

To address Hypothesis H4, we study the evolution of the bid-ask spread in anticipation of the takeover announcement. The prediction of Hypothesis H4 is that the percentage bid-ask spread in option premia should widen prior to the announcement. Strong evidence in favor of this hypothesis would indicate that the market (i.e., the market-maker) is reacting to a substantial increase in the demand for options, in particular OTM calls. Figure A-3c plots the evolution of the average percentage bid-ask spread from 90 days before the announcement date to 90 days after the event. The figure shows that the average percentage bid-ask spread on target options rises from about 35% to 55%, and then jumps up to approximately 80% following the announcement. Interestingly, this rise in bid-ask spreads is restricted to DOTM and OTM options, as is illustrated in Figure A-3e.

As we did in our earlier exercise, we verify whether we are able to observe such a pattern on a random day. Thus, for each takeover transaction, we draw a random pseudo-event date and construct the average bid-ask spread in pseudo-event time. The outcome is illustrated by the flat line in Figure A-3d. Clearly, the average percentage bid-ask spread calculated in event time, for randomly chosen announcement dates, exhibits no pattern of rising bid-ask spreads in response to the arrival of any asymmetric information from potential insiders.

Our analysis shows that the average percentage bid-ask spread on target options rises from about 35% to 55%, and then jumps up to approximately 80% following the announcement. Interestingly, this rise in bid-ask spreads is restricted to DOTM and OTM options, and such a pattern of rising bid-ask spreads in response to the arrival of any asymmetric information from potential insiders is not observed ahead of randomly chosen announcement dates. In order to get further insights into the economic drivers of the rise in bid-ask spreads, we build a model of the determinants of bid-ask spreads.

We regress the percentage bid-ask spread BA in the 30 pre-announcement days on a series of option- and issuer-specific measures of trading volume, return performance, volatility and trade imbalance, controlling for the overall level of market activity in both the stock and options markets. More specifically, we examine the impact of trading volume by incorporating the natural logarithm of options volume (OV) at the options level i, and the natural logarithm of stock volume (SV) at the issuer level j, defined as $OV = \ln(1 + Volume_O)$ and $SV = \ln(1 + Volume_S)$, respectively. We also control for return performance through the log returns of stock prices (ret^S) at the issuer level, and through the log returns of option prices (ret^O) at the option level. We capture trade imbalance as the natural logarithm of the ratio of aggregate call-to-put trading volume, measured at the issuer level (CP). In addition, we examine the effect of the option-specific implied volatility (IV) and the realized volatility over the past 30 days ($RV30$), measured at the firm level. To capture overall market activity and trends, we control for the natural logarithm of the median options market volume (Mkt^{OV}), measured across all traded options, and for the natural logarithm of the median stock market volume (Mkt^S), measured across all traded stocks. We further control for the CBOE Volatility Index (VIX), the excess return on the market ($Mktrf$), calculated as the value-weighted return on all NYSE, AMEX, and NASDAQ stocks (from CRSP) minus the one-month Treasury bill rate (from Ibbotson Associates). We further include five dummy variables (D) that take on the value one if an option is DOTM, OTM, ATM, ITM, or DITM, respectively, and zero otherwise. In addition, we include three dummy variables ($TT1$, $TT2$, and $TT3$) that take on the value one if an option is short term (less than 30 days), medium-term (between 30 and 60 days), or long-term (more than 60 days), respectively, and zero otherwise. We examine the relationship between the bid-ask spreads and the lagged values of the economic determinants in order to capture the response of market-makers to activity in the equity and options markets.[11] We run a time-series regression, where the benchmark model is specified as

$$\begin{aligned} BA_{i,j,t+1} = {} & \alpha_0 + \beta_1 OV_{i,j,t} + \beta_2 SV_{j,t} + \beta_3 ret^O_{i,j,t} + \beta_4 ret^S_{j,t} + \beta_5 CP_{j,t} + \beta_6 IV_{i,j,t} \\ & + \beta_7 RV30_{j,t} + \beta_8 Mkt^{OV}_t + \beta_9 Mkt^S_t + \beta_{10} VIX_t + \beta_{11} Mktrf_t \\ & + \sum_{i=2}^{5} D_i + \sum_{i=2}^{3} TTE_i + \sum_{i=1}^{5} D_i \times OV_{i,j,t} + \gamma_i + \varepsilon, \end{aligned} \tag{A-6}$$

where the interaction terms $\sum_{i=1}^{5} D_i \times OV_{i,j,t}$ measure the response of the bid-ask spread to options volume within each moneyness category. All results are reported in Table A-5. The negative and statistically significant coefficent on OV suggests that, on average, greater options trading volume is associated with lower percentage bid-ask spreads. However, the breakdown by moneyness, characterized through the interaction coefficients between options volume and the moneyness dummy variables, is consistent with the view that market-makers increase bid-ask spreads in response to higher options trading volume in order to protect themselves against the arrival of informed traders. This asymmetric information problem is visible in particular for DOTM and OTM options, which are the options that drive the increase in bid-ask spreads ahead of the announcements. The economic magnitudes suggest that increasing the natural logarithm of options volume from one to two

[11] With daily data and end-of-day values, the bid-ask spread response is better captured through lagged variables of the economic determinants.

increases the bid-ask spread of the average DOTM (OTM) option by three (one) percentage points, which is an economically meaningful number. In contrast, the effect is negative for ITM and DITM options, which are arguably less vulnerable to the asymmetric information problem. Part of the rise in the percentage bid-ask spread can also be ascribed to trade imbalance, given the positive and statistically significant sign on the log ratio of aggregate call-to-put trading volumes at the firm level. The average percentage bid-ask spread decreases as we move further into the money, as suggested by the negative coefficients on ATM, ITM, and DITM, which measure the percentage bid-ask spreads relative to DOTM options. Moreover, medium- and long-dated options have lower bid-ask spreads than short-dated options in the 30 pre-announcement days.

The time-series regression suggests that the bid-ask spread increases in response to both higher option implied volatility and higher realized stock volatility, the former having a much more meaningful economic impact, as the coefficient is more than six times larger in magnitude. More specifically, the coefficient suggests that the bid-ask spread, as a fraction of the mid option price, will increase by six percentage points in response to an increase in the implied volatility of one percentage point. The relationship between aggregate options volume and the percentage bid-ask spread is negative, suggesting that higher liquidity decreases transactions costs, and similarly for the VIX index, which suggests that higher market volatility decreases percentage bid-ask spreads. Higher aggregate trading volume in the stock market appears to be positively associated with the percentage bid-ask spread, but the effect is insignificant if we control for the lagged bid-ask spread. In that specification, the return on the aggregate stock market exhibits no statistical relationship with the dependent variable.

To summarize, the findings confirm the intuition that dealers increase the bid-ask spreads in response to incoming order flow in the options markets, in order to protect themselves against the arrival of informed traders. This is particularly visible for DOTM, OTM, but slightly less so for ATM options. In addition, an increase in call trading volume relative to put trading volume is associated with higher bid-ask spreads, as well as an increase in implied and realized volatility.

A-II.G The Term Structure of Implied Volatility

Informed traders can obtain the highest leverage by buying short-dated OTM call options that expire soon after the announcement date. Given this preference, demand pressure on short-dated options should lead to a relative price increase (or a tendency to buy at the offer price) in options with a shorter time to expiration, compared to long-dated options. Thus, the slope of the term structure of implied volatility should decrease for call options written on target firms. Thus, expect to confirm the following hypothesis:

- H5: *The slope of the term structure of implied volatility decreases for options on the target firms before takeover announcements.*

Hypothesis H5 states that the term structure of implied volatility for options on the target firms should decrease before takeover announcements. The justification for this hypothesis is that informed traders obtain the highest leverage by investing in short-dated OTM call options that expire soon after the announcement, so as to maximize the “bang for their buck.” Hence, demand pressure for short-dated options should lead to a relative price increase in options with a short time to expiration compared to long-dated options. Thus, a confirmation of our hypothesis would be supportive of the fact that, on average, activity in the options market before major takeover announcements is partially influenced by informed traders. Figure A-3b documents that the slope of the average term structure of implied volatility, calculated as the difference between the implied volatilities of the 3-month and 1-month options, decreases from -1.8% by about 2.5 percentage points to approximately -4.3% over the 30 days before the announcement date. This result is obtained for both call and put options. However, the term structure of implied volatility remains at approximately the same level, essentially unchanged, if we randomize the announcement dates as a control sample. In a nutshell, we find evidence in support of the fact that the term structure of implied volatility becomes more negative for targets as we approach the announcement date.

A-II.H Takeover Predictability

Kosowski, Naik, and Teo (2007) document that hedge funds earn abnormal returns that are difficult to be explained by pure luck. The economic sources of such "hedge fund alpha" are, however, not uncontestably pinned down. Could it be that the positive abnormal performance of a certain class of hedge funds is rationally justified by a superior ability to predict M&A deal activity? We examine this question by looking at the ability of traders to predict merger activity through the lens of a takeover prediction model. More precisely, we estimate the likelihood that a firm will be a target in an M&A transaction using observable firm-specific and industry characteristics. We use the entire spectrum of completed takeover targets in the SDC Platinum database for which we can identify full firm-level information in Compustat over the period from 1995 to 2012. This generates a sample of 4,061 to 4,978 targets, depending on the specified model, with 101,306 firm-year observations for the most restrictive specification. Between 1,260 and 1,354 of these deals overlap with our option sample, and we therefore cover approximately 68% to 73% of the 1,859 deals that we studied in the previous section.[12] Depending on the specification, we have between 101,306 and 121,696 firm-year observations.

We estimate the ex-ante probability of a takeover using a logit regression framework. We define a target indicator variable MA that takes the value one if a firm was a target in a given calendar year, and zero otherwise. If a target was acquired, it drops from the sample in the year following its acquisition. In a second step, we attempt to predict the probability of treatment (i.e., a firm is a takeover target) using the previous year's balance sheet information. Formally, we run the regression

$$Prob(MA_{t+1}^{i} = 1) = \Phi\left(X_t^i \beta\right), \tag{A-7}$$

where $\Phi(\cdot)$ is the cumulative distribution function of the logistic distribution, and X_t^i is the vector of observable covariates that contains both firm-specific and industry characteristics. We include several variables that have previously been used in the literature to determine the probability of being acquired (Palepu, 1986; Ambrose and Megginson, 1992; Cremers, Nair, and John, 2009; Bil-

[12] Our sample is substantially larger than that of Billett and Xue (2007), who have 23,208 firm-year observations, and Cremers, Nair, and John (2009), who study a sample of 2,812 targets.

lett and Xue, 2007). We use the natural logarithm of total firm assets (Ln_Assets), the natural logarithm of employees (measured in thousands, $Ln\_Employees$) and a firm's market capitalization ($MarketEquity$) as proxies for firm size. We further incorporate variables relating to firm performance into our prediction model. Specifically, we use return on assets (ROA), return on equity (ROE), the total 12-month cumulative return over the previous calendar year ($CumRet$), and earnings per share (EPS). In addition, we incorporate several measures capturing the capital structure of the firm: $Leverage$, defined as total liabilities over total assets, total net property, plant, and equipment divided by total assets ($PPENT\_ratio$), retained earnings over total assets (RE_ratio), the market to book ratio (Q), capital expenditure divided by total assets ($CAPEX\_ratio$), and the dividend yield ($DivYield2$). All balance sheet variables are winsorized at the 99th percentile of the distribution.

Following the intuition that takeovers become more likely in the presence of large external blockholders (Shleifer and Vishny, 1986), we further include an indicator variable ($BLOCK$) that takes the value one if there exists at least one institutional shareholder that holds more than 5% of the company's stock. We extract the information on institutional ownership from the Thomson Reuters Institutional 13F holdings. To capture the clustering of mergers in industries over time, we also include a dummy variable ($WAVE$) that equals one if a takeover attempt occurred in the same industry in the previous year, based on the four-digit SIC code. We also include a proxy for the liquidity of the stock, measured as the natural logarithm of the average trading volume in the previous calendar year (Log_Volume). Last, we include an indicator variable ($Option1$) that is equal to one if the company has option information in the OptionMetrics database.[13]

Table A-8 in the appendix provides the results of the maximum likelihood estimation from the takeover prediction model. Generally speaking, our results are qualitatively similar to those reported in earlier studies. For example, takeover probability increases in asset size, return on assets, and retained earnings, but it decreases in the market capitalization, leverage, earnings per share, return on equity, dividend yields, and cumulative market returns of the company over the previous calendar year. Moreover, a takeover indeed becomes more likely if there exists at least one large institutional shareholder, and if there was a takeover attempt in the same industry in the previous year. Finally, the probability of acquisition is also higher if a company's stock price is more liquid, but it is less likely if the firm has traded options. The pseudo R^2 of the logit regression, at between 4% and 5%, is modest but consistent with the results of previous takeover probability estimations (Cremers, Nair, and John, 2009). The distribution of takeover probabilities, reported in Figure A-6 of the Online Appendix, also resembles the results in Billett and Xue (2007). The average (median) takeover propensity is 4% (3.6%), with an interquartile range of 2.89%, whereas the 5th and 95th percentiles are 0.62% and 8.71%, respectively.

The results of our takeover probability model are consistent with previous results in the literature. Yet, we generate only low takeover propensity scores, and the regression specifications have rather

[13]We cannot use the corporate governance measure of Gompers, Ishii, and Metrick (2003) or Bebchuk, Cohen, and Ferrell (2009) because of insufficient matching observations: the reduced sample would no longer be representative of the options sample.

weak explanatory power. This suggests that, to some extent, it is difficult to correctly predict, using publicly observable information available to the econometrician, whether a company is subject to a future takeover threat. Even if we were to interpret the jointly low probability scores and R^2s as evidence that hedge funds have superior ability to process information (Solomo and Scholtes, 2015), it is much less conceivable that hedge funds could correctly predict the exact *timing* of a deal. Given that our examination of abnormal options activity is restricted to the short period preceding the announcement, and that most of the abnormal volume is generated a few days immediately before the event, our evidence is not likely to have arisen from a superior ability to legally predict mergers. Thus, it seems unlikely that the abnormal options volume we document can be traced back to investors correctly predicting future announcement dates.

Table A-1: Bivariate Kolmogorov-Smirnov Tests - Target

Each entry in Table A-1 represents the test statistic from a generalization of the bivariate two-sample Kolmogorov-Smirnov test based on Fasano and Franceschini (1987). The null hypothesis of the test is that two bivariate samples come from the same empirical distribution function. The bivariate distribution of trading volume is compared across different event-time windows of five consecutive days (except for the announcement window, which contains a single day, and the event window immediately preceding it, which contains only four days): The first event window stretches from $t = -29$ to $t = -25$ ($[-29, -25]$) and the last from $t = -4$ to $t = -1$ ($[-4, -1]$). We also compare every event-time window against the announcement day ($[0, 0]$). Panel A contains the results for call options and Panel B contains the results for put options. For each group, we report the results from sub-samples based on the time to expiration (TTE): less than or equal to 30 days, greater than 30 but less than or equal to 60 days, and more than 60 days. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

	Panel A: Calls						**Panel B: Puts**					
	Full Sample						**Full Sample**					
Event Window	[−24, −20]	[−19, −15]	[−14, −10]	[−9, −5]	[−4, −1]	[0, 0]	[−24, −20]	[−19, −15]	[−14, −10]	[−9, −5]	[−4, −1]	[0, 0]
[−29, −25]	0.0279***	0.0482***	0.0616***	0.1007***	0.1592***	0.4070***	0.0331***	0.0414***	0.0382***	0.0607***	0.0820***	0.2760***
[−24, −20]	.	0.0228***	0.0368***	0.0744***	0.1334***	0.3911***	.	0.0209**	0.0242***	0.0403***	0.0677***	0.2657***
[−19, −15]	.	.	0.0173**	0.0556***	0.1134***	0.3694***	.	.	0.0176*	0.0301***	0.0524***	0.2549***
[−14, −10]	.	.	.	0.0410***	0.0988***	0.3581***	.	.	.	0.0295***	0.0561***	0.2564***
[−9, −5]	.	.	.	.	0.0606***	0.3256***	.	.	.	.	0.0389***	0.2351***
[−4, −1]	.	.	.	.	.	0.2798***	.	.	.	.	.	0.2132***
	TTE = [0,30]						**TTE = [0,30]**					
Event Window	[−24, −20]	[−19, −15]	[−14, −10]	[−9, −5]	[−4, −1]	[0, 0]	[−24, −20]	[−19, −15]	[−14, −10]	[−9, −5]	[−4, −1]	[0, 0]
[−29, −25]	0.0348	0.1255***	0.2157***	0.2750***	0.3388***	0.6102***	0.0318	0.1246***	0.1978***	0.2886***	0.3400***	0.5275***
[−24, −20]	.	0.1212***	0.2121***	0.2645***	0.3340***	0.6093***	.	0.1280***	0.1978***	0.2893***	0.3407***	0.5266***
[−19, −15]	.	.	0.0979***	0.1667***	0.2377***	0.5105***	.	.	0.1003***	0.1752***	0.2280***	0.4149***
[−14, −10]	.	.	.	0.0979***	0.1700***	0.4408***	.	.	.	0.0961***	0.1484***	0.3397***
[−9, −5]	.	.	.	.	0.0867***	0.3607***	.	.	.	.	0.0653***	0.2509***
[−4, −1]	.	.	.	.	.	0.2854***	.	.	.	.	.	0.2104***
	TTE =]30,60]						**TTE =]30,60]**					
Event Window	[−24, −20]	[−19, −15]	[−14, −10]	[−9, −5]	[−4, −1]	[0, 0]	[−24, −20]	[−19, −15]	[−14, −10]	[−9, −5]	[−4, −1]	[0, 0]
[−29, −25]	0.0605***	0.0859***	0.0905***	0.1341***	0.1843***	0.4324***	0.0670***	0.0975***	0.0907***	0.1228***	0.1355***	0.3370***
[−24, −20]	.	0.0390**	0.0453***	0.0874***	0.1421***	0.3925***	.	0.0465**	0.0430*	0.0672***	0.0896***	0.3047***
[−19, −15]	.	.	0.0246	0.0628***	0.1111***	0.3746***	.	.	0.0353	0.0484***	0.0747***	0.2895***
[−14, −10]	.	.	.	0.0554***	0.1050***	0.3605***	.	.	.	0.0619***	0.0983***	0.3094***
[−9, −5]	.	.	.	.	0.0611***	0.3232***	.	.	.	.	0.0514**	0.2729***
[−4, −1]	.	.	.	.	.	0.2885***	.	.	.	.	.	0.2361***
	TTE = [60,...]						**TTE = [60,...]**					
Event Window	[−24, −20]	[−19, −15]	[−14, −10]	[−9, −5]	[−4, −1]	[0, 0]	[−24, −20]	[−19, −15]	[−14, −10]	[−9, −5]	[−4, −1]	[0, 0]
[−29, −25]	0.0227***	0.0323***	0.0364***	0.0675***	0.1195***	0.3897***	0.0293***	0.0309***	0.0264**	0.0371***	0.0657***	0.2706***
[−24, −20]	.	0.0165*	0.0210***	0.0503***	0.1009***	0.3763***	.	0.0288***	0.0288***	0.0337***	0.0553***	0.2703***
[−19, −15]	.	.	0.0158*	0.0390***	0.0885***	0.3623***	.	.	0.0187	0.0184*	0.0487***	0.2525***
[−14, −10]	.	.	.	0.0350***	0.0853***	0.3599***	.	.	.	0.0175	0.0454***	0.2534***
[−9, −5]	.	.	.	.	0.0549***	0.3324***	.	.	.	.	0.0361***	0.2429***
[−4, −1]	.	.	.	.	.	0.2883***	.	.	.	.	.	0.2235***

Table A-2: Zero-Volume Runs

Table A-2 reports sample proportions of observations that have more than, respectively, 0, 100, 500 and 1,000 option contracts (for instance, $P(V_t > 0)$). The proportions are reported for the overall sample, and for categories stratified by depth-in-moneyness. We assign five groups for depth-in-moneyness, which is defined as S/K, the ratio of the stock price S to the strike price K. Deep out-of-the-money (DOTM) corresponds to $S/K \in [0, 0.80]$ for calls ($[1.20, \infty)$ for puts), out-of-the-money (OTM) corresponds to $S/K \in (0.80, 0.95]$ for calls ($[1.05, 1.20)$ for puts), at-the-money (ATM) corresponds to $S/K \in (0.95, 1.05)$ for calls ($(0.95, 1.05)$ for puts), in-the-money (ITM) corresponds to $S/K \in [1.05, 1.20)$ for calls ($(0.80, 0.95]$ for puts), and deep in-the-money (DITM) corresponds to $S/K \in [1.20, \infty)$ for calls ($[0, 0.80]$ for puts). Panel A reports sample statistics for March 5, 2003. Panel B reports statistics for our entire sample. Panel C reports statistics for the five days preceding the actual announcement days ($t \in [-5, -1]$), as well as for the five days preceding random pseudo-event dates. Each comparison indicates the number of standard deviations difference between the random proportion and the actual proportion. Panel C also reports proportions of observations that have more than, respectively, 0, 100, 500 and 1,000 option contracts, conditional on there having been zero trading volume on the preceding day, and respectively during the five preceding days.

		DOTM	OTM	ATM	ITM	DITM	Full Sample
Panel A: March 5, 2003							
	N	28,402	17,319	12,052	17,319	28,404	103,496
$P(V_t > 0)$		0.1064	0.2718	0.3022	0.1524	0.0539	0.1502
$P(V_t \geq 100)$		0.0193	0.0641	0.0720	0.0243	0.0046	0.0297
$P(V_t \geq 500)$		0.0038	0.0172	0.0241	0.0059	0.0011	0.0080
$P(V_t \geq 1000)$		0.0021	0.0083	0.0128	0.0035	0.0004	0.0042
Panel B: Full Sample							
	N	3,411,873	1,428,467	2,380,397	1,428,286	3,412,545	12,061,568
$P(V_t > 0)$		0.1033	0.2581	0.3487	0.1584	0.0688	0.1668
$P(V_t \geq 100)$		0.0155	0.0474	0.0879	0.0220	0.0071	0.0320
$P(V_t \geq 500)$		0.0040	0.0138	0.0270	0.0062	0.0018	0.0093
$P(V_t \geq 1000)$		0.0022	0.0076	0.0144	0.0034	0.0010	0.0050
Panel C: $t \in [-5, -1]$ - Actual vs. Random							
	N	78,424	32,500	27,074	32,540	78,436	248,974
	N_{RS}	34,508	15,185	21,066	15,192	34,553	120,504
$P(V_t > 0)$	Actual	0.1155	0.3681	0.4265	0.2408	0.0922	0.1913
	Random	0.0982	0.2519	0.3239	0.1502	0.0695	0.1554
	# SD away	11	33	32	31	17	34
$P(V_t \geq 1000)$	Actual	0.0038	0.0165	0.0260	0.0067	0.0023	0.0078
	Random	0.0016	0.0052	0.0110	0.0024	0.0008	0.0036
	# SD away	10	19	21	11	10	24
$P(V_t > 0 \mid V_{t-1} = 0)$	Actual	0.1037	0.2734	0.2766	0.2034	0.0859	0.1521
	Random	0.0882	0.1852	0.2120	0.1260	0.0647	0.1201
	# SD away	10	28	23	29	16	34
$P(V_t \geq 1000 \mid V_{t-1} = 0)$	Actual	0.0034	0.0121	0.0163	0.0054	0.0022	0.0058
	Random	0.0016	0.0037	0.0073	0.0021	0.0008	0.0027
	# SD away	8	17	15	9	9	21
$P(V_t > 0 \mid \sum_{i=1}^{3} V_{t-i} = 0)$	Actual	0.0835	0.1499	0.1155	0.1429	0.0746	0.1006
	Random	0.0711	0.1029	0.0910	0.0892	0.0559	0.0765
	# SD away	9	19	12	23	15	31
$P(V_t \geq 1000 \mid \sum_{i=1}^{3} V_{t-i} = 0)$	Actual	0.0027	0.0067	0.0063	0.0038	0.0020	0.0035
	Random	0.0012	0.0020	0.0035	0.0018	0.0007	0.0016
	# SD away	8	13	7	6	9	16
$P(V_t > 0 \mid \sum_{i=1}^{5} V_{t-i} = 0)$	Actual	0.0676	0.0799	0.0481	0.1004	0.0650	0.0705
	Random	0.0568	0.0583	0.0371	0.0623	0.0485	0.0518
	# SD away	9	11	8	19	14	29
$P(V_t \geq 1000 \mid \sum_{i=1}^{5} V_{t-i} = 0)$	Actual	0.0021	0.0036	0.0025	0.0023	0.0017	0.0022
	Random	0.0009	0.0014	0.0015	0.0011	0.0007	0.0010
	# SD away	7	7	4	5	7	13

Table A-3: Strongly Unusual Trading (SUT) Sample and Matched Random Sample

Panel A presents sample statistics for the strongly unusual trading (SUT) sample, reflecting four selection criteria: (1) the best bid price of the day is zero, (2) non-zero volume, (3) option expiration after the announcement date, and (4) transaction within the 30 days prior to the announcement date. Panel B presents comparative statistics for a sample randomly selected from the entire dataset, where for each event we choose a pseudo-event date and then apply the same selection criteria as for the SUT sample. Both panels contain statistics for the aggregated sample, as well as separately for call and put options. We report the number of observations (Obs), the corresponding number of unique announcements (# Deals) and unique option classes (# Options), the average (Mean vol) and median (Med vol) trading volume, the percentiles of the distribution, and the minimum and maximum observations. Panel C shows results for the one- and two-sided Kolmogorov-Smirnov (KS) tests for the difference in distributions, and the one- and two-sided tests for differences in means (t-test). The statistical tests are carried out for the samples including both call and put options. *H0* denotes the null hypothesis of each test, *Statistic* denotes the test statistic type (D-distance for the KS test and t-statistic for the t-test), *Value* indicates the tes$t$-statistic value, and *p-val* the p-value of the test.

Panel A: SUT selection with the historical 1,859 event dates for the target - zero bid

Target	Obs	# Deals	# Options	Mean vol	Med vol	Min vol	1st pctile	5th pctile	25th pctile	75th pctile	95th pctile	99th pctile	Max vol
All	2,042	437	1,243	123.78	20	1	1	1	6	62	479	2,076	13,478
Calls	1,106	299	570	137.23	20	1	1	1	5	65	543	2,517	6,161
Puts	936	316	673	107.9	20	1	1	1	7.5	60	390	1,494	13,478

Panel B: One random sample of 1,859 pseudo-event dates for the target

Target	Obs	# Deals	# Options	Mean vol	Med vol	Min vol	1st pctile	5th pctile	25th pctile	75th pctile	95th pctile	99th pctile	Max vol
All	3,412	574	1,901	57	10	1	1	1	5	32	200	813	5,000
Calls	1,813	351	941	64	11	1	1	1	5	40	232	893	5,000
Puts	1,599	387	960	49	10	1	1	1	5	30	182	759	3,000

Panel C: Tests for statistical significance between SUT and random sample with all options

Target	KS (two-sided)	KS (one-sided)	KS (one-sided)	t-test (mean)	t-test (mean)	t-test (mean)
H0:	SUT=RS	SUT$\leq$ RS	SUT$\geq$ RS	SUT=RS	SUT$\leq$ RS	SUT$\geq$ RS
Statistic	D	D	D	t	t	t
Value	0.12	0.12	1.00	-6.90	-6.90	-6.90
p-val	2.80e-12	4.14e-17	1.00	5.99e-12	2.99e-12	1.00

Table A-4: Positive Excess Implied Volatility

Panel A in this table reports the results from a classical event study in which we test whether there was statistically significant positive excess implied volatility in anticipation of the takeover announcements. Two different models are used: excess implied volatility relative to a constant-mean-volatility model, and a market model, in which we use as the market-implied volatility the CBOE S&P 500 Volatility Index (VIX). The estimation window starts 90 days before the announcement date and runs until 30 days before it. The event window stretches from 30 days before until one day before the announcement date. Panel A reports the number (#) and frequency (freq.) of events with statistically significant positive excess implied volatility at the 5% significance level. The results are illustrated separately for the 30-day at-the-money (ATM), in-the-money (ITM) and out-of-the-money (OTM) implied volatility, defined as, respectively, 50, 80 and 20 delta (δ) options in absolute value.

Panel A

	Market Model (VIX)		Constant-Mean Model	
Option Type	Calls	Puts	Calls	Puts
30-day ATM Implied Volatility ($\|\delta\| = 50$) - Target				
Sign.t-stat 5% (#)	812	798	794	766
Sign.t-stat 5% (freq.)	0.44	0.43	0.43	0.41
30-day ITM Implied Volatility ($\|\delta\| = 80$) - Target				
Sign.t-stat 5% (#)	733	756	712	762
Sign.t-stat 5% (freq.)	0.39	0.41	0.38	0.41
30-day OTM Implied Volatility ($\|\delta\| = 20$) - Target				
Sign.t-stat 5% (#)	791	671	772	668
Sign.t-stat 5% (freq.)	0.43	0.36	0.42	0.36

Table A-5: Bid-Ask Spread Determinants

This table presents the results from a regression of the percentage bid-ask spread, BA, in the 30 pre-announcement days, on a series of option- and issuer-specific measures of trading volume, return performance, volatility and trade imbalance, controlling for the overall level of market activity in both the stock and options market. OV (OS) denotes the natural logarithm of options (stock) volume, defined as $OV = \ln(1 + Volume_O)$ ($SV = \ln(1 + Volume_S)$). The log returns of stock (option) prices is represented by ret^S (ret^O). CP denotes the natural logarithm of the ratio of aggregate call-to-put trading volume, measured at the issuer level. IV denotes the option-specific implied volatility and $RV30$ denotes the trailing 30-day realized stock volatility. The natural logarithm of the median options (stock) market volume, measured across all traded options (stocks), is given by Mkt^{OV} (Mkt^S). VIX is the CBOE Volatility Index, $Mktrf$ is the excess return on the market, calculated as the value-weighted return on all NYSE, AMEX, and NASDAQ stocks (from CRSP) minus the one-month Treasury bill rate (from Ibbotson Associates). $D1$ to $D5$ are dummy variables that take the value one if an option is DOTM, OTM, ATM, ITM, or DITM, respectively, and zero otherwise. $TT1$, $TT2$, and $TT3$ are dummy variables that take the value one if an option is short-term (less than 30 days), medium-term (between 30 and 60 days), and long-term (more than 60 days), respectively, and zero otherwise. N denotes the number of firm-quarter observations, *adj.R2*, the R-squared of the model in percentage terms. The time-series regressions contain option fixed effects. We report the within-adjusted $R2$, and we cluster at the option level to correct for serial correlation in the error terms. Source: OptionMetrics, CRSP, CBOE, Kenneth French's website.

	(1)	(2)
VARIABLES	BA_{t+1}	BA_{t+1}
BA_t		0.6786***
OV	-0.0097***	-0.0009***
OS	0.0169***	0.0028***
$DOTM \times OV$	0.0223***	0.0316***
$OTM \times OV$	-0.0038	0.0055***
$ATM \times OV$	-0.0124***	-0.0024***
$ITM \times OV$	-0.0279***	-0.0109***
$DITM \times OV$	-0.0278***	-0.0120***
CP	0.0004*	0.0006***
OTM	-0.2239***	-0.0994***
ATM	-0.2981***	-0.1327***
ITM	-0.3185***	-0.1411***
$DITM$	-0.3326***	-0.1474***
$TTE2$	-0.1457***	-0.0478***
$TTE3$	-0.2270***	-0.0757***
ret^O	-0.0911***	-0.0109***
ret^S	-0.0410***	-0.0486***
$RV30$	0.0197***	0.0031**
IV	0.1095***	0.0631***
Mkt^{OV}	-0.0110***	-0.0036***
Mkt^S	0.0070***	-0.0004
VIX	-0.0013***	-0.0009***
$Mktrf$	-0.1248***	-0.0225
Constant	0.4939***	0.2544***
	-0.0235	(0.0136)
N	868,021	868,021
Option FE	YES	YES
CLUSTER TIME	NO	NO
CLUSTER OPTION	YES	YES
adj.R2(%)	7.82	46.63

*** p<0.01, ** p<0.05, * p<0.1

Table A-6: Summary Statistics for Treatment and Control Groups

This table reports summary statistics for the treatment and matched control groups. We report the average value in each group and the p-value from a t-test for the differences in means. The column labeled *Treatment* reports results for the treatment group, while the columns labeled *Match* report the means for the matched samples using the first best match (*PS1*) or the two best matches (*PS2*). In Panel A, the match is based on the month prior to the takeover announcement. RETURN ($RETURN$) defines the monthly log return on the firm's stock; BIDASK ($BIDASK$) is the bid-ask spread scaled by the stock price; Stock Volume ($VOLUME$) is the natural log of the monthly stock trading volume; Stock return volatility ($VOLATILITY$) is computed using the EWMA model with an autoregressive coefficient of 0.94. $CUMRET$ refers to the 3-month cumulative log return on the underlying stock. All firms are matched based on 3-month moving averages and we match based on the month prior to the takeover announcement. We match on the return, bid-ask spread, stock volume, and stock volatility. In Panel B, firms are taken from the same industry and matched on firm characteristics. ASSETS ($ASSETS$) is the natural log of total assets; WAVE ($WAVE$) equals one if a takeover attempt occurred in the same 4-digit SIC code in the previous calendar year. Blockholder ($BLOCK$) equals one if there exists at least one institutional shareholder with a minimum 5% equity stake. Leverage ($Leverage$) is defined as the ratio of total liabilities over total assets. Stock Volume ($STOCKVOLUME$) is the natural log of the average stock trading volume in the previous calendar year. Source: Thomson Reuters SDC Platinum, CRSP, OptionMetrics, Compustat, Thomson Reuters 13F filings.

Panel A	PS1			PS2		
	Treatment	Match	p	Treatment	Match	p
RETURN	0.09	0.08	0.09	0.09	0.08	0.01
BIDASK	0.01	0.01	0.16	0.01	0.01	0.03
VOLUME	0.34	0.33	0.88	0.34	0.32	0.65
VOLATILITY	0.05	0.04	0.01	0.05	0.04	0.00
CUMRET	0.26	0.24	0.09	0.26	0.23	0.01
Panel B	PS1			PS2		
	Treatment	Match	p	Treatment	Match	p
ASSETS	6.75	6.85	0.13	6.75	6.83	0.17
WAVE	0.70	0.71	0.44	0.70	0.71	0.73
BLOCK	0.51	0.53	0.23	0.51	0.53	0.17
LEVERAGE	0.52	0.51	0.19	0.52	0.51	0.06
STOCKVOLUME	15.83	15.90	0.13	15.83	15.89	0.09

Table A-7: Positive Abnormal Trading Volume in Treatment and Control Groups (12-month MOM)

This table reports the number (#) and frequency (freq.) of deals with statistically significant positive cumulative abnormal volume at the 5% significance level, as well as the average cumulative abnormal volume ($E[CAV]$) and corresponding t-statistic ($t_{C\bar{A}V}$), computed using heteroscedasticity-robust standard errors. We use the MMV model to calculate abnormal volume. The MMV model accounts for the median of the total daily trading volume across all options, the VIX index and the contemporaneous return on the S&P500 market index and the underlying stock, as well as lagged variables of the dependent and all independent variables. All results are reported separately for call options, put options, and for the aggregate option volume. The estimation window starts 90 days before the announcement date and runs until 30 days before the announcement date. The event window stretches from 30 days before until one day before the announcement date. Panel A reports results for the treatment group, Panel B for the matched control groups using the first (and second) best matches. Targets are matched based on size (natural logarithm of firm assets), market-to-book ratios (market to book capitalization ratio), and momentum (either the 12-month cumulative return over the previous calendar year or the past 3-month cumulative stock return in the month prior to the takeover). Panel C reports the average treatment effects obtained from a regression of the cumulative abnormal options volume on an indicator variable that takes on the value one if a target belongs to the treatment group, and zero otherwise. All regressions control for the matching variables, year fixed effects, and standard errors are clustered by announcement date to account for cross-sectional correlation due to possible clustering of announcement dates. Source: Thomson Reuters SDC Platinum, CRSP, OptionMetrics.

Panel A:	**Magnitude and Frequency of Cum. Abnormal Volume Deals Treatment Group PS0 - Takeover Sample**		
	All	Call	Put
Sign.t-stat 5% (#)	330	359	239
Sign.t-stat 5% (freq.)	0.25	0.27	0.18
$E[C\bar{A}V]$	10,548	10,586	-38
$t_{C\bar{A}V}$	2.93	5.13	-0.01

Panel B:	**Magnitude and Frequency of Cum. Abnormal Volume Deals**					
	Control Group PS1 Best Match			**Control Group PS2 Two Best Matches**		
	All	Call	Put	All	Call	Put
Sign.t-stat 5% (#)	175	170	158	331	315	306
Sign.t-stat 5% (freq.)	0.15	0.14	0.13	0.14	0.13	0.13
$E[C\bar{A}V]$	592	891	-299	-276	-364	88
$t_{C\bar{A}V}$	0.40	0.88	-0.38	-0.26	-0.36	0.15

Panel C:	**Differences in Cum. Abnormal Volume Deals across Treatment and Control Groups**					
Treatment1	10,289**	10,334***	-45			
	(4,045)	(2,299)	(3,161)			
Treatment2				11,046***	11,312***	-266
				(3,812)	(2,287)	(3,036)
CONTROLS	YES	YES	YES	YES	YES	YES
YEAR FE	YES	YES	YES	YES	YES	YES
CLUSTER	YES	YES	YES	YES	YES	YES

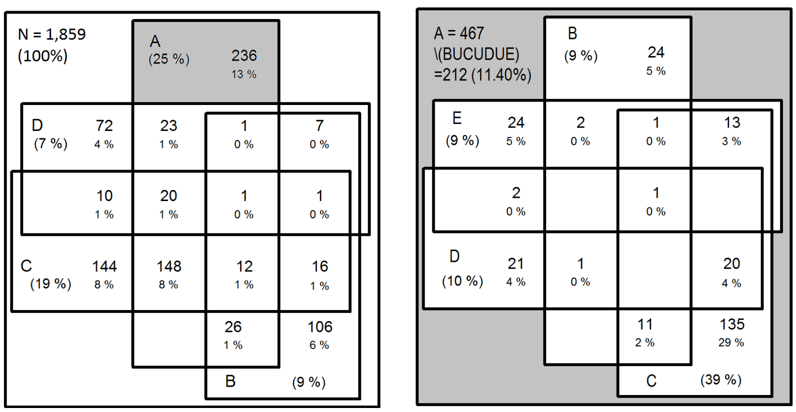
Table A-8: Takeover Prediction Model

This table reports the maximum likelihood estimation results from a logit regression for the prediction of takeover probability, where the dependent variable takes the value one if a takeover of a company was completed in a calendar year. *Ln_Assets* is the natural log of total assets. The industry dummy ($WAVE$) equals one if a takeover attempt occurred in the same four-digit SIC code industry in the previous calendar year. $BLOCK$ equals one if there exists at least one institutional shareholder with a minimum 5% equity stake. *Leverage* is defined as the ratio of total liabilities to total assets. Log_Volume is the natural log of the average stock trading volume in the previous calendar year. $Option1$ takes the value one if the company has option information in OptionMetrics. $DivYield2$ is a company's dividend yield. $PPENT\_ratio$ is the net total power, property and equipment scaled by total assets. ROA refers to return on assets, ROE is the return on equity and *CumRet* defines the 12-month cumulative log-return in the previous calendar year. *RE_ratio* is the ratio of retained earnings to total assets. The market-to-book ratio is denoted by Q. $MarketEquity$ is the previous year's market capitalization. *Ln_Employees* is the natural log of of the number of employees a company has, measured in thousands. EPS is the earnings per share ratio. $CAPEX\_ratio$ is the ratio of capital expenditure to total assets. All balance sheet variables are winsorized at the 99th percentile level and correspond to the calendar year preceding the takeover announcement. Each regression contains year fixed effects ($YEAR\ FE$), industry fixed effects ($INDUSTRY\ FE$), and ratings fixed effects ($RATING\ FE$), and standard errors are clustered at the firm level ($CLUSTER$). We report the number of observations (*Observations*), the log-likelihood function value (LL), the pseudo R-squared in per cent ($ps.R2$), the number of target firm-year observations ($M\&A(\#)$), the percentage of target firm-year observations ($M\&A(\%)$), and the fraction of target firm-year observations belonging to the option sample (*M&A in sample*(%)). ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively. Source: Thomson Reuters SDC Platinum, CRSP, OptionMetrics, Compustat, Thomson Reuters 13F filings.

VARIABLES	(1) MA2	(2) MA2	(3) MA2
Ln_Assets	0.15***	0.14***	0.22***
	(0.01)	(0.01)	(0.02)
WAVE	0.22***	0.22***	0.21***
	(0.03)	(0.03)	(0.04)
BLOCK	0.44***	0.43***	0.39***
	(0.03)	(0.03)	(0.04)
Leverage	-0.10***	-0.03	-0.11***
	(0.02)	(0.03)	(0.04)
Log_Volume	0.07***	0.07***	0.08***
	(0.01)	(0.01)	(0.01)
Option1	-0.78***	-0.77***	-0.70***
	(0.04)	(0.04)	(0.04)
DivYield2			-0.05***
			(0.01)
PPENT_ratio			-0.11
			(0.10)
ROA		0.19***	0.14***
		(0.04)	(0.04)
ROE		-0.02	-0.03
		(0.02)	(0.02)
CumRet			-0.00
			(0.00)
RE_ratio			0.10***
			(0.02)
Q			0.00*
			(0.00)
MarketEquity			-0.00***
			(0.00)
Ln_Employees			-0.03**
			(0.02)
EPS		-0.03***	-0.02***
		(0.01)	(0.01)
CAPEX_ratio			0.19
			(0.29)
Constant	-6.44***	-6.20***	-5.21***
	(0.70)	(0.70)	(0.97)
Observations	121,696	119,664	101,306
LL	-19,884	-19,643	-16,241
ps.R2(%)	4.35	4.46	4.70
M&A(#)	4,978	4,933	4,061
M&A(%)	4.09	4.12	4.01
M&A in sample(%)	72.83	72.46	67.78

Table A-9: Sources of Informed Options Trading

This table documents the sources of informed options trading for a sample of 1,859 takeovers from January 1996 to December 2012. Out of the 1,859 companies, 467 (25.12, subset A) have abnormal options trading volume at the 5% significance level over the 30 pre-announcement days. The sample of news and rumors amounts to 170 deals (9.14%, subset B). 352 of all deals (18.93%, subset C) have abnormal stock trading volume in the run-up to the announcement, while 135 deals (7.26%, subset D) have abnormal stock returns in the run-up to the announcement. The SEC/DoJ initiated a litigation for 154 (8.28%, subset E) of all deals in the sample. In total, 427 of all deals (22.97%) have abnormal options trading volume ahead of the announcement, as well as abnormal returns and volume in the underlying stock, without any news or rumors. 236 of all deals (13%, grey shaded area) have only abnormal options trading volume and are difficult to associate with public sources of information. Out of all 467 deals with abnormal options trading volume, 212 (11.40%, grey shaded area) are neither litigated by the SEC, nor can they be associated with other legal explanations.



Set	#	%	Cum%	A	B	C	D	E	Description
Ω	1,859	100.00	100.00	✓	✓	✓	✓	✗	Takeover Sample
A	467	25.12	25.12	✓	✗	✗	✗	✗	Abnormal Options Volume (A)
Ω\A	1,392	74.87	100.00	✗	✓	✓	✓	✗	No Abnormal Options Volume
B	170	9.14	9.14	✗	✓	✗	✗	✗	News & Rumors (B)
Ω\B	1,689	90.86	100.00	✓	✗	✓	✓	✗	No News & Rumors
C	352	18.93	18.93	✗	✗	✓	✗	✗	Abnormal Stock Volume (C)
Ω\C	1,507	81.07	100.00	✓	✓	✗	✓	✗	No Abnormal Stock Volume
D	135	7.26	7.26	✗	✗	✗	✓	✗	Abnormal Stock Returns (D)
Ω\D	1,724	92.74	100.00	✓	✓	✓	✗	✗	No Abnormal Stock Returns
Ω\(A ∩ B ∩ C ∩ D)	1,036	55.73	55.73	✗	✗	✗	✗	✗	No A, B, C, D
A\(B ∪ C ∪ D)	236	12.69	68.42	✓	✗	✗	✗	✗	A, No B, C, D
(A ∩ C)\(B ∪ D)	148	7.96	76.38	✓	✗	✓	✗	✗	A, C, No B, D
C\(A ∪ B ∪ D)	144	7.75	84.13	✗	✗	✓	✗	✗	C, No A, B, D
B\(A ∪ C ∪ D)	106	5.70	89.83	✗	✓	✗	✗	✗	B, No A, C, D
D\(A ∪ B ∪ C)	72	3.87	93.70	✗	✗	✗	✓	✗	D, No A, B, C
(A ∩ B)\(C ∪ D)	26	1.40	95.10	✓	✓	✗	✗	✗	A, B, No C, D
(A ∩ D)\(B ∪ C)	23	1.24	96.34	✓	✗	✗	✓	✗	A, D, No B, C
(A ∩ C ∩ D)\B	20	1.08	97.42	✓	✗	✓	✓	✗	A, C, No B, D
(B ∩ C)\(A ∪ D)	16	0.86	98.28	✗	✓	✓	✗	✗	B, C, No A, D
(A ∩ B ∩ C)\D	12	0.65	98.93	✓	✓	✓	✗	✗	A, B, No C, D
(C ∩ D)\(A ∪ B)	10	0.54	99.47	✗	✗	✓	✓	✗	C, D No A, B
(B ∩ D)\(A ∪ C)	7	0.38	99.85	✗	✓	✗	✓	✗	B, D, No A, C
(A ∩ B ∩ D)\ C	1	0.05	99.90	✓	✓	✗	✓	✗	A, B, D No C
∅∪(A ∩ B ∩ C∩ D)	1	0.05	100.00	✓	✓	✓	✓	✗	A, B, C, D
E	154	8.28	8.28	✓	✗	✗	✗	✓	SEC/DoJ (E)
Ω\E	1,705	91.72	100.00	✓	✓	✓	✓	✗	No SEC/DoJ
A\(B ∪ C ∪ D ∪ E)	212	11.40	11.40	✗	✗	✗	✗	✗	No A, B, C, D

Table A-10: SEC Predictability Regressions

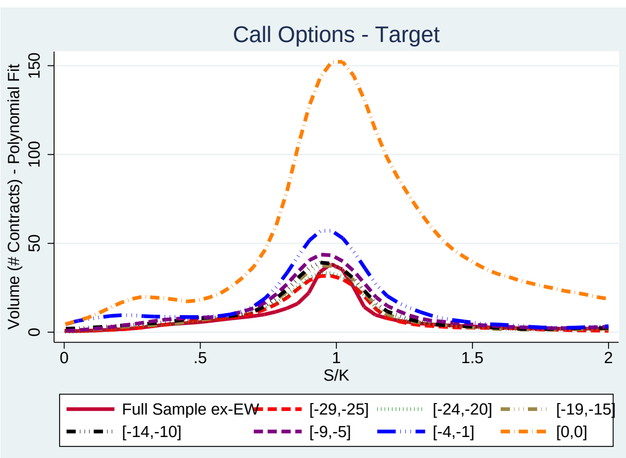
Table A-10 reports logit coefficients from the logistic regressions (odds ratios in parentheses). The dependent variable SEC takes the value one if there was litigation in respect of a deal involving options, and zero otherwise. The explanatory variables take the value one if a condition is met, and zero otherwise: $SIZE$ takes the value one for deals with a value greater than the median takeover deal value, $CASH$ for cash-financed takeovers, $CHALLENGE$ for challenged deals, $COMPLETE$ for completed transactions, TOE if a bidder already has a toehold in the target company, $PRIVATE$ if the acquirer privatized the target post-acquisition, $COLLAR$ for transactions with a collar structure, $TERM$ for deals with termination fees, $FRIENDLY$ if the deal attitude is considered to be friendly, and US if the bidder is a U.S.-based company. $PREM1D$ refers to the premium of the offer price over the target's closing stock price one day prior to the original announcement date, expressed as a percentage. $PRICE$ denotes the price per common share paid by the acquirer, $TRUNUP$ the target's pre-announcement cumulative abnormal stock return, $TANNRET$ the target's announcement-day abnormal return, $TTPRET1$ the target's post-announcement cumulative abnormal return. $ARUNUP$ is the acquirer's pre-announcement abnormal stock return, and $MKTVOL$ defines the market volume on the day before the announcement. $ABNORMVOLC$ is the total abnormal call volume for the target over the 30 days preceding the announcement. All specifications have year fixed effects. We report the number of observations (*Observations*) and the pseudo R-squared (*ps.R-squared*). ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, based on Firth's method for bias reduction in logistic regressions. Source: Thomson Reuters SDC Platinum, CRSP, OptionMetrics, SEC, DoJ.

VARIABLES	(1) Logit (Odds Ratio)	(2) Logit (Odds Ratio)	(3) Logit (Odds Ratio)	(4) Logit (Odds Ratio)
SIZE	0.63***	0.44*	0.79***	0.79***
	(1.87)	(1.55)	(2.21)	(2.20)
CASH	0.15	0.10	0.02	0.01
	(1.17)	(1.10)	(1.02)	(1.01)
CHALLENGE	-0.64	-0.76	-0.57	-0.59
	(0.53)	(0.47)	(0.56)	(0.55)
COMPLETE	1.05*	1.06*	1.07*	1.07*
	(2.87)	(2.88)	(2.92)	(2.92)
TOE	-0.76	-0.74	-0.73	-0.73
	(0.47)	(0.48)	(0.48)	(0.48)
PRIVATE	0.20	0.27	0.30	0.31
	(1.22)	(1.31)	(1.35)	(1.36)
COLLAR	0.43	0.37	0.30	0.29
	(1.53)	(1.45)	(1.35)	(1.33)
TERM	0.67	0.60	0.63	0.64
	(1.95)	(1.83)	(1.88)	(1.89)
FRIENDLY	-0.36	-0.36	-0.34	-0.35
	(0.70)	(0.70)	(0.71)	(0.70)
US	-0.55**	-0.59**	-0.57**	-0.56**
	(0.58)	(0.55)	(0.57)	(0.57)
PREM1D		0.01***		
		(1.01)		
PRICE		0.01***		
		(1.01)		
TRUNUP			-0.65	-0.68
			(0.52)	(0.51)
TANNRET			-0.69	-0.67
			(0.50)	(0.51)
TTPRET1			2.10***	2.12***
			(8.18)	(8.31)
ARUNUP			0.12	0.07
			(1.12)	(1.07)
MKTVOL				0.00
				(1.00)
ABNORMVOLC				0.00
				(1.00)
Constant	-3.56***	-3.85***	-3.78***	-3.86***
	(0.03)	(0.02)	(0.02)	(0.02)
Observations	1,859	1,807	1,859	1,859
ps.R-squared	0.11	0.12	0.13	0.16

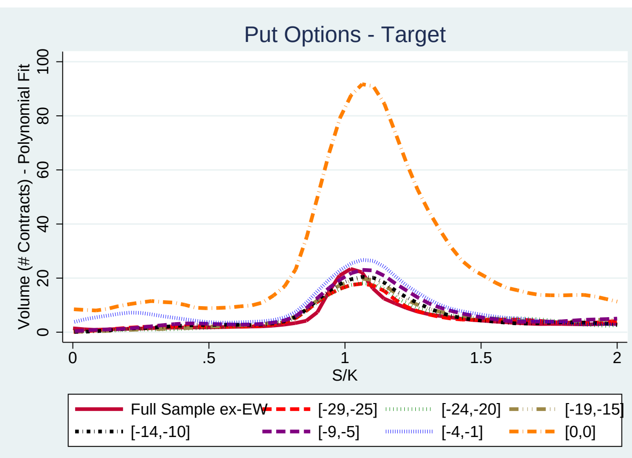
Figure A-1: Volume vs. Depth-in-Moneyness across Event Windows

Figure A-1 shows local polynomial functions fitted to the volume-depth distribution across seven different event windows and for the full sample (excluding the event windows). Figures (A-1a) and (A-1b) show the polynomial fits for, respectively, call and put options on the target companies. Volume is defined as the number of option contracts. Depth-in-moneyness is defined as S/K, the ratio of the stock price S to the strike price K. Deep out-of-the-money (DOTM - solid line) corresponds to $S/K \in [0, 0.80]$ for calls ($[1.20, \infty)$ for puts), out-of-the-money (OTM - dashed-dotted line) corresponds to $S/K \in (0.80, 0.95]$ for calls ($[1.05, 1.20)$ for puts), at-the-money (ATM - dashed-double-dotted line) corresponds to $S/K \in (0.95, 1.05)$ for calls ($(0.95, 1.05)$ for puts), in-the-money (ITM - dotted) corresponds to $S/K \in [1.05, 1.20)$ for calls ($(0.80, 0.95]$ for puts), and deep in-the-money (DITM - dash-triple-dot) corresponds to $S/K \in [1.20, \infty)$ for calls ($[0, 0.80]$ for puts). Volume is winsorized at the upper 99th percentile. Figures (A-1c) and (A-1d) replicate Figures (A-1a) and (A-1a), but omit the announcement effect. Source: OptionMetrics.

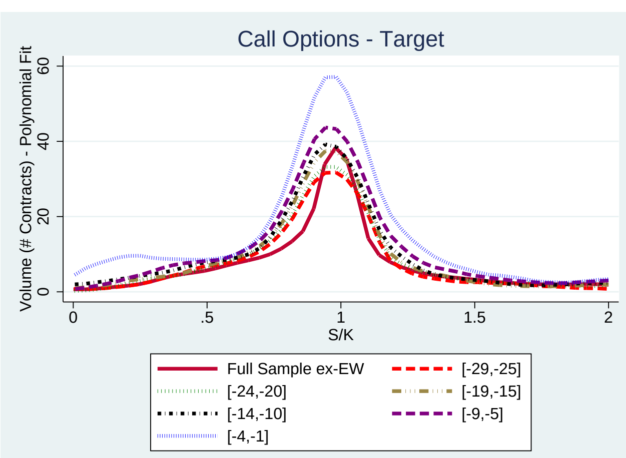
(a)



(b)



(c)



(d)

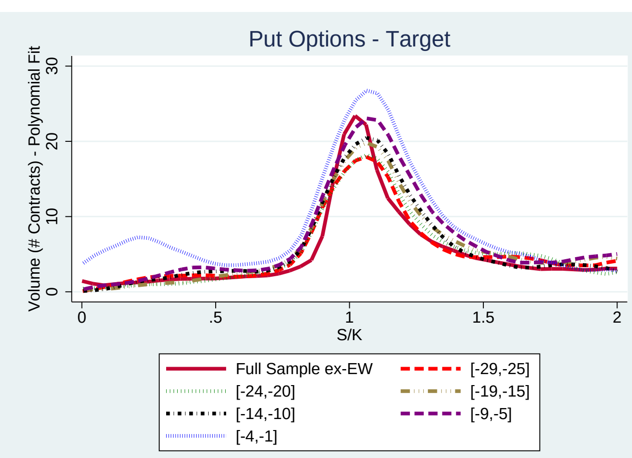


Figure A-2: Trading Volume Distribution around Announcement Dates

Figure A-2 plots distributional statistics of the options trading volume, defined as the number of traded contracts, from 30 days before until 20 days after the announcement date. The left axis on each subfigure plots the 90th (dashed line) and 95th (solid line) percentiles of the volume distribution, while the right axis on each subfigure refers to the interquartile range (dotted line). Figures (A-2a) and (A-2b) refer to, respectively, the call and put volumes for the target companies. Source: OptionMetrics.

(a) (b)

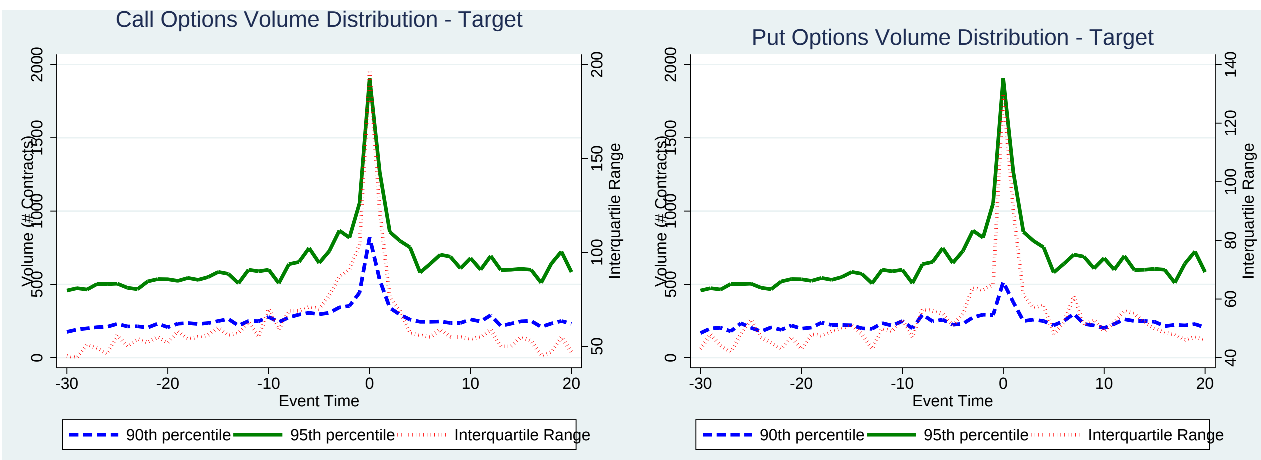
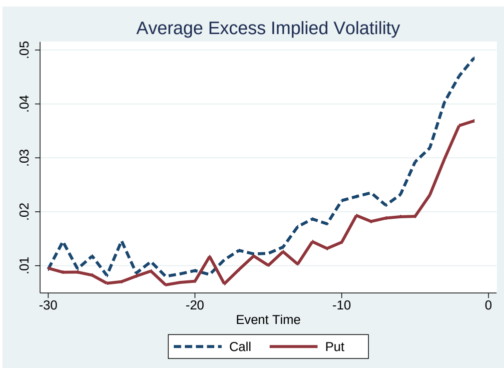


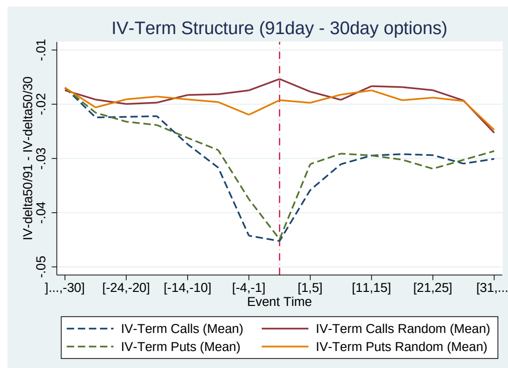
Figure A-3: Excess Implied Volatility and the Term Structure of Implied Volatility

Figure (A-3a) plots, for the target companies, the average excess implied volatility (IV) relative to the VIX index for the 30-day at-the-money (ATM) implied volatility for call (dashed line) and put (solid line) options, respectively, over the 30 pre-announcement days. Figure (A-3b) depicts the IV term structure for call options, defined as the difference between the ATM IVs of call options (delta = 50) with 91 and respectively 30 days to maturity (left axis), respectively, as well as the IV term structure for put options, defined as the difference between the ATM IVs of put options (delta = 50) with 91 and respectively 30 days to maturity (left axis). Each node in Figure A-3b represents the cross-sectional average within a time window defined on the x-axis. We compare the actual averages to that computed for a sample of randomly selected announcement dates. Figure (A-3c) illustrates the evolution of the average percentage bid-ask spread from 90 days before the announcement date to 90 days after the announcement date. Figure (A-3d) compares the evolution of the average percentage bid-ask spread against the average percentage bid-ask calculated for randomly chosen announcement dates. Figure (A-3e) illustrates a stratification by depth-in-moneyness, defined by the ratio of the stock price to the strike price (S/K): DOTM (solid line), OTM (dashed-dotted line), ATM (dashed-double-dotted line), ITM (dotted line), and DITM (dashed-triple-dotted line). Source: OptionMetrics.

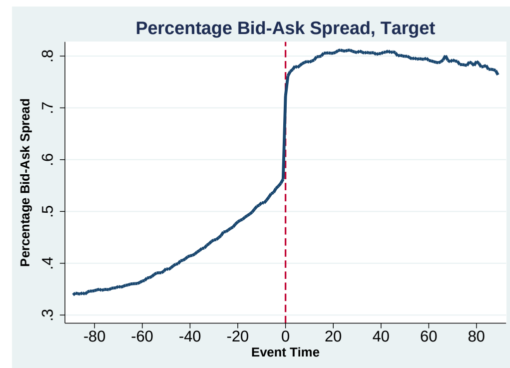
(a)



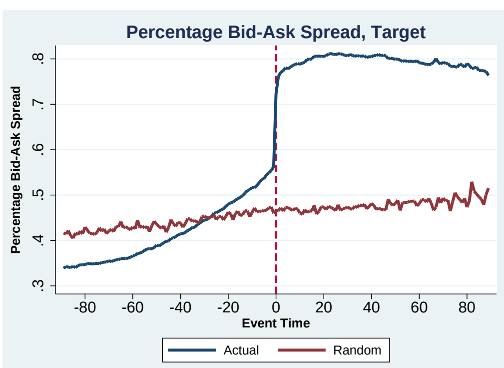
(b)



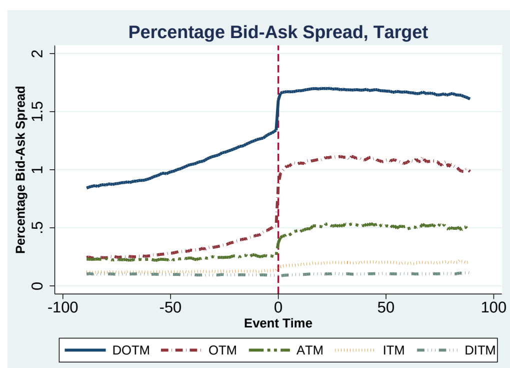
(c)



(d)



(e)



(f)

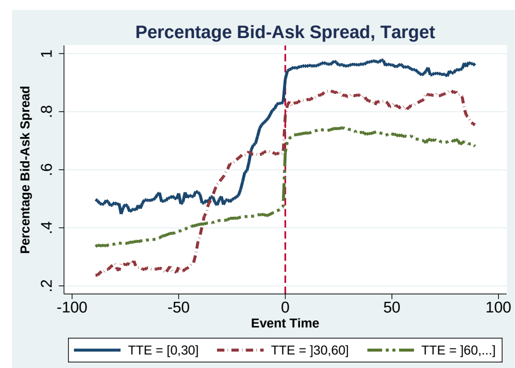
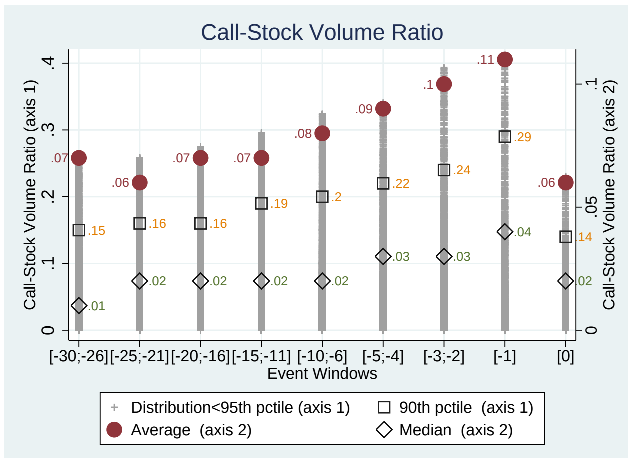


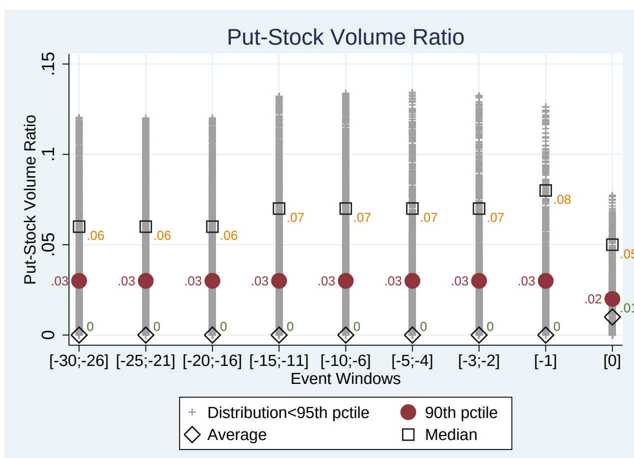
Figure A-4: Option-to-Stock Trading Volumes

Figure A-4 plots distributional statistics of the option trading volume, defined as the number of traded contracts, and stock trading volume, defined as the number of traded shares, over event-day windows from 30 days before until the day of the announcement. On each graph, we report the average, the median, the 90th percentile and either the distribution (below the 95th percentile) or the interquartile range. Figure (A-4a) plots the call-to-stock volume ratios. Figure (A-4b) plots the put-to-stock volume ratios. Figure (A-4c) plots the call-to-put volume ratio. The Figures (A-4a), (A-4b) and (A-4c)) correspond to the ratios for the target firms. Source: OptionMetrics.

(a)



(b)



(c)

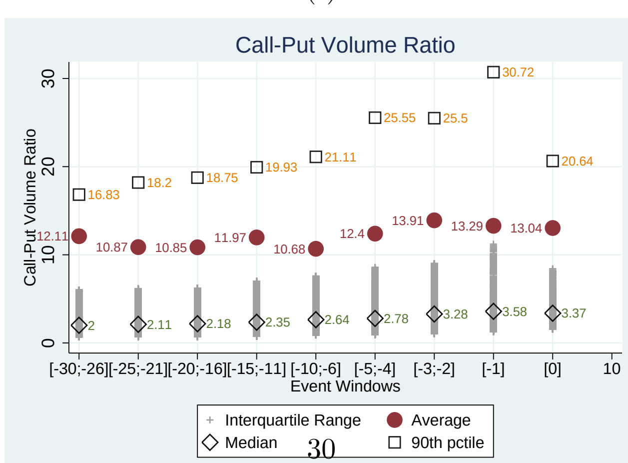
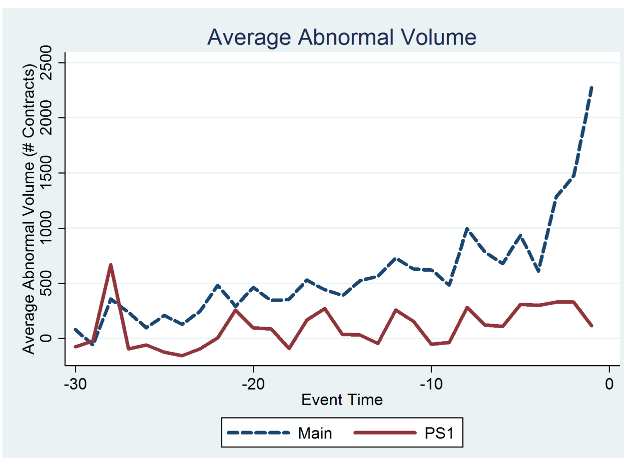


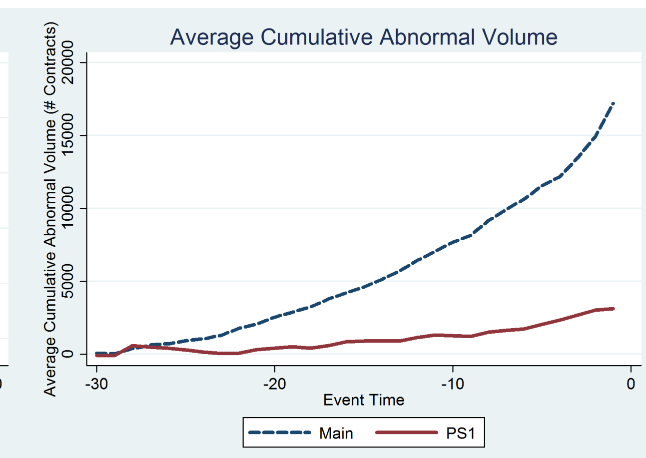
Figure A-5: Abnormal Trading Volumes - Treatment and Matched Control Groups

Figures (A-5a) and (A-5b) plot the average and average cumulative abnormal trading volume, respectively, for aggregate options volume in the treatment group (Main - dashed line) and the matched control group using the best match (PS1 - solid line), over the 30 days preceding the announcement date. Volume is defined as the number of option contracts. Firms are matched directly on a number of firm characteristics, including assets, the existence of takeover attempts in the same four-digit SIC code industry in the previous calendar year, leverage, trading volume in the underlying stock, the existence of institutional blockholders with stakes above 5% in the company's stock, and industry affiliation. We sample with replacement and use the Mahalanobis distance metric to evaluate the closeness of the match. Figures (A-5c) and (A-5d) plot the average and average cumulative abnormal trading volume, respectively, in the treatment group (Main - dashed line) and the matched control group using the two best matches (PS2 - solid line), over the 30 days preceding the announcement date. Source: Thomson Reuters SDC Platinum, CRSP, OptionMetrics, Compustat, RavenPack News Analytics, Thomson Reuters 13F filings.

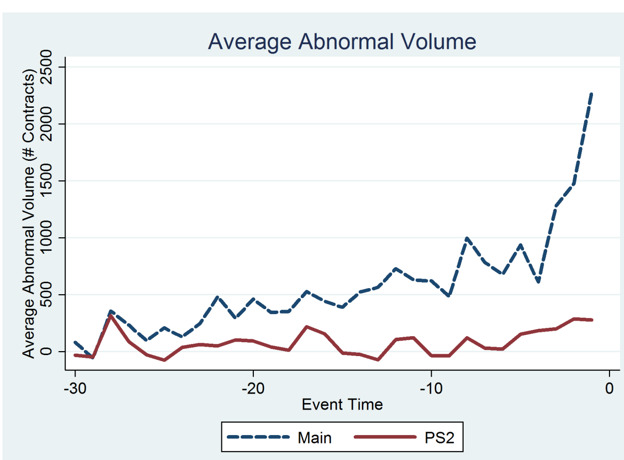
(a)



(b)



(c)



(d)

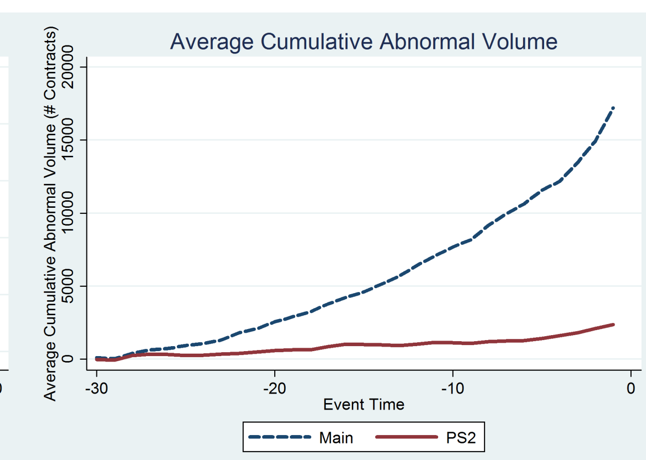


Figure A-6: Percentiles of the Estimated Takeover Probability

Figure A-6 plots the estimated takeover probabilities against the associated percentile rankings of the sample. The takeover probabilities are estimated using a logistic regression framework. Source: Thomson Reuters SDC Platinum, CRSP, OptionMetrics, Compustat, Thomson Reuters 13F filings.

(a)