Expecting the Unexpected? Tests of Informed Trading Using a Refined Measure of Likelihood

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Abstract

Using a novel, market-based measure of event expectedness, we test a sample of 769 major takeovers to determine whether informed trading is greater around takeovers with more information asymmetry or less information asymmetry. We find that options trades contain economically and statistically significant information about the future stock returns of the targets in the *least expected* takeovers, but not the most expected. The degree of return predictability is significantly higher for the least expected takeovers than for the most expected takeovers. Complementary analysis shows a direct link between the generation of private information and trading by informed investors, suggesting that informed trading is more prevalent for those firms that are least expected to eventually become targets in a takeover attempt. Results are shown to be robust to a battery of checks.

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1. Introduction

A large and growing literature has established that future stock returns are reliably predicted, on average, by the information contained in options trades.[1] Some studies also find that return predictability is more pronounced the greater the degree of information asymmetry between those investors endowed with private information (hereafter, "informed investors") and those without (Hayunga and Lung, 2014; Du, Fung and Loveland, 2018) and that informed investors trade more often, and more profitability, around events with greater degrees of information asymmetry (Engelberg, Reed and Ringgenberg, 2012). This last empirical finding has intuitive appeal: investor's privy to non-public information about the timing, direction and/or magnitude of future events would prefer to trade on that information when others are least likely to possess material information about the events.

One difficulty in studying the relationship between informed trading[2] and information asymmetry is the identification of a useful, market-based proxy for information asymmetry. Examples of proxies commonly employed in previous studies include measures of the probability of informed trading (PIN), the bid-ask spread, or binary indicators and comparisons. However, each of these proxies and identification schemes suffer from shortcomings that prohibit more instructive inferences or that make them unreliable, thus leading to incorrect inferences.

The validity of the PIN as a measure of informed trading has been questioned in a growing body of research. In essence, these studies investigate whether the PIN captures information-based or liquidity-based trading (Akay, Cyree, Griffiths, and Winters, 2012). The empirical

[1] General return predictability is found by e.g., Pan and Poteshman (2006) and Cremers and Weinbaum (2010). Other studies suggest that return predictability is particularly strong during such events as earnings announcements (Jin, Livnat and Zhang, 2012; and Atilgan, 2014), corporate takeovers (Cao, Chen and Griffin, 2005), leveraged buyouts (Acharya and Johnson, 2007), and stock splits (Gharghori, Maberly and Nguyen, 2016), among others.

[2] We use the term "informed investors/investing" and "informed traders/trading" interchangeably throughout the remainder of this paper.

estimation of the PIN involves the identification of abnormal trading, or clustering (see, e.g., Easley, Kiefer, O'Hara, and Paperman, 1996), which the under arching theory attributes to investors trading on informational advantage. However, if clustering is driven by other factors, then estimates of PIN may be biased. Recent studies find that the PIN: identifies trading clusters driven by discretionary liquidity traders, not informed trading resulting from asymmetric information (Akay, Cyree, Griffiths, and Winters, 2012); is a proxy for illiquidity (Duarte and Young, 2009); and does not reflect information-based trading (Aktas, de Bodt, Declerck and Van Oppens, 2007). Lin and Ke (2011) conclude that 44% of PIN estimates for stocks are underestimated due to computing bias. Boehmer, Grammig, and Theissen (2007) find that estimates of PIN undershoot the "true" PIN by 18%, on average due, to inaccurate trade classification used PIN estimates.

Estimating the level of information-based abnormal trading from bid-ask spreads, a measure considered reflective of information asymmetry, suffers similar pitfalls in practice. Because bid-ask spreads reflect inventory costs, market-making costs, as well as asymmetric information costs, assigning intent (i.e. asymmetric information vs. inventory management) to classify individual trades is problematic (Hasbrouck, 1988 and 1999).

Some researchers sidestep these estimation issues entirely by instead utilizing simple classification schemes and empirical designs. For example, Bernile, Hu and Tang (2016) model Federal Reserve rate announcements as surprise vs. non-surprise using the level of unexpected changes in the federal funds rate. Du, Fung and Loveland (2018) utilize the same classification by contrasting unscheduled Federal Reserve meetings versus scheduled Federal Reserve meetings. Many studies, relying on the assumption that information asymmetry is greater around unplanned events than around pre-announced events, simply compare the findings from empirical analyses of planned corporate events to those from unplanned corporate events (see, e.g., Cao, Chen and Griffin, 2005; Hayunga and Lung, 2014; Hao, 2016). These binary variables and comparisons, however, are relatively coarse and thus limit the range of inferences that may be obtained.

Our innovation in this study is the use of a more refined, continuous and market-based measure of event expectedness – "acquisition probability" – to measure the likelihood of a specific type of corporate event: takeovers. Expectedness (i.e., predictions about timing) of an event is one dimension of information asymmetry that holds potential value to those investors that possess this information. Our use of the acquisition probability measure follows from evidence in Song and Walking (2000) and Cai, Song and Walking (2011) that the likelihood of future acquisitions is reliably determined by the information content of an industry rival's merger. Song and Walking (2000) develop a model in which an unexpected acquisition attempt causes an industry-specific shock that prompts the market to update the probability of acquisition for all industry rivals. The more alike the rival to the industry participant in the initial merger, the more likely the rival is to be a future takeover candidate themselves. Related empirical analysis finds that the probability of being a future acquisition target is significantly, positively related to event returns and firm characteristics. To the best of our knowledge, our study is the first to utilize this acquisition probability measure in tests of informed trading.

Using a sample of 769 major takeovers announced in the period 1996 to 2019, we investigate whether stock return predictability is greater around takeovers that feature more information asymmetry, those not expected by the market, or greater around takeovers with lower degrees of information asymmetry, such as takeovers that are expected by the market, on average. If informed trading is greater around more informationally asymmetric events, we expect return predictability to be greater around takeovers that are less expected. Using our measure of acquisition probability, we classify takeovers by degrees of expectedness and test for evidence of return predictability. We follow recent studies in the use of volatility spread, defined as the difference between call and put implied volatilities, to measure return predictability.

Our results can be summarized as follows. Our main contribution is to show that options trades contain economically and statistically significant information about the future stock returns of the targets in the least expected takeovers, but not the most expected. Abnormal volatility spread is considerably greater just prior to the announcement of takeovers that are least expected by the stock market as compared to those takeovers that are most expected. Announcement day returns to a trading strategy that is long high volatility spread stocks and short low volatility spread stocks are significantly higher for the least expected takeovers than for the most expected takeovers. The difference in risk-adjusted announcement day return of acquisition targets is 13.4% (*t*-statistic of 3.18). Regression analysis confirms significant return predictability just prior to the announcement of the least expected takeovers, but not for the most expected. Findings are robust to alternative merger samples, definitions of industry and factor models used to estimate hedge portfolio alphas.

Our second contribution is to show a direct link between the generation of private information and trading by informed investors. We use SEC merger filings to identify, ex-post, the dates of important, value-relevant non-public events that occurred in the private takeover process that preceded the public announcement of the least expected and the most expected takeovers. We find significantly positive abnormal returns on the dates corresponding to the private negotiation events, demonstrating that informed investors immediately trade on new private information. However, hedge portfolio returns on the dates of the private events show that return predictability is greater for the portfolio of the least expected mergers than for the portfolio of the most expected mergers, suggesting that informed trading is more prevalent for those firms that are least expected to eventually become targets in a takeover attempt.

Collectively, the evidence in this study suggests that informed trading takes place predominately around informationally asymmetric events, such as unexpected takeovers. We find significant return predictability only in the subsample of takeovers that feature the most information risk, or about 25% of our overall sample. This rate of occurrence corresponds to that in Augustin, Brenner and Subrahmanyam (2019)'s large sample review of informed option trading prior to takeovers. Their study investigates sources of information behind informed option trading, inferring that the majority of takeover deals may not involve informed trading for lack of informational advantage. Our study shows that informational advantage is only part of the story. As Fung and Loveland (2020, pg. 1461) conclude: "*when* informed traders exploit private information may be as important as obtaining the information in the first place."

This study contributes to the literature in several ways. First, we provide new evidence on informed trading in the options market prior to corporate takeovers. Our novel application of Song and Walking's (2000) acquisition probability provides a reliable, market-based measure of information asymmetry that avoids many of the estimation obstacles and resulting biases in prior empirical research. Indeed, Aktas, de Bodt, Declerck and Van Oppens (2007) caution against the use of PIN as an information-based trading indicator around the announcement of takeovers. For instance, Pan and Poteshman (2006) find that the stock return predictability of option trading volume is significantly and positively related to the level of the PIN, regardless of firm size. In contrast, Cremers and Weinbaum (2010) find that stock return predictability related to volatility spreads is significantly greater, conditioned on the level of the PIN, only for smaller firms. We resolve this seeming contradiction by using our measure of information asymmetry to obtain similar results for large firms as well, demonstrating that information asymmetry is important regardless of firm size.

In a more recent study, Brennan, Huh and Subramanian (2018) develop a conditional PIN model and find that the probability of informed trading increases before and after merger announcements. They interpret their findings as evidence that trading may be on public information (consistent with Kim and Verrecchia (1994, 1997)). However, their study does not examine information in option trades and does not focus on cross-sectional implications. In addition, we provide direct evidence that informed investors trade on new private information in the run-up to merger announcements, strongly suggesting that informed investors use private information to profit around the announcement of the takeover as well. In this way, our findings are consistent with Heitzman and Klasa (2020) who find that informed investors immediately trade on private information; however the authors do not making predictions about the level of informed activity conditioned on information risk.

The remainder of the paper proceeds as follows. Section 2 describes our measure of event expectedness and develops our tests of informed trading. Section 3 describes our sample formation process, variable construction, and the characteristics of the sample. Section 4 reports the analysis of return predictability and tests of informed trading. Section 5 reports complementary tests using alternative measures of private events, industries and time periods. Section 6 concludes.

2. Background and methodology

2.1. The acquisition probability hypothesis

An extensive body of research has investigated mergers and acquisitions. Amongst the most established findings are the stylized facts that, on average, combined firms benefit, acquirers (roughly) break even, and targets gain. Studies of industry takeover activity also find that the targets' industry rivals gain, however, the positive average returns earned by these rivals are subject to wide cross-sectional variation (e.g., Eckbo, 1983 and 1985; Mitchell and Mulherin, 1996). In their seminal analysis, Song and Walking (2000), develop the acquisition probability hypothesis to explain the source of these positive rival returns. The acquisition probability hypothesis asserts that "rivals of initial acquisition targets earn abnormal returns because of the increased probability that they will be targets themselves", Song and Walking (2000, pg. 143).

Song and Walking (2000) argue that an *unexpected* takeover attempt of a target will spur an industry-specific shock that causes the market to reassess the probability of future takeover attempts for the target's industry rivals. Several implications of this theory are particularly useful for our study of informed trading and information asymmetry. First, rival returns around the announcement of the initial merger will be significantly positive, on average, and higher for those rivals that subsequently become targets. Song and Walking (2000, pg. 170) conclude that "rivals that become targets in the subsequent year earn significantly larger abnormal returns at the initial industry acquisition announcement than untargeted rivals" and that "abnormal returns for rivals are significantly positively related to the predicted probability of acquisition attempts." The second important implication is that the cross-sectional variation in the initial merger returns of rival firms is driven by the degree to which the firm characteristics of the rivals are similar to that of the initial targets. Song and Walking (2000, pg. 170) find that "rivals that become targets in the year subsequent to the initial industry acquisition announcement have a financial profile similar to the initial industry target."

For our purposes, the fact that abnormal returns for rivals around the announcement of the initial merger (hereafter, initial rival returns) are significantly positively related to both the predicted probability and rate of occurrence of subsequent takeover attempts of the rivals allows us to treat the initial rival returns as a measure of likelihood, or expectedness, of future takeover attempts. Okoeguale and Loveland (2017) provide support for this treatment in an empirical study of the telecommunications industry. They find that initial rival returns are significantly greater for those rivals that become targets in subsequent mergers than for those rivals that are not subsequently targeted for takeover.

2.2. Estimating acquisition probability

To generate a set of acquisition probabilities, we follow the procedures used by Song and Walking (2000) to empirically test their acquisition probability model. An important feature of their model is the length of the so-called "dormant period" needed to ensure that the initial industry merger is unexpected, thus prompting a revaluation of rival firms' stock in light of the new valuation information contained in the merger bid. We follow Song and Walking (2000) in the use of a minimum 12 month dormant period to quantify an initial merger as unexpected. Figure 1 illustrates the timeline and the framework of our empirical analysis.

<Insert Figure 1 about here>

To begin, we sort acquisitions of target firms chronologically within each industry. An initial merger is defined as the first merger announced after a period of at least 12 months in which no takeovers in that industry are announced. As depicted in Figure 1, we then estimate the abnormal returns of industry rivals at the time of the initial merger. Industry rivals are defined as firms in the same industry as the target of the initial merger, when it is announced. Sorting rivals' abnormal returns in descending order provides a set of estimates than may be interpreted as pseudo-probabilities of future takeovers of the rival firms. The rivals with the largest positive abnormal returns have the highest likelihoods of being acquired within the next three years. Conversely, the rivals with the smallest abnormal returns have the lowest likelihoods of being acquired within the next three years.

The merger wave that took place in the pharmaceutical industry in 2019 illustrates this dynamic. Allergan Plc's stock priced spiked on January 3, 2019 when its rival, Celgene Corp, announced it was being taken over by Bristol-Meyers Squibb Co in the largest biopharmaceutical deal in history.[3] Six months, later, on June 25, 2019, Allergan announced it was itself being bought by AbbVie Inc.[4] In contrast, rival Eli Lilly, whose stock price declined significantly upon the announcement of the Celgene takeover, remains an independent company with no takeover bids.

2.3. Tests of return predictability

We study in this paper whether return predictability, and by extension informed trading, is greater around takeovers that are less expected or greater around takeovers that are more expected. Recent studies show that options trading often clusters around events with high degrees of information asymmetry (Du, Fung and Loveland, 2018; Fung and Loveland, 2020) and/or disagreements among investors (Cao and Ou-Yang, 2009). If option prices contain information not yet contained in stock prices due to informed trading in the options market (Cremers and Weinbaum, 2010), then the impact of information contained in option prices should be most pronounced on asset prices in underlying markets during informationally asymmetric events such as unexpected takeover announcements.

We follow past research (e.g., Amin, Coval, and Seyhun, 2004; Cremers and Weinbaum, 2010; Jin, Livnat and Zhang, 2012; Xing, Zhang, and Zhao, 2010) in the use of volatility spread as a measure of informed trading in the options market. Volatility spread is defined as the difference between call and put implied volatilities. Cremers and Weinbaum (2010) posit that volatility spread measures deviations from put–call parity and, as such, contains traders' private information about future stock returns. In their model, when dealers anticipate an increase

[3] Bristol-Myers to buy Celgene for $74 billion in largest biopharma deal, Reuters, January 3, 2019.
[4] AbbVie looks beyond Humira with $63 billion deal for Botox-maker Allergan, Reuters, June 25, 2019.

(decrease) in the price of the underlying stock they will set a higher premium for call (put) options. Thus, a positive difference in implied volatilities between call and put options would produce a positive volatility spread. This positive spread should, in turn, predict positive future returns and vice versa.

To examine the degree of return predictability around takeovers, we form quartile portfolios based on volatility spreads. Quartile 1 contains stocks with low volatility spreads; Quartile 4 contains stocks with high volatility spreads. We then form a hedge portfolio that is long the quartile of high volatility spread stocks and short the quartile of low volatility stocks. Stocks are equally weighted within each quartile portfolio. Variable construction is detailed in Section 3.

We examine daily hedge portfolio returns for the day of the takeover announcement to determine whether implied volatility spread just before the announcement does predict subsequent stock returns. A testable prediction that follows from the preceding discussions is that the degree of stock return predictability associated with volatility spread, as measured by hedge portfolio return, is inversely related to the likelihood of acquisition. If informed trading is greater around more informationally asymmetric events, we expect return predictability to be greater around takeovers that are less expected. Thus, a related prediction is that stock return predictability increases monotonically as the likelihood of acquisition decreases.

3. Data and sample characteristics

3.1. Sample formation

To study the effects of information asymmetry on informed trading in the options markets, we compile an extensive sample of takeovers for the period from 1996 to 2019. The starting year of 1996 is chosen because it is the first year that option trading and option valuation data is available from OptionMetrics. The ending year of 2019 is the latest year available when we began our analysis.

We follow Song and Walking (2000) in the use of the Value Line Investment Survey to determine our base sample of target firms and to classify targets and rival firms according to Value Line industry. The Investment Survey covers publicly traded, large cap stocks (typically a minimum size of about $100 million in market capitalization). It is often used in the merger literature for industry classifications (e.g., Mitchell and Mulherin, 1996; Mulherin and Boone, 2000; Andrade and Stafford, 2004). The Investment Survey classifies firms into 109 different industries over our sample period. We exclude regulated industries from our sample because the need for regulatory approval of takeovers within these industries reduces the probability of acquisition (Song and Walking, 2000).[5]

To construct our measure of acquisition probability, we first use Refinitiv's Securities Data Company (SDC) Platinum to compile a comprehensive sample of merger and acquisition deals during our sample period. We assemble our initial sample of mergers by selecting: (1) all deals with announcement date from January 1, 1996 to December 31, 2019, (2) disclosed and undisclosed [deal value] mergers and acquisitions (deal type: 1, 2) and (3) percentage of shares acquired in transaction: 50 to HI. From this initial sample we then select deals in which either the acquirer or target ultimate parent nation is the United States. We eliminate duplicate transactions by matching on SDC Deal ID, acquirer CUSIP and target CUSIP. Finally, we keep only deals in which the target firm is listed in the Value Line Investment Survey.

[5] The regulated Value Line industries excluded from the sample include the Banking, Investment and Insurance industries, the Power and Energy industries, the Telecommunication industries, the Transportation industries and the Utility industries.

After sorting each merger chronologically within the Value Line industries of the target firms, we identify the initial merger (the first merger announced after a period of at least 12 months in which no mergers in that industry are announced) in each Value Line industry. We then determine the Value Line industry rivals of each initial merger and estimate the abnormal returns of the rival firms at the time of the initial merger. An industry rival is defined as a firm in the same Value Line industry as the target of the initial industry merger, at the time of the merger announcement. The initial rival returns are used as our measure of expectedness of future takeover attempts of these same rival firms.

Column 2 of Table 1 reports the annual count of initial mergers over our sample period. There are an average (mean) of 22 mergers annually and a total of 516 initial mergers over the sample period. The merger time-series exhibits some variation, particularly at the beginning of the sample period when the annual number of initial mergers is below the sample average. The relatively low number of initial mergers in the late 1990s is consistent with the high level of merger activity that occurred during the merger wave of the 1990s (Harford, 2005). A large number of overall mergers makes it less likely that at least 12 months passes without a merger in a specific industry, resulting a smaller number of initial mergers in the following year.

<Insert Table 1 about here>

Column 3 of Table 1 reports the annual count of industry rivals associated with the targets of the initial mergers. There are a total of 7,808 rivals associated with the initial targets over the sample period, an average of 339 rivals per year. The mean number of rivals per initial target in our sample, 15.1, is consistent with the mean of 17.4 reported by Song and Walking (2000).

To compile the sample of subsequent rival mergers used to test our hypotheses, we next identify the rivals that become targets in takeovers after the initial industry mergers. To be included in the sample, the subsequent mergers of industry rivals must be announced no later than three years after the initial industry merger. We manually confirm, and revise if necessary, the announcement dates of the subsequent mergers using financial press reports. Following past research, we define announcement date as the first date on which news reports about a takeover or sale of the target appear in financial press reports.[6]

Column 4 of Table 1 details the annual count of subsequent rival mergers. The sample of subsequent mergers is comprised of 769 total mergers over the sample period, an average of 35 mergers per year. The number of annual mergers increases from 8 at the start of the sample period to a peak of 79 mergers in 2006. Surges in the number of annual rival mergers generally follow, within a few years, increases in the annual number of industry rivals. The average annual number of subsequent rival mergers in our sample matches the 35 average annual rival mergers, announced within three years following the initial industry mergers, reported by Song and Walking (2000).

3.2. Variable construction

To construct our measure of informed trading, volatility spread, we follow past research (e.g., Cremers and Weinbaum, 2010) and compute volatility spread as the weighted difference in implied volatilities between call and put options (with the same strike price and maturity) across all option pairs. For each day *t* and for each stock *i* with put and call options on day *t*, we compute the volatility spread as:

$$VS_{i,t} = \sum_{j=1}^{N_{i,t}} w_{j,t}^{i} \left(IV_{j,t}^{i,call} - IV_{j,t}^{i,put} \right) \quad (1)$$

where *j* refers to the *j*th pair of call and put options with the same strike prices and maturities, $w_{j,t}^{i}$ are weights based on the average open interest in the put and call options, $N_{i,t}$ is the number of

[6] For this purpose, we treat as an acquisition announcement reports such as: an announcement by the target firm of the initiation of a strategic review including possible sale of the firm, published rumors of merger talks that include the identify, or description, of the eventual acquirer, or press release announcing the acquisition. For instance, general press speculation about the likelihood of a future sale of a target firm is *not* treated as an acquisition announcement.

matched pairs of put and call options on stock i on day t, and $IV_{j,t}^{i,call}$ and $IV_{j,t}^{i,put}$ are the implied volatilities of calls and puts, respectively. Implied volatilities are calculated by OptionMetrics and based on a binomial tree model adjusted for dividends and the possibility of early exercise. To ensure that there is sufficient liquidity in the option contracts, we follow Xing, Zhang and Zhao (2010), Jin, Livnat and Zhang (2012) and Fung and Loveland (2020) by computing the implied volatility spread based on option contracts that have greater-than-zero open interest and time to expirations of 10 to 60 days.

As detailed in Section 2.3, we use estimates of daily hedge portfolio returns (based on volatility spreads) to determine the degree of stock return predictability. To ensure that portfolio returns are not driven by a shared systematic component, we report risk-adjusted returns, in addition to raw returns, for all quartile and hedge portfolios. Tests of risk-adjusted returns enable us to focus only on the idiosyncratic component of returns. The estimated risk-adjusted return of the portfolios is the constant, α_j, in the following regression:

$$R_{j,t} = \alpha_j + \delta_{1j} MKT_t + \varepsilon_{j,t} \quad (2)$$

where $R_{j,t}$ is the excess return over the risk-free rate of portfolio j over time t; and MKT is the excess return on the market portfolio. We choose to utilize a single factor market model over a multifactor model such as Fama French (1993) because the estimated returns are smaller, and thus more conservative, than those produce by other models.[7]

We use standard event study techniques to calculate announcement period returns. Cumulative abnormal returns are estimated using a market model for the (-1,+1) period, where day 0 is the merger announcement date. The market is proxied by the CRSP value-weighted index;

[7] Unreported results utilizing the Fama French (1993) three factor and four factor models are consistent with those reported and result in the same qualitative findings.

the estimation period spans the days -240 to -61 relative to announcement date. We require a minimum of 100 observations during the estimation period.

We also examine abnormal magnitudes of daily volatility spread, option open interest and option trading volume during the merger announcement period. We compute abnormal volatility spread as the difference between daily volatility spreads during the announcement period and average daily volatility spreads during the estimation period from days -301 to -61 relative to the announcement date. Abnormal open interest and option trading volume are constructed in the same way.

Table 2 reports (-1,+1) period abnormal returns for the targets in initial industry mergers. The mean return is 19.5% and the median return is 17.1%. Both mean and median returns are statistically significant. As expected, most (85%) of the returns are positive. The results are consistent with the magnitude of returns to acquisition targets reported in the merger literature (see, e.g., Ovtchinnikov, 2013). Also reported are the abnormal returns for rivals of the targets for the same (-1,+1) period around the announcement of the initial industry mergers. To be included in this analysis, the rivals must have been targeted for acquisition within three years following the initial industry merger. The returns are essentially breakeven – neither the mean (0.17%) nor median (0.05%) return are statistically different from zero. However, the distribution of returns is quite dispersed. The maximum abnormal return is about 39% and the minimum is about 29%. 50.5% of rival returns are positive. Thus, the distribution of abnormal returns to rivals around the announcement of initial industry mergers is dispersed and symmetric about zero. These rival abnormal returns will serve as our measure of acquisition likelihood in subsequent tests.

<Insert Table 2 about here>

4. Informed trading around rival firms' subsequent merger announcements

In this section, we examine whether return predictability is greater around takeovers that are least expected or greater around takeovers that are most expected. We begin by sorting the 769 subsequent rival mergers by the acquisition probabilities calculated in Section 3. Using these probabilities we then form quartile portfolios in which Quartile 1 contains the mergers least likely to occur and Quartile 4 contains the mergers most likely to occur. We contrast the abnormal measures and return predictabilities of the least expected mergers in Quartile 1 with that of the most expected mergers in Quartile 4 in tests reported in the following sections.

4.1. Event study analysis of rivals' mergers

Figure 2 presents daily abnormal stock returns for the targets in the least expected (solid line) and most expected (dashed line) mergers in a ten day window, where day 0 is the merger announcement date. To reduce the influence of outliers we report median returns. Daily abnormal returns are displayed on the vertical axis; days are displayed on the horizontal axis. Both return series display the same pattern: a spike in abnormal returns on announcement day, but virtually no abnormal returns outside of day 0. The most expected mergers have a median day 0 return of 19.2%, the least expected a 17.1% return. The returns, however, are not statistically distinguishable. We examine abnormal returns in greater detail in Section 4.2.

<Insert Figure 2 about here>

Figure 3 presents daily abnormal option trading volume for the targets in the least expected and most expected mergers. Median abnormal trading volume for both time series is negligible in the run-up to day 0, spikes on announcement day, and remains elevated for several days after the announcement. However, the least expected mergers have higher average volume on announcement day and their level of trading activity remains considerably higher on day 1 and day 2 following announcement day than does that of the most expected mergers.

<Insert Figure 3 about here>

We next look at a related measure, abnormal option open interest in the targets, in Figure 4. The median open interest for both time series diverge from zero on day -5 and display elevated but comparable levels through day 0. Beginning the day after announcement, however, the time series diverge. The level of open interest for the least expected mergers spikes dramatically upward on day 1 and continues to rise through day 5. Open interest for the most expected mergers rises modestly on day 1 but remains much lower than that for the least expected mergers through the end of the reporting window.

<Insert Figure 4 about here>

Finally, we present our measure of informed trading, volatility spread, in Figure 5. Median volatility spread for both time series fluctuates considerably in the reporting window. However, the key question is the level of volatility spread in the several days immediately preceding announcement day. Because information is oftentimes leaked, and thus incorporated into option prices, the day prior (day -1) to a merger announcement, a cleaner test is the level of volatility spread on day -3 and day -2 preceding announcement day. Figure 5 shows that the level of volatility spread for the least expected mergers is positive, elevated and considerably higher on day -3 and day -2 as compared to the most expected mergers, which display a negative volatility spread on these days. Volatility spread for both time series are positive and about equal on the day preceding announcement.

<Insert Figure 5 about here>

To summarize, event study results presented in this section show that substantially all of the announcement-related abnormal stock returns for the targets in both the least expected and most expected mergers occur on announcement day, on average. Option trading volume for both groups also spikes on announcement day, but volume for the least expected mergers remains considerably elevated for several days after announcement. Similarly, the level of open interest for the least expected mergers spikes and continues to rise after announcement day, while open interest for the most expected mergers rises only modestly.

The findings for volume and open interest are consistent with evidence from Brennan, Huh and Subramanian (2018) that the probability of informed trading increases after merger announcements due to trading on public (and/or private) information about the likelihood of subsequent deal completion. Our measure of information asymmetry provides an explanation for the disparate results between the quartile portfolios. Informed investors choose to trade only around the deals with the greatest information asymmetry: the least expected takeovers but not the most expected. In addition, uninformed investors react on day 0 to the news announcements of the least expected takeovers and subsequently increase their holdings of the targets of those takeovers, by inference because this information was unknown (or less known) to the market prior to the announcement. By contrast, uninformed investors only modestly increase their holdings of the targets in the most expected takeovers after the news announcements, by inference because this information was already expected by the market.

The findings for volatility spread provide preliminary support for the hypothesis that return predictability is inversely related to the likelihood of acquisition. The positive day -3 and day -2 volatility spreads for the least expected mergers foreshadows the positive abnormal return on announcement day. In contrast, the negative day -3 and day -2 volatility spreads for the most expected mergers does not foreshadow the positive abnormal return on announcement day.

4.2. Portfolio returns sorted by volatility spreads

If informed investors possess private information regarding impending takeovers, we expect this new information to be impounded in option implied volatilities prior to being impounded in stock prices (see, e.g. Cremers and Weinbaum, 2010). However, this private information will have more value to the informed investors the less it is known to other investors in the marketplace. Thus, we expect a positive relationship between the level of information asymmetry around takeovers and the level of informed trading, on average. Evidence of this informed trading should be revealed in significant return predictability prior to the announcement of the subset of takeovers that are least expected by the market (and thus feature the greatest level of information asymmetry). Furthermore, the subset of takeovers that are most expected by the market (and feature the lowest level of information asymmetry) should feature significantly less return predictability. In this section, we test the predictions that (i) the degree of stock return predictability, as measured by hedge portfolio returns, is inversely related to the likelihood of acquisition and (ii) hedge portfolio returns increase monotonically as the likelihood of acquisition decreases.

Table 3 reports daily and event window abnormal returns for the 769 subsequent rival mergers used in the hedge portfolio return tests to follow. The results indicate that, for the full sample of subsequent rival mergers, substantially all of the announcement-related abnormal stock returns occur on announcement day. This finding is important for two reasons. First, it allows us to use day 0 (announcement day) returns as our return measure as that single day is shown to capture substantially all announcement-related returns. Second, it maintains the relevancy of the acquisition probabilities we use in our tests. Recall that we set the announcement date as the first date in which relevant news about a takeover or sale of the target appears in financial press reports. In this way, we ensure that the calculated acquisition probabilities have not been invalidated by significant merger-related news after the original industry merger dates but before the rivals' subsequent merger dates captured in Table 3. The first significant merger-related news is captured in Day 0 returns, as demonstrated in the Table 3 results.

<Insert Table 3 about here>

Table 4 reports target announcement day returns for stock portfolios formed based on acquisition probabilities and volatility spreads. To form the portfolios, we first sort the full set of subsequent rival mergers by their acquisition probabilities and form quartile portfolios. For each of these quartile portfolios, we next sort by volatility spread and again form quartile portfolios. We use volatility spreads as of the close of trading two days prior to announcement day because they are, on average, free of the merger-related information that typically begins to leak to the market on day -1, the day preceding announcement (see Figure 2). To reduce the influence of outliers, we winsorize returns.

<Insert Table 4 about here>

Results in Table 4 are reported in order of acquisition likelihood. The results for the least expected portfolio, reported at the top of the table, show that stocks with high volatility spreads have higher announcement day returns than do stocks with low volatility spreads. The mean return for the hedge portfolio is 11.4% and the risk-adjusted return is 11.9%. Both returns are statistically significant. Raw returns increase monotonically from volatility spread quartile 1 to volatility spread quartile 4; risk-adjusted returns increase nearly monotonically. The results for the most expected portfolio, reported at the bottom of the table, show that stocks with high volatility spreads have lower announcement day returns than do stocks with low volatility spreads. The mean return for the hedge portfolio is -3.4% and the risk-adjusted return is -1.5%. Neither returns are statistically different than zero. Hedge portfolio returns for quartile 2 and quartile 3 are also considerably lower than that of the least expected quartile and are statistically insignificant.

Furthermore, returns for quartile 2 and quartile 3 do not increase monotonically across volatility spread quartiles and display considerable variation.

Comparing average returns based on acquisition likelihood reveals that announcement day returns are significantly greater for the portfolio of the least expected mergers than for the portfolio of the most expected mergers. The final two rows of Table 4 report differences in returns between the least and most expected mergers. Hedge portfolio average and risk adjusted returns for the least expected mergers are 14.8% and 13.4% greater, respectively, than that of the most expected mergers. Results of t tests of differences indicate that the differences are statistically significant. Taken together, the results in Table 4 are consistent with the hypothesis that stock return predictability is greater around takeovers that are less expected. However, the evidence thus far does not support the hypothesis that stock return predictability increases monotonically as the likelihood of acquisition decreases.

4.3. Regression analysis

To synthesize our analysis, we next examine return predictability around announcement days by estimating the following cross-sectional panel regression for the pooled sample of the least expected mergers (Quartile 1) and the most expected mergers (Quartile 4):

$$R_{i,t} = \beta_{0i} + \beta_{1i}R_{i,t-2} + \beta_{2i}IVSkew_{i,t-2} + \beta_{3i}IVSpread_{i,t-2} + \beta_{4i}AnnounceDay_t + \beta_{5i}AnnounceDay_t \times IVSpread_{i,t-2} + \varepsilon_{i,t} \quad (3)$$

where $R_{i,t}$ is the daily return of firm i on day t; $Return_{i,t\text{-}2}$ is the return of firm i on day t–2; $IVSkew_{i,t-2}$ is the volatility skew for firm i on day t–2;[8] $IVSpread_{i,t-2}$ is the volatility spread for

[8] Volatility skewness is defined as the implied volatility of out-of-money put option minus the implied volatility of at-the-money call option (with the same strike price and maturity) across all option pairs with greater-than-zero open interest and time to expirations of 10 to 60 days. Following Xing, Zhang and Zhao (2010) and Jin, Livnat and Zhang

firm i on day t–2, as calculated in equation 1. The primary variable of interest, $AnnounceDay_t \times IVSpread_{i,t-2}$, is an interaction variable that captures the effect of volatility spread on day t–2 only. $AnnounceDay_t$ is a dummy variable equal to 1 on merger announcement day, zero otherwise. If volatility spread has a stronger predictive effect two days prior to merger announcement day as compared to the average trading day during the sample period, we should find a positive and significant coefficient for the interaction variable. Following guidance from Petersen (2009), regressions incorporate time fixed-effects, while standard errors are corrected for clustering at the firm and date level. To reduce the influence of outliers, all variables are winsorized. All regression specifications examine the pooled sample of announcement and non-announcement days over the entire sample period.

Table 5 reports regression results. Model 1 reports that daily returns on the average trading day during our sample period is significantly predicted by the level of volatility spread two days prior. This result is consistent with past research (e.g., Cremers and Weinbaum, 2010). We next examine return predictability on merger announcement days. The variable of interest in this test is the interaction variable (*Announce Day x IV Spread*). Model 2 reports that the magnitude of the coefficient on the interaction variable is considerably higher than that of the volatility spread variable, however, the estimated coefficient is not statistically significant at conventional levels.

<Insert Table 5 about here>

Given the suggestive evidence in model 2 that return predictability is greater on merger announcement days, we next test the significance of this effect for the least expected mergers only, in model 3, and the most expected mergers only, in model 4. Results in model 3 show that the interaction variable has a positive and significant effect on future stock returns, indicating that

(2012), out-of-the-money put options are identified as option contracts with deltas between −0.15 and −0.45. At-the-money call options are identified as option contracts with deltas between 0.4 and 0.7.

return predictability is significantly higher on merger announcement days than on non-announcement days for the least expected mergers. In contrast, model 4 reports that for the most expected mergers, the interaction variable has an insignificant effect on future stock returns. Moreover, the magnitude of the estimated coefficient is considerably less than for the least expected mergers in model 3. In all specifications, volatility skew has in insignificant effect on future stock returns, suggesting that tail risk is not a significant concern for these merger targets.

Hence, the analysis presented in Table 5 demonstrates that for the quartile of least expected mergers, return predictability is significantly greater on merger announcement days than on non-announcement days. Importantly, the magnitude of the effect on announcement days is three times that of the quartile of the most expected mergers, for which there is no statistically distinguishable return predictability effect on merger announcement days. This result supports the hypothesis that return predictability is greater around takeovers that are less expected.

5. Further analysis of informed trading

5.1. Informed trading around private merger negotiation events

Thus far, our empirical analysis has used tests centered on the public disclosures of corporate takeovers to provide indirect evidence of informed trading. As a more direct alternative test, we follow the approach of Heitzman and Klasa (2020) and identify, from ex-post SEC merger filings, non-public milestone events that occur during private merger negotiations between acquirers and targets. Tests centered on the dates of non-public information events, identified as relevant to firm value, enable us to directly link the private information to trading by informed investors.

For this test, we focus on the same two quartiles of the least expected and the most expected mergers tested in Section 4. We examine the stock return predictability of trading during these events by forming hedge portfolios following the procedures outlined in Section 4.2. We use the Background of the Merger section of SEC filings to manually identify important, value-relevant merger negotiation events. We follow Boone and Mulherin (2007) and Heitzman and Klasa (2020) to identify the milestone events that occur in the private takeover process that precedes the public announcement of a takeover. Such events include, for instance: target receives indication of interest, target retains financial advisor, target signs confidentiality agreement with bidder. We identify 415 such unique dates for the targets in the least expected and the most expected quartiles.

The mean (median) abnormal return in the (-1,+1) window for the sample of 415 private merger negotiation events is a statistically significant 1.8% (0.6%). These average abnormal returns are roughly consistent with the 2.3% (0.9%) negotiation event period abnormal returns reported by Heitzman and Klasa (2020). The level and significance of the returns in our sample are also consistent with Heitzman and Klasa's (2020) finding that informed investors immediately trade on new private information.

Table 6 reports daily target returns for stock portfolios on the dates corresponding to the merger negotiation private events. The results show that return predictability is greater for the portfolio of the least expected mergers than for the portfolio of the most expected mergers. Hedge portfolio average and risk adjusted returns for the least expected mergers are 47 bps and 46 bps, respectively, as compared to 13 bps and 0 bps for the most expected mergers. Although t tests indicate that the differences are not statistically significant, the results provide suggestive evidence that informed trading is more prevalent for those firms that are least expected to eventually become targets in a takeover attempt. This finding is also consistent with the hypothesis that stock return predictability, and thus informed trading, is greater around takeovers that are less expected.

<Insert Table 6 about here>

5.2. *Portfolio returns using other industry classifications and portfolio formation*

The return predictability analysis in Section 4 (i) utilizes the Value Line industry classification scheme to determine industry targets and rivals and (ii) limits subsequent rival mergers to those in unregulated industries announced within three years. To test the robustness of the results, we repeat the analysis using (i) an alternative definition of industry to determine industry targets and rivals and (ii) relaxing some of the portfolio formation constraints.

For this robustness test, we use 4-digit SIC codes to define industries and determine industry targets and rivals. We follow the same overall sample formation process used to compile our primary sample from the sample of SDC mergers, as outlined in Section 3, however, we do not limit the sample of initial targets to those covered by Value Line. In addition, we eliminate initial mergers in industries with a small number of firms (fewer than five firms). These screens produce a sample of 751 initial mergers across the 1,005 4-digit SIC industries. The sample size is consistent with the 694 initial mergers found by Cai, Song and Walkling (2011) over a similar time period using 4-digit SIC industry codes. For the 559 initial targets with available CRSP data, the (-1,+1) period mean (median) abnormal return is a statistically significant 21.0% (17.7%), consistent with the abnormal returns for initial industry mergers reported in Table 2.

To form the sample of subsequent rival mergers we include all subsequent mergers, regardless of the length of time following the initial industry mergers, and include mergers in regulated industries. These procedures produce a sample of 1,674 mergers. By including mergers across all subsequent years and in regulated industries, we test the power of the merger likelihood estimates to proxy for information asymmetry because acquisition probabilities are muted for these two groups of target firms.

Table 7 reports results of the return predictability analysis. Given the much larger number of mergers in this analysis, we sort by volatility spread into quintile portfolios. The central finding from Table 7 is that return predictability is significantly greater for the portfolio of the least expected mergers than for the portfolio of the most expected mergers. Hedge portfolio average and risk adjusted returns for the least expected mergers are 12.0% and 7.9% greater, respectively, than that of the most expected mergers. Results of t tests of differences indicate that the differences are statistically significant. The difference in returns between the least expected and most expected mergers is smaller in this analysis than that of our primary analysis in Table 4, as expected, given the inclusion of rival mergers with lower acquisition probabilities. However, similar to our primary analysis, the evidence produced using alternative specifications supports the hypothesis that stock return predictability is greater around takeovers that are least expected.

<Insert Table 7 about here>

5.3. Portfolio returns for rivals acquired within one year

As a further robustness check, we test the accuracy of our estimated merger probabilities using an empirical prediction from past research. Song and Walking (2000), in their study of rivals of acquisition targets, find that initial industry mergers have the greatest impact on the ex-ante probability of acquisition of industry rivals that are targeted for acquisition themselves within one year of the initial merger. These rivals earn significantly greater abnormal returns at the announcement of the initial merger than rivals not subsequently targeted for acquisition within three years. Given that abnormal returns are significantly positively related to the probability of subsequent acquisition, we would expect the accuracy and reliability of the estimated probabilities, and thus the difference in return predictability between the least expected and most expected mergers, to be greatest in the 12 months following the initial merger

To test this prediction, we limit the sample of subsequent rival mergers to those targeted for acquisition within one year of the initial merger and re-form the volatility and hedge portfolios following the procedures described in Section 4.2. Given the diminished sample size within each volatility quartile, we are unable to reliably estimate alphas and thus report only raw returns. The announcement day returns reported in Table 8 indicate that return predictability is greater for the rivals acquired within one year of the initial merger than for those acquired within three years. The difference in average returns between the least expected and most expected mergers that occur within one year is 22.2% and statistically significant, considerably greater than the difference in returns of 14.8% for the mergers that occur within three years. Moreover, returns of the least expected portfolio increase monotonically from volatility spread quartile 1 to volatility spread quartile 4. Returns of the most expected portfolio do not increase monotonically across volatility spread quartiles. Hence, the results of this test are consistent with a prediction of the acquisition probability hypothesis and provide support for the estimated acquisition probabilities used in this study.

<Insert Table 8 about here>

6. Summary and conclusions

A growing body of empirical evidence suggests that informed investors prefer to trade around events with greater degrees of information asymmetry. However, the lack of a reliable proxy for information asymmetry has produced mixed evidence about the characteristics of the relationship between informed trading and information asymmetry. In particular, the frequent reliance in the empirical literature on the PIN as a measure of informed trading is problematic since recent studies cast doubt on its validity.

Using a novel measure of information asymmetry that provides consistent, market-based predictions about the likelihood of future takeovers, we test a sample of 769 major takeovers to determine whether stock return predictability is greater around takeovers that feature more information asymmetry or greater around takeovers with lower degrees of information asymmetry. We find that options trades contain economically and statistically significant information about the future stock returns of the targets in the least expected takeovers, but not the most expected. Announcement day hedge portfolio returns are significantly higher for the least expected takeovers than for the most expected takeovers. The difference in risk-adjusted return to acquisition targets is 13.4% (t-statistic of 3.18).

Our second contribution is to show a direct link between the generation of private information and trading by informed investors. We find significantly positive abnormal returns on the dates of private merger negotiation events, however, hedge portfolio returns are again greater for the least expected takeovers than for the most expected takeovers. This finding suggests that informed trading is more prevalent for those firms that are least expected to eventually become targets in a takeover attempt.

Hence, the collective evidence presented in this study suggests that informed trading takes place predominately around informationally asymmetric events, such as unexpected takeovers. We find significant return predictability only in the subsample of takeovers that feature the most information risk, or about 25% of our overall sample. We also show a direct link between the generation of private information and trading by informed investors. However, our study shows that informational advantage is only part of the story. As Fung and Loveland (2020, pg. 1461) conclude: "*when* informed traders exploit private information may be as important as obtaining the information in the first place."

Appendix: Variable definitions

Variable	Definition	Source
Initial industry merger	First merger announced after a period of at least 12 months passes in which no takeover in that industry is announced	
Industry rival	Firm in the same industry as the target of the initial industry merger, at the time of the merger announcement	
Subsequent rival merger	Takeover of an industry rival that is announced after, but no later than three years following, the initial industry merger	
Volatility spread	Weighted difference in implied volatilities between call and put options (with the same strike price and maturity) across all option pairs with greater-than-zero open interest and time to expirations of 10 to 60 days	OptionMetrics; see Xing, Zhang and Zhao (2010) and Jin, Livnat and Zhang (2012)
Volatility skew	The implied volatility of out-of-money put option minus the implied volatility of at-the-money call option (with the same strike price and maturity) across all option pairs with greater-than-zero open interest and time to expirations of 10 to 60 days. Out-of-the-money put options are identified as option contracts with deltas between −0.15 and −0.45. At-the-money call options are identified as option contracts with deltas between 0.4 and 0.7.	OptionMetrics; see Xing, Zhang and Zhao (2010) and Jin, Livnat and Zhang (2012)
Lagged return	Firm-level stock return on day *t*-2, where t is event day	CRSP
Announcement day dummy	Binary variable equal to 1 if firm/day observation is a merger announcement day	

This table defines the variables used in this study.

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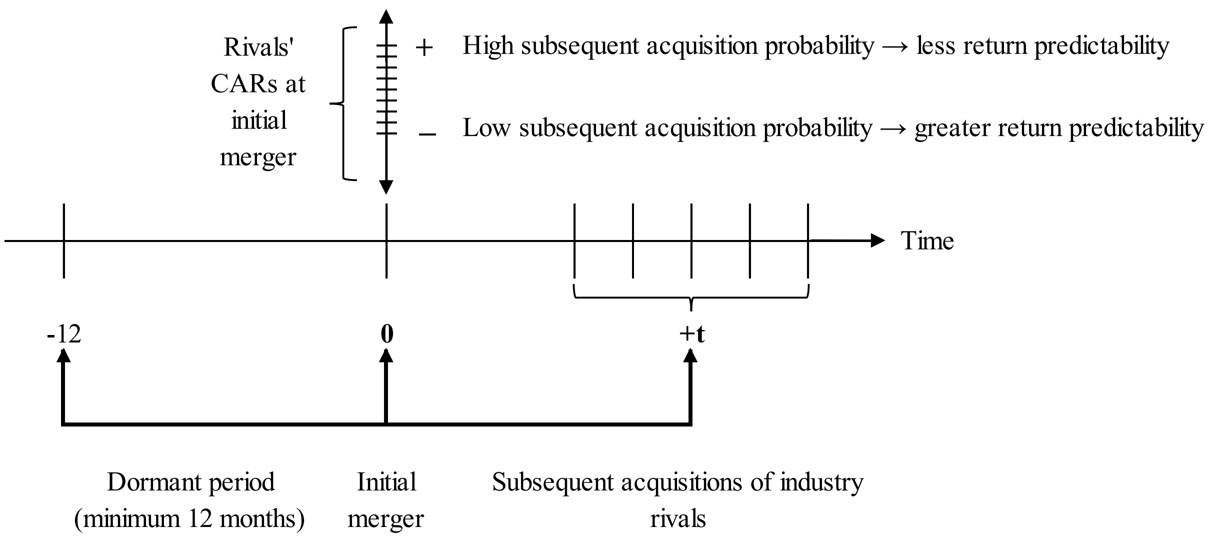
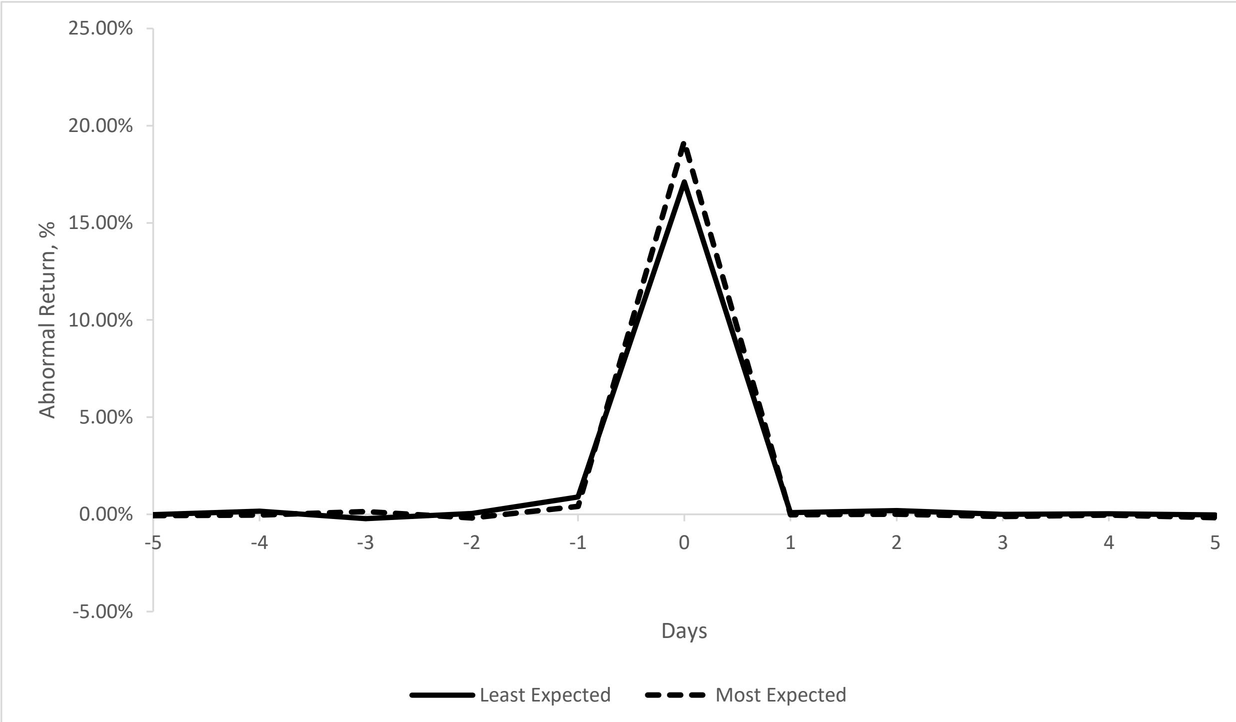
Figure 1: Timeline of industry takeover activity, subsequent merger probability and return predictability



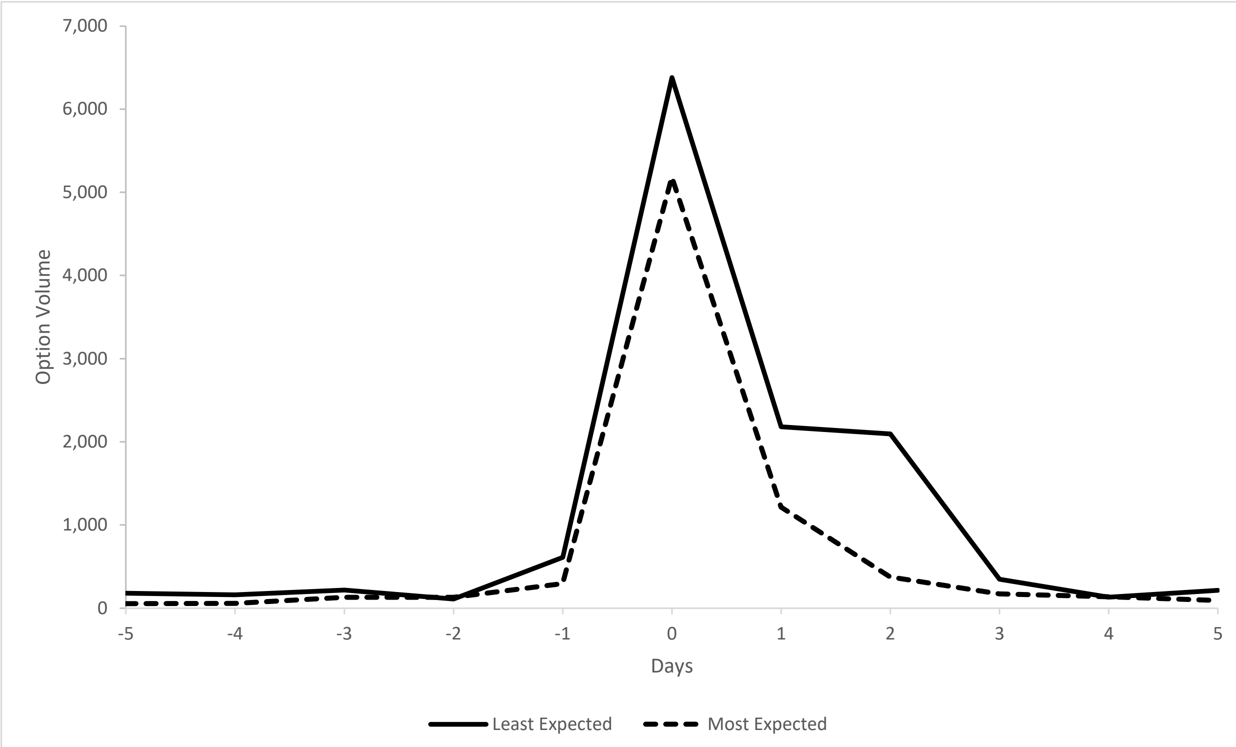
This figure presents the timeline and framework of our empirical analysis to examine the relation between informed options trading and information asymmetry. Acquisitions of target firms are first sorted chronologically within each industry. Initial mergers are defined as the first mergers announced after a period of at least 12 months in which no takeovers in that industry are announced. Abnormal returns of industry rivals are estimated at the time of the initial merger. Industry rivals are defined as firms in the same industry as the target of the initial merger, when it is announced. We sort rivals' abnormal returns in descending order to provide a set of estimates than may be interpreted as pseudo-probabilities of future takeovers of the rival firms. The rivals with the highest (lowest) abnormal returns have the highest (lowest) likelihoods of being acquired within the next three years.

Figure 2: Abnormal returns



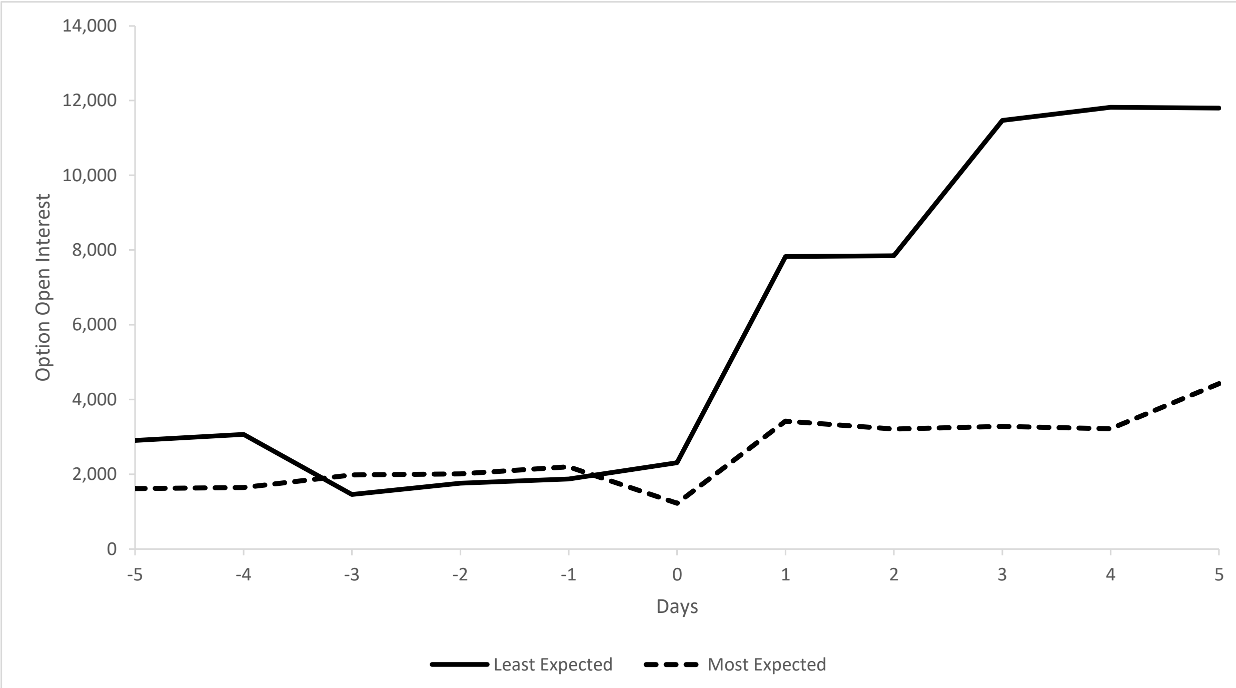
This figure displays daily median abnormal stock returns for the targets in the quartile portfolios of the least expected (solid line) and most expected (dashed line) takeovers.

Figure 3: Abnormal option trade volume



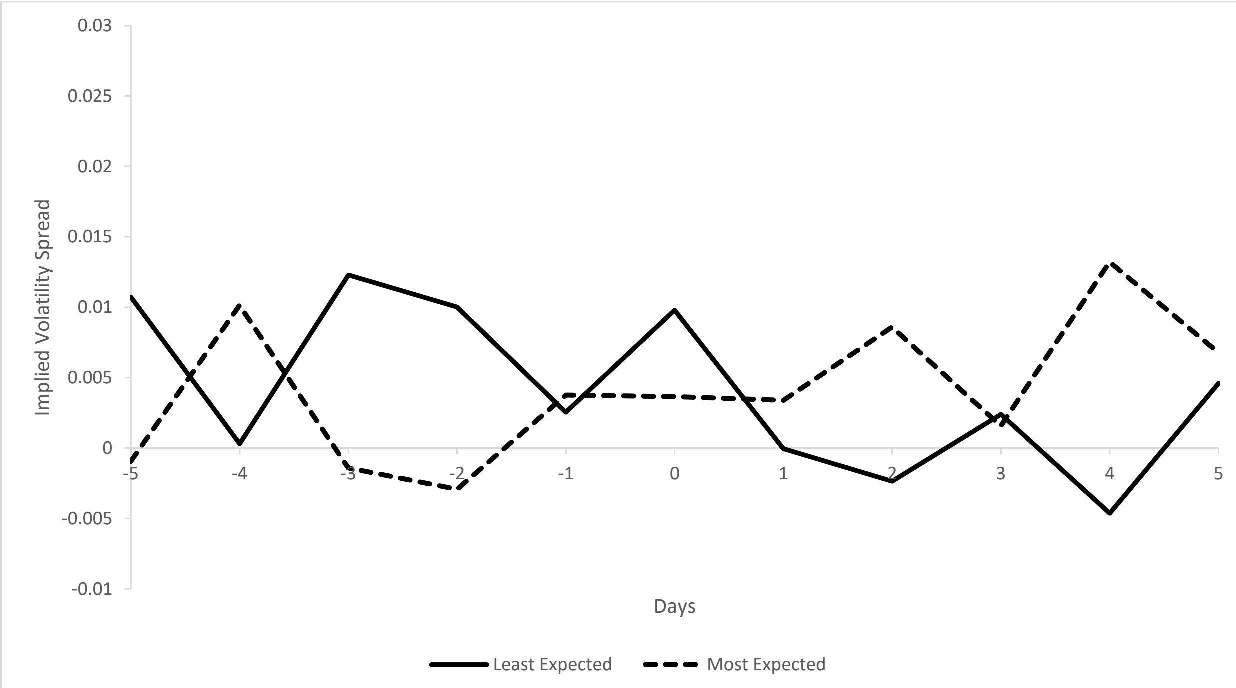
This figure displays daily median abnormal option trade volume for the targets in the quartile portfolios of the least expected (solid line) and most expected (dashed line) takeovers.

Figure 4: Abnormal open interest



This figure displays daily median abnormal option open interest for the targets in the quartile portfolios of the least expected (solid line) and most expected (dashed line) takeovers.

Figure 5: Abnormal volatility spread



This figure displays daily median abnormal implied volatility spread for the targets in the quartile portfolios of the least expected (solid line) and most expected (dashed line) takeovers. Variable definitions are reported in the Appendix.

Table 1: The sample of initial industry mergers, industry rivals and subsequent mergers over time

Year	Initial Industry Merger	Industry Rivals	Subsequent Mergers
1996	-	-	-
1997	3	46	-
1998	8	128	8
1999	14	241	32
2000	17	214	24
2001	21	253	23
2002	20	296	11
2003	22	373	26
2004	21	332	35
2005	33	522	58
2006	27	319	79
2007	25	327	75
2008	20	277	35
2009	24	305	36
2010	30	346	53
2011	28	401	43
2012	26	494	44
2013	24	334	38
2014	24	385	53
2015	26	455	57
2016	33	584	26
2017	15	160	2
2018	37	626	5
2019	18	390	6
Total	516	7,808	769
Average	22	339	35

This table reports the annual count of initial industry mergers, industry rivals and subsequent rival mergers by year for the full sample period 1996 to 2019. An initial industry merger is the first merger announced after a period of at least 12 months passes in which no takeover in that industry is announced. An industry rival is a firm in the same industry as the target of the initial industry merger, at the time of the merger announcement. A subsequent merger is the takeover of an industry rival that is announced after, but no later than three years following, the initial industry merger. Variable definitions are reported in the Appendix.

Table 2: Distribution of (-1,+1) abnormal returns for targets and rivals in initial industry mergers

Category	N	Mean	Min.	Q1	Median	Q3	Max.	% Pos.
Initial industry merger	415	19.53 ***	-83.71	5.79	17.06 ***	30.74	261.19	85.06
Rival firms subsequently acquired	769	0.17	-29.41	-2.36	0.05	2.61	39.30	50.46

This table presents cumulative abnormal returns to target firms in initial industry mergers and rival firms subsequently acquired for the 1996 to 2019 sample period. Returns are computed using the market model for the (-1,+1) period, where day 0 is the initial announcement date. The market is proxied by the CRSP value-weighted index. An initial industry merger is the first merger announced after a period of at least 12 months passes in which no takeover in that industry is announced. A subsequent merger is the takeover of an industry rival that is announced after, but no later than three years following, the initial industry merger. An industry rival is a firm in the same industry as the target of the initial industry merger, at the time of the merger announcement. Variable definitions are reported in the Appendix. The symbol *** denotes statistical significance at the 0.01 level.

Table 3: Abnormal returns of subsequent rival mergers

	Day -1	Day 0	Day +1	(-1, 0)	(-1,+1)	(-5,+5)	No. of obs.
Mean	1.14%	23.19%	0.14%	24.32%	24.47%	25.76%	769
(*p* -value)	(0.00)	(0.00)	(0.28)	(0.00)	(0.00)	(0.00)	
Median	0.38%	19.24%	-0.01%	21.07%	21.02%	21.88%	769
(*p* -value)	(0.00)	(0.00)	(0.76)	(0.00)	(0.00)	(0.00)	

This table presents daily and cumulative abnormal returns to target firms in subsequent mergers of rival firms for the 1996 to 2019 sample period. Daily abnormal returns are presented for day -1, day 0 and day +1, and cumulative abnormal returns are presented for the (-1,0), (-1,+1) and (-5,+5) periods, where day 0 is the initial announcement date. A subsequent rival merger is the takeover of an industry rival that is announced after, but no later than three years following, the initial industry merger. *p*-values reported in parentheses. Variable definitions are reported in the Appendix

Table 4: Daily returns on volatility spread portfolios on merger announcement days

	Volatility spread quartiles				Hedge
	(1)	(2)	(3)	(4)	Portfolio
Least expected					
Return	13.00 ***	15.03 ***	19.52 ***	24.41 ***	11.40 *
Alpha	13.23 ***	12.82 ***	20.05 ***	25.17 ***	11.94 *
Return	20.22 ***	20.14 ***	21.54 ***	18.47 ***	-1.75
Alpha	22.79 ***	20.10 ***	21.69 ***	18.52 ***	-4.27
Return	19.73 ***	14.43 ***	16.26 ***	21.50 ***	1.77
Alpha	22.37 ***	15.08 ***	16.11 ***	17.89 ***	-4.49
Most expected					
Return	24.04 ***	19.10 ***	21.72 ***	20.64 ***	-3.40
Alpha	24.95 ***	20.37 ***	20.39 ***	23.47 ***	-1.48
Difference					
Return					14.80*
Alpha					13.43***

This table presents the performance of quartile and hedge portfolios, formed on the level of acquisition probability and volatility spread. Acquisition probability is the abnormal return of industry rivals estimated at the time of the initial merger as described in Figure 1. Industry rivals are defined as firms in the same industry as the target of the initial merger, when it is announced. Initial mergers are defined as the first mergers announced after a period of at least 12 months in which no takeovers in that industry are announced. Volatility spread is the open interest-weighted difference in implied volatilities between call and put options (with the same strike price and maturity) across all option pairs with greater-than-zero open interest and time to expirations of 10 to 60 days. Volatility spread is observed as of the close of trading on day *t*-2. Returns are from the close on day *t*-1 to the close on day *t*. Performances for quartiles are returns for long positions in each quartile. Performances for hedge portfolios are the returns for a portfolio which is long high volatility spread stocks and short low volatility spread stocks. Portfolios are presented in ascending order of acquisition probability. The panel labeled Least Expected reports portfolio returns for the quartile portfolio of mergers with the lowest acquisition probability. The panel labeled Most Expected reports portfolio returns for the quartile portfolio of mergers with the highest acquisition probability. The panel labeled Difference reports the difference in returns between the Least Expected quartile portfolio of mergers and the Most Expected quartile portfolio of mergers. Return is mean unconditional return, expressed in percentage points and not annualized. Alpha is risk-adjusted return defined as the constant from the CAPM model. Alpha is expressed in percentage points and is not annualized. Statistical significance for difference testing is determined by two-tailed tests of difference in means. The symbols * and *** denote statistical significance at the 0.10 and 0.01 levels, respectively.

Table 5: Regressions of daily stock returns on explanatory variables

Dependent Variable = Return			Quartile 1	Quartile 4
Explanatory Variables	(1)	(2)	(3)	(4)
Lagged return	-0.021 ***	-0.021 ***	-0.021 ***	-0.021 ***
	(4.94)	(5.00)	(4.98)	(4.96)
Volatility skew	0.000	0.000	0.000	0.000
	(0.19)	(0.17)	(0.16)	(0.20)
Volatility spread	0.007 ***	0.007 ***	0.007 ***	0.007 ***
	(3.24)	(3.11)	(3.12)	(3.22)
Announcement day dummy		8.051 ***	8.224 ***	7.791 ***
		(13.83)	(9.32)	(10.31)
Announce day x Volatility spread		0.080	0.122 *	0.041
		(1.32)	(1.71)	(0.50)
Constant	0.116 ***	0.115 ***	0.115 ***	0.116 ***
	(2.86)	(2.85)	(2.85)	(2.86)
Time fixed effects	Yes	Yes	Yes	Yes
R-squared	0.0015	0.0059	0.0038	0.0036
Observations	102,943	102,943	102,943	102,943

This table presents the results from pooled, cross-sectional panel regression analysis of daily stock returns on explanatory variables for the 1996 to 2019 sample period. All models utilize the same pooled sample of announcement and non-announcement days for the least expected mergers (Quartile 1) and the most expected mergers (Quartile 4). Announcement day dummy is a binary variable equal to 1 if a firm/day observation is a merger announcement day. In Model 2 announcement day dummy is set to 1 for all merger announcement days in both Quartile 1 and Quartile 4. Model 3 sets the announcement day dummy to 1 for merger announcements in Quartile 1 only. Model 4 sets the announcement day dummy to 1 for merger announcements in Quartile 4 only. Lagged return is firm-level stock return on day t-2, where t is event day. Volatility skew and volatility spread are observed as of the close of trading on day t-2, where t is event day. Volatility spread (skew) is the open interest-weighted difference in implied volatilities between (at-the-money) call and (out-of-money) put options, with the same strike price and maturity, across all option pairs with greater-than-zero open interest and time to expirations of 10 to 60 days. Following guidance from Petersen (2009), regressions incorporate time fixed-effects (year dummies), while standard errors are corrected for clustering at the firm and date level. Accordingly, absolute values of t-statistics reported in parentheses are corrected for clustering at the firm and date level. The symbols * and *** denote statistical significance at the 0.10 and 0.01 levels, respectively. Variable definitions are reported in the Appendix.

Table 6: Daily returns on volatility spread portfolios on the days of non-public merger negotiation events.

	Volatility spread quartiles				Hedge
	(1)	(2)	(3)	(4)	Portfolio
Least expected					
Return	0.38	0.58 *	0.37	0.86 **	0.47
Alpha	0.43	0.87 ***	0.22	0.89 **	0.46
Most expected					
Return	0.03	0.92 ***	-0.26	0.15	0.13
Alpha	0.13	1.03 ***	-0.18	0.13	0.00
Difference					
Return					0.35
Alpha					0.46

This table presents the performance of quartile and hedge portfolios, formed on the level of acquisition probability and volatility spread, on the dates corresponding to non-public merger negotiation events. Acquisition probability is the abnormal return of industry rivals estimated at the time of the initial merger as described in Figure 1. Industry rivals are defined as firms in the same industry as the target of the initial merger, when it is announced. Initial mergers are defined as the first mergers announced after a period of at least 12 months in which no takeovers in that industry are announced. Volatility spread is the open interest-weighted difference in implied volatilities between call and put options (with the same strike price and maturity) across all option pairs with greater-than-zero open interest and time to expirations of 10 to 60 days. Volatility spread is observed as of the close of trading on day *t*-2. Returns are from the close on day *t*-1 to the close on day *t*. Performances for quartiles are returns for long positions in each quartile. Performances for hedge portfolios are the returns for a portfolio which is long high volatility spread stocks and short low volatility spread stocks. The panel labeled Least Expected reports portfolio returns for the quartile portfolio of mergers with the lowest acquisition probability. The panel labeled Most Expected reports portfolio returns for the quartile portfolio of mergers with the highest acquisition probability. The panel labeled Difference reports the difference in returns between the Least Expected quartile portfolio of mergers and the Most Expected quartile portfolio of mergers. Return is mean unconditional return, expressed in percentage points and not annualized. Alpha is risk-adjusted return defined as the constant from the CAPM model. Alpha is expressed in percentage points and is not annualized. Statistical significance for difference testing is determined by two-tailed tests of difference in means. The symbols *, **, and *** denote statistical significance at the 0.10, 0.05 and 0.01 levels, respectively.

Table 7: Daily returns on volatility spread portfolios on merger announcement days for CRSP targets and rivals utilizing 4-digit SIC industry definitions

	Volatility spread quintiles					Hedge
	(1)	(2)	(3)	(4)	(5)	Portfolio
Least expected						
Return	10.45 ***	14.79 ***	17.38 ***	17.69 ***	16.12 ***	5.67
Alpha	11.64 ***	14.27 ***	16.99 ***	17.73 ***	15.98 ***	4.34
Return	15.46 ***	15.55 ***	17.16 ***	18.94 ***	13.17 ***	-2.29
Alpha	16.25 ***	15.17 ***	18.66 ***	19.12 ***	13.06 ***	-3.19
Return	10.71 ***	14.67 ***	13.41 ***	16.06 ***	14.30 ***	3.58
Alpha	10.15 ***	13.38 ***	12.14 ***	15.24 ***	13.12 ***	2.97
Most expected						
Return	17.54 ***	14.05 ***	13.69 ***	21.17 ***	11.17 ***	-6.37
Alpha	15.85 ***	16.27 ***	12.72 ***	18.63 ***	12.33 ***	-3.52
Difference						
Return						12.04***
Alpha						7.86***

This table presents the performance of quartile and hedge portfolios, formed on the level of acquisition probability and volatility spread. The merger sample tested is based on 4-digit SIC codes to define industries and determine industry targets and rivals. In addition, all subsequent mergers regardless of the length of time following the initial industry mergers and mergers in both regulated and unregulated industries are included in the sample. Acquisition probability is the abnormal return of industry rivals estimated at the time of the initial merger as described in Figure 1. Industry rivals are defined as firms in the same industry as the target of the initial merger, when it is announced. Initial mergers are defined as the first mergers announced after a period of at least 12 months in which no takeovers in that industry are announced. Volatility spread is the open interest-weighted difference in implied volatilities between call and put options (with the same strike price and maturity) across all option pairs with greater-than-zero open interest and time to expirations of 10 to 60 days. Volatility spread is observed as of the close of trading on day *t*-2. Returns are from the close on day *t*-1 to the close on day *t*. Performances for quartiles are returns for long positions in each quartile. Performances for hedge portfolios are the returns for a portfolio which is long high volatility spread stocks and short low volatility spread stocks. Portfolios are presented in ascending order of acquisition probability. The panel labeled Least Expected reports portfolio returns for the quartile portfolio of mergers with the lowest acquisition probability. The panel labeled Most Expected reports portfolio returns for the quartile portfolio of mergers with the highest acquisition probability. The panel labeled Difference reports the difference in returns between the Least Expected quartile portfolio of mergers and the Most Expected quartile portfolio of mergers. Return is mean unconditional return, expressed in percentage points and not annualized. Alpha is risk-adjusted return defined as the constant from the CAPM model. Alpha is expressed in percentage points and is not annualized. Statistical significance for difference testing is determined by two-tailed tests of difference in means. The symbol *** denotes statistical significance at the 0.01 levels.

Table 8: Daily returns on volatility spread portfolios on announcement days of subsequent rival mergers announced no later than twelve months following initial industry mergers

	Volatility spread quartiles				Hedge
	(1)	(2)	(3)	(4)	Portfolio
Least expected					
Return	6.47 **	17.18	21.64	32.83 **	26.35 ***
Return	21.43	21.24	16.59 **	20.44	-0.99
Return	27.98 *	20.85	19.79 **	23.91	-4.08
Most expected					
Return	20.84	13.72	18.52 **	25.02 ***	4.18
Difference					
Return					22.18*

This table presents the performance of quartile and hedge portfolios, formed on the level of acquisition probability and volatility spread. The merger sample tested is comprised of subsequent mergers announced within one year of the initial merger. Acquisition probability is the abnormal return of industry rivals estimated at the time of the initial merger as described in Figure 1. Industry rivals are defined as firms in the same industry as the target of the initial merger, when it is announced. Initial mergers are defined as the first mergers announced after a period of at least 12 months in which no takeovers in that industry are announced. Volatility spread is the open interest-weighted difference in implied volatilities between call and put options (with the same strike price and maturity) across all option pairs with greater-than-zero open interest and time to expirations of 10 to 60 days. Volatility spread is observed as of the close of trading on day t-2. Returns are from the close on day t-1 to the close on day t. Performances for quartiles are returns for long positions in each quartile. Performances for hedge portfolios are the returns for a portfolio which is long high volatility spread stocks and short low volatility spread stocks. Portfolios are presented in ascending order of acquisition probability. The panel labeled Least Expected reports portfolio returns for the quartile portfolio of mergers with the lowest acquisition probability. The panel labeled Most Expected reports portfolio returns for the quartile portfolio of mergers with the highest acquisition probability. The panel labeled Difference reports the difference in returns between the Least Expected quartile portfolio of mergers and the Most Expected quartile portfolio of mergers. Return is mean unconditional return, expressed in percentage points and not annualized. Statistical significance for difference testing is determined by two-tailed tests of difference in means. The symbols *, **, and *** denote statistical significance at the 0.10, 0.05 and 0.01 levels, respectively.