# Learning about Uncertainty from Options Trading

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**Abstract**

We hypothesize that managers can learn about a firm's investment uncertainty from the equity options market. Using a US sample of 1,865 merger and acquisition attempts during 1996–2015, we show that the volatility implied from an acquiring firm's equity options around an acquisition announcement negatively predicts the likelihood of acquisition attempts being completed. This negative impact is robust to controls for stock prices, alternative uncertainty proxies, and endogeneity tests. Moreover, we document three economic channels, finding that the effect of option implied volatility on deal completion is stronger among acquirers in which disinvestment is more difficult, whose managers are more susceptible to risk aversion, and whose options market is expected to have more information. Our findings suggest that options trading functions as a feedback mechanism to help managers learn about riskiness when making investment decisions.



**Keywords:** Learning, Feedback effect, Uncertainty, Equity options, Option implied volatility, Acquisition

**JEL classification:** G14, G34

## 1. Introduction

Financial markets feature a prominent feedback effect that a firm's managers can learn information from the stock price to guide corporate decisions.[1] "Learning" here means that managers would increase (decrease) investment if the stock price rises (falls). In principal, the stock price should provide two types of information: the expected value and uncertainty about the firm's future cash flows. However, previous studies focus on the former, and evidence on the feedback effect based on the second moment of the stock price is lacking. In this study, we bridge this gap by investigating whether managers can learn about uncertainty from the options market when making an investment decision.

The options market is widely believed to be the best available place to obtain information about uncertainty (Cox and Rubinstein, 1985; Ni, Pan, and Poteshman, 2008). The volatility implied from an option's price (generally referred to as "option implied volatility") reflects options market participants' expectations of the future uncertainty in an underlying process. Unlike a stock, the nonlinear payoff structure of an option contract allows investors to trade on volatility. Accordingly, options trading by investors informed about volatility leads to option implied volatility being more informative about future uncertainty than other volatility proxies obtained from the stock market. Indeed, many studies assert that option implied volatility outperforms other uncertainty measures when forecasting volatility.[2] Given the informational advantage of option implied volatility, we therefore study whether managers can learn about uncertainty from the equity options market during M&As.

The analysis of M&A decisions is ideal for our study for several reasons. First, an M&A is among the largest and most prominent forms of corporate investment (Masulis, Wang, and Xie, 2007). Given the importance of an M&A to a firm, managers are expected to improve their M&A decisions, for example, by collecting information from various sources. Second, an M&A is accompanied by substantial uncertainty such that the M&A deal value changes considerably even after the agreement (Bhagwat, Dam, and Harford, 2016). Since the appeal of the acquisition attempt often varies with external factors other than the acquirer's

[1] Bond, Edmans, and Goldstein (2012) comprehensively review the literature on the feedback effect of financial markets. For example, the feedback effect has been documented in theory (e.g., Dow and Gorton, 1997; Subrahmanyam and Titman, 1999; Edmans, Goldstein, and Jiang, 2015), and tested empirically for a number of corporate decisions including mergers and acquisitions (M&As) (Luo, 2005; Edmans, Goldstein, and Jiang, 2012), general investment (Chen, Goldstein, and Jiang, 2007; Bakke and Whited, 2010; Foucault and Fresard, 2012, 2014; Loureiro and Taboada, 2015; Edmans, Jayaraman, and Schneemeier, 2017; Dessaint, Foucault, Frésard, and Matray, 2019), and IPOs (Jegadeesh, Weinstein, and Welch, 1993; Michaely and Shaw, 1994).

[2] These studies include Day and Lewis (1992), Lamoureux and Lastrapes (1993), Christensen and Prabhala (1998), Christensen, Hansen, and Prabhala (2001), and Blair, Poon, and Taylor (2001).

fundamentals, acquiring managers are motivated to acquire outside information about the riskiness of the acquisition attempt from the options market. Third, previous studies show that managers decide whether to conclude the M&A deal by considering the stock price reaction to an M&A announcement (Luo, 2005; Kau, Linck, and Rubin, 2008; Liu and McConnell, 2013). Compared with the first moment of the deal value, its second moment, or uncertainty, is arguably of greater concern to managers and of central interest to this study.[3]

Using a US sample of 1,865 M&A attempts announced by public firms over 1996–2015, we show that the volatility implied from an acquiring firm's equity options around an M&A announcement predicts whether the announced deal is later completed or abandoned. Specifically, we first implement the portfolio approach by grouping these M&A attempts into quintiles based on acquirers' option implied volatility. We find that an increase in acquirers' option implied volatility by the spread between the lowest and highest quintiles is associated with a 10% decline in the probability of the acquisition attempt being completed. This magnitude is economically significant relative to the standard deviation of the deal completion rate, which is less than 5%. We further conduct two-way conditional sorting and multivariate regression analyses and find that the negative effect of option implied volatility is robust after accounting for a variety of control variables such as the acquirer's cumulative abnormal returns (CAR), its square, the relative size of the transaction, and the acquirer's firm size.

We explore several alternative explanations of the result. First, the uncertainty captured by the acquirer's option implied volatility might be correlated with either the acquiring firm's alternative investment opportunities or acquiring managers' inside information about the deal. We thus use the ratio of the at-the-money (ATM) option open interest to the total open interest as the instrument for option implied volatility and employ an instrumental variable approach to mitigate this concern.

Second, option implied volatility may proxy for other uncertainty measures such as those already observable in the stock market. Hence, we calculate three alternative uncertainty measures based on stock market returns and show that these alternatives do not subsume the effect of option implied volatility on deal completion.

Third, the literature documents that the options market conveys information about the level of future stock prices (so-called "directional information") as well as about riskiness. To

[3] Uncertainty plays a central role in firms' investment decisions (Abel, 1983; Bloom, 2009; Caballero, 1991; Chen, Miao, and Wang, 2010; DeMarzo, Fishman, He, and Wang, 2012).

address this possibility, we employ two options market variables for acquiring firms: the option volatility spread and option volatility skew. We show that the other moments of future stock returns implied by option prices do not alter the effect of implied volatility on acquiring managers' decision to complete the deal.

Furthermore, our finding of a negative relationship between option implied volatility and deal completion could be due to the realization of the information contained in option implied volatility. In other words, a potential bad shock captured by high implied volatility might occur after the M&A announcement, reducing the initial appeal of the deal. The negative deal value due to a bad shock will cause managers to abandon the deal. In this way, even if managers do not learn from the options market, high option implied volatility can be associated with a low likelihood of deal completion simply because it foreshadows a bad event.

To weigh this nonlearning hypothesis against the learning hypothesis, we perform additional tests to examine the mechanisms through which option implied volatility affects deal completion. Specifically, we examine how their relationship varies with managerial incentives to learn. The degree to which managers try to avoid risky projects would change depending on both the irreversibility of investment and managerial risk-taking incentives such as ownership and a compensation scheme. In addition, managers' incentives to learn would vary with the informativeness of the options market. Consistent with these conjectures, we indeed find that the negative relationship between option implied volatility and deal completion is stronger among acquirers in which disinvestment is more difficult, managers are more likely to be risk averse, and the options market is perceived to have more information. Taken together, the negative effect of option implied volatility on deal completion is better explained by managerial learning from the options market.

Having established that managers learn from the options market during M&As, in the last part of the paper, we investigate whether managerial learning from the options market applies to the general investment decision. Specifically, following the framework of Chen, Goldstein, and Jiang (2007) and Panousi and Papanikolaou (2012), we analyze the relationship between option implied volatility and the level of capital expenditure for all public firms with exchange-traded equity options. We find that option implied volatility is significantly negatively related to capital expenditure even after controlling for other uncertainty measures

and firm characteristics. This finding implies that when managers learn about high riskiness from the options market, they choose to reduce investment.

This study contributes to the learning literature by suggesting that the equity options market is an important source of information from which managers learn about uncertainty. Theoretical studies of learning argue that firm managers can improve their decisions by obtaining information from financial markets, which are efficient at producing and aggregating information unknown to managers (e.g., Dow and Gorton, 1997; Subrahmanyam and Titman, 1999; Dye and Sridhar, 2002; Bond, Goldstein, and Prescott, 2010; Edmans, Goldstein, and Jiang, 2015). Empirical studies provide supporting evidence but focus only on learning about the first-moment (valuation) information from the stock price (e.g., Jegadeesh, Weinstein, and Welch, 1993; Michaely and Shaw, 1994; Bommel, 2002; Luo, 2005; Chen, Goldstein, and Jiang, 2007; Bakke and Whited, 2010; Edmans, Goldstein, and Jiang, 2012; Foucault and Fresard, 2012, 2014; Loureiro and Taboada, 2015; Edmans, Jayaraman, and Schneemeier, 2017; Dessaint, Foucault, Frésard, and Matray, 2019). To the best of our knowledge, this study is the first to provide evidence on the learning of second-moment (uncertainty) information from option prices. We thus provide a link between the informational role of options and managerial learning by showing that managers use volatility information implicit in equity option prices to make corporate investment decisions.

Moreover, this study extends the scant literature on the real effects of the equity options market. While the informational role of the options market has been examined extensively in the literature,[4] less is known about how the options market affects the actions of decision-makers in the real side of the economy. Roll, Schwartz, and Subrahmanyam (2009) provide seminal evidence that options trading increases firm value by improving price informativeness. Consistent with the positive real effect of options trading, Naiker, Navissi, and Truong (2013) show that options trading enables firms to raise equity capital at a lower cost. Blanco and Wehrheim (2017) also show that options trading enhances firm innovation such as the numbers of patents and patent citations. We provide additional evidence that the options market has real consequences for firms' investment policies by showing that option prices affect a firm's M&A decisions.

The rest of the paper is organized as follows. Section 2 reviews the literature and develops our hypothesis. Section 3 provides data sources and describes the sample. In Section 4, we

[4] See Easley, O'Hara, and Srinivas (1998), Cao, Chen, and Griffin (2005), Pan and Poteshman (2006), and Johnson and So (2012).

show the baseline relationship between option implied volatility and the likelihood of acquisition completion and conduct several robustness tests. Section 5 presents economic channel tests and further extends our analysis to the relationship between option implied volatility and capital expenditure. Section 6 concludes.

## 2. Related literature and hypothesis development

This study rests on three main strands of the literature: investment-to-price sensitivity, the informational role of the equity options market, and the relationship between investment and uncertainty. First, the investment-to-price sensitivity literature highlights the feedback effect of financial markets—that security market prices guide managers' investment decisions (e.g., Luo, 2005; Chen, Goldstein, and Jiang, 2007; Bakke and Whited, 2010; Bond, Edmans, and Goldstein, 2012; Foucault and Fresard, 2012, 2014; Loureiro and Taboada, 2015; Edmans, Jayaraman, and Schneemeier, 2017; Dessaint et al., 2019). The argument is that because market prices aggregate diverse pieces of information and ultimately transmit some incremental information about a firm's prospects, managers can learn from this information and incorporate it into their investment decisions. In particular, Luo (2005) finds that the stock market reaction to an M&A announcement predicts the likelihood of deal completion, suggesting that acquiring companies extract information from stock prices and reflect it in closing the deal.

Second, a substantial body of the options literature focuses on the role of the options market as a unique venue for trading based on volatility information (e.g., Back, 1993; Ni, Pan, and Poteshman, 2008). Unlike a stock, the nonlinear payoff structure of an option contract allows investors to trade on volatility. As investors informed about uncertainty trade options, their insights into future uncertainty become embedded in option prices. Many empirical studies of volatility measurement provide supportive evidence that option implied volatility outperforms other measures when forecasting uncertainty (e.g., Day and Lewis, 1992; Lamoureux and Lastrapes, 1993; Christensen and Prabhala, 1998; Christensen, Hansen, and Prabhala, 2001; Blair, Poon, and Taylor, 2001).

The third strand of the literature addresses the question of how uncertainty affects firms' investment decisions (e.g., Abel, 1983; Caballero, 1991; Bloom, 2009; Chen, Miao, and Wang, 2010; DeMarzo et al., 2012). Most notably, the theoretical studies of Bernanke (1983) and Bloom, Bond, and Van Reenen (2007) predict that firm managers are cautious and may

reduce investment under uncertainty. Their predictions are proven in empirical findings (e.g., Leahy and Whited, 1996; Guiso and Parigi, 1999; Panousi and Papanikolaou, 2012). Among them, Panousi and Papanikolaou (2012) document that a firm's capital expenditure decreases with its idiosyncratic risk, suggesting the negative impact of managerial risk aversion on investment.

Taken together, we expect acquiring managers to learn about the riskiness of their acquisition attempt from the options market around the acquisition announcement and consider this when making their future decisions. In particular, on the decision of whether to complete or abandon the acquisition attempt, we formulate the *learning hypothesis* as follows:

**H1.** When the equity options market of an acquiring firm implies higher volatility at the M&A announcement, managers are more likely to abandon the acquisition attempt.

## 3. Data and descriptive statistics

### *3.1. M&A data*

We obtain our initial sample of M&A attempts from the Thomson Financial Securities Data Company (SDC) database of M&As in the United States. We begin with all M&A announcements between January 1, 1996 and June 30, 2015. Following the previous literature on M&As (e.g., Luo, 2005; Masulis, Wang, and Xie, 2007; Wang and Xie, 2009; Liu and McConnell, 2013; Masulis, Wang, and Xie, 2019), we apply a series of data filters: (1) a deal type must be classified as "disclosed value M&A," "leveraged buyout," "tender offer," or "exchange offer"; (2) the proposed deal value must be at least $10 million; (3) the potential acquirer must own less than 50% of the target firm's shares before the acquisition attempt and must seek to own more than 50% after the transaction; and (4) both the potential acquirer and the target must be public companies whose stock price information is available from the Center for Research in Security Prices (CRSP). Finally, since our goal is to examine managerial learning about a deal's riskiness from the options market, we restrict our sample to the deals in which a potential acquirer has exchange-traded equity options with the available estimates of implied volatility. Appendix A explains our sample selection procedure in detail.

Following the literature, we construct a set of M&A variables. Our key dependent variable, the M&A completion dummy, is equal to one if an M&A deal is completed. We then define the acquirer's CAR over various trading intervals around the M&A announcement as the sum

of the differences between the acquirer's daily stock returns and CRSP value-weighted market returns over the trading intervals.

We also measure the acquiring and target firms' size as their equity market capitalization on the 41st trading day before the M&A announcement. The relative deal value is computed as the transaction value (i.e., the total value of payments that the acquirer proposes to pay for the target firm) divided by the acquirer's size. Moreover, we calculate the premium offered for the target firm's shares as the percentage change in the offer price from the target firm's stock price 41 trading days before the announcement of the acquisition attempt. Following Jennings and Mazzeo (1991), we compute the target normalized price response (TNPR) as the change in the target's stock price following the acquisition announcement relative to the premium offered by the acquirer.[5]

We finally construct various indicator variables of deal characteristics, such as the target's receptive attitude, the presence of termination fees, a lockup condition, tender offers, and the payment method. The definitions of these variables are provided in Appendix B.

### *3.2. Equity options data*

Our data for acquirers' equity options come from the Ivy OptionMetrics database, which provides end-of-day bid and ask quotes, open interest, and trading volume for all exchange-listed options on US equities beginning in 1996. The database also provides option implied volatility using Cox, Ross, and Rubinstein's (1979) binomial tree model. Following the common procedure in the option literature, we exclude all observations for which the bid/ask spread is negative or greater than $5, the midpoint of bid and ask quotes is below 50% of the option intrinsic value, or the implied volatility is less than zero or greater than 200% to screen out records that may contain errors. We also eliminate observations with zero open interest to exclude illiquid options.

Our key variable of interest is the acquirer's option implied volatility around the M&A announcement. We first compute daily implied volatility by averaging the implied volatilities of all the options traded on the acquirer's stock during a day. These daily implied volatilities are then averaged over the trading days [-1, +7] around the announcement. We also consider the option volatility spread and skew as control variables. The volatility spread is defined as the difference in implied volatility between a pair of call and put options with the same strike

[5] Jennings and Mazzeo (1991) propose the TNPR as a proxy for the market's opinion of the offer: the higher the TNPR, the greater is the likelihood of the proposal being successfully concluded.

price and maturity date following Cremers and Weinbaum (2010). The volatility skew is computed as the difference in implied volatility between out-of-the-money (OTM) puts and ATM calls in line with Xing, Zhang, and Zhao (2010). A detailed description of our variable construction is provided in Appendix B.

### *3.3. Sample and summary statistics*

Our final sample consists of 1,865 acquisition attempts, of which 1,719 (92.2%) are completed. Our sample covers both hot and cold M&A periods. Consistent with the merger wave of the late 1990s, M&A attempts cluster in the early part of the sample period and generally decline thereafter. Yet, the deal completion rate is evenly distributed over time, with one exception for the 2008 global financial crisis when it falls noticeably to 73%. The industrial distribution of our acquirers also shows that the deal completion rate is reasonably evenly dispersed across industries. For example, the completion rate is the highest at 100% for deals in the fabricated product industry and the lowest at 78% for those in the food industry. Appendix C presents the time series and industry composition of M&A attempts along with the deal completion rate.

Table 1 presents the deal and firm characteristics for the full sample of proposed M&A attempts as well as separate summary statistics for completed and abandoned attempts. Acquirer firms in our sample are particularly large, with an average firm size of around $18 billion. Given that the sample focuses on firms with traded options, these firms tend to be larger than those without traded options (Mayhew and Mihov, 2004). The proposed transaction value accounts for 35% of the acquirer's firm size on average. The 41-day premium has a mean of 46%. The TNPR has a mean of 67% in our acquisition sample of optioned firms, which is high relative to that for the average acquisition attempt.[6]

[Table 1 about here]

A comparison of the deal characteristics between completed and abandoned attempts confirms previous findings on the factors determining whether a proposed acquisition is completed or abandoned. The right part of Table 1 shows that the acquisition attempts proposed by larger firms are more likely to be completed, which is consistent with the finding of Chen, Harford, and Li (2007), Kau, Linck, and Rubin (2008), and Liu and McConnell (2013). In addition, the smaller the transaction value relative to the acquirer's firm size, the

[6] By way of a comparison, the mean TNPR is 46% in Liu and McConnell's (2013) sample of value-reducing US acquisition attempts from 1990 to 2010.

greater is the likelihood of deal completion, as in Luo (2005) and Masulis, Wang, and Xie (2009). Furthermore, the proposed acquisitions are more likely to be completed when the target premium is greater and the target's stock price reaction to the announcement is larger, concurring with the finding of Jennings and Mazzeo (1991).

Panel B of Table 1 shows that the acquisition attempts accompanied by a friendly attitude on the target's part are more likely to be completed, whereas those financed by the acquirer's stock are less likely to be completed.[7] Further, the likelihood of transaction completion is positively correlated with the presence of both a termination fee that the potential acquirer must pay to the target in the case of abandonment and a lockup option that allows the acquirer to purchase target shares at a fixed price in the emergence of competing bidders.[8]

Overall, we include all these characteristics as controls throughout the analysis to isolate the impact of option implied volatility on acquiring managers' decision to conclude an acquisition attempt.

## 4. Option implied volatility and M&A completion

### *4.1. Baseline results*

#### *4.1.1. Univariate tests*

We first examine the relationship between M&A deal completion and our key explanatory variable, volatility implied by the acquirer's equity options. We obtain daily option implied volatility by averaging the implied volatilities of all options traded over a day for the acquirer's stock. We examine the average of daily option implied volatilities over two event widows: the trading days [-1, +1] and [-1, +7] around the M&A announcement.[9]

Table 2 presents the acquirer's option implied volatility for completed and abandoned acquisition attempts along with statistical tests as to whether the means and medians differ between the two groups. We find that the acquirer's option implied volatility is much higher for abandoned acquisition attempts than for completed ones. For example, the mean and median values of option implied volatility over the window [-1, +7] are 44% and 39%, respectively, for completed attempts, while those for abandoned attempts are 51% and 45%,

[7] Huang and Walking (1987) report that an acquisition attempt financed by common stock is less likely to be completed.

[8] Bates and Lemmon (2003) report that the presence of termination fees in an acquisition attempt increases the likelihood of its completion. Burch (2001) documents that an acquisition attempt is more likely to be concluded when it includes a lockup option.

[9] Previous studies such as Luo (2005) examine an event window extended to +7 trading days to allow markets to fully reflect the announced information.

respectively. The *t*-tests and Wilcoxon tests, reported in the last two columns, indicate that the difference in implied volatilities between the two groups is highly statistically significant. The results over the window [-1, +1] are similar. This observation is consistent with our conjecture that acquiring managers are likely to abandon the acquisition attempt when they learn about the high risk of the deal from the options market.

[Table 2 about here]

Table 2 also reports the acquirer's CAR at the M&A announcement. The stock price reaction to the announcement is one of the most important determinants of acquiring managers' decision on deal completion. Managers are more likely to abandon acquisition attempts when they observe a more negative stock market reaction to the announcement (Luo, 2005; Chen, Harford, and Li, 2007; Kau, Linck, and Rubin, 2008; Liu and McConnell, 2013).

To obtain the CAR, we compute the abnormal stock returns using the market model. Specifically, we estimate the beta of the market model using the daily returns of the acquiring firm's stock and CRSP value-weighted market portfolio over the trading days [-250, -50] before the announcement.[10] Consistent with previous studies, our results show that abandoned attempts have a more negative stock price reaction at the announcement than completed attempts. For example, the mean CAR over the trading days [-1, +7] is -3.9% for abandoned attempts, whereas it is -1.3% for completed attempts. Since different trading windows around the announcement generate similar results, we focus on the trading window [-1, +7] in the remainder of the paper for simplicity.

To further understand the relationship between M&A deal completion and option implied volatility, we employ the portfolio approach. Specifically, we divide all 1,865 acquisition attempts into five groups based on acquirers' option implied volatility measured over the [-1, +7] window, leaving 373 attempts in each quintile. Then, we investigate the percentage of completed transactions in each quintile. Panel A of Table 3 reports the results.

Our sample acquirers exhibit wide variation in their option implied volatility: the acquirer with the lowest option implied volatility (Q1) has an average implied volatility of 23.4% and the acquirer with the highest option implied volatility (Q5) has an average implied volatility of 77.8%. The spread of 54.5% between the lowest and highest quintiles corresponds to a two standard deviation change in option implied volatility. More importantly, the deal completion

[10] Alternatively, we measure CAR using a simple market model as the sum of the acquirer's daily stock returns minus the CRSP value-weighted market returns over the event window. We repeat the entire analysis using the alternative measure and find similar results.

rate decreases significantly from 96.2% to 86.3% from Q1 to Q5. This difference of 10% in the deal completion rate is economically significant considering that the standard deviation of the yearly deal completion rates is less than 5%.[11] Thus, the univariate analysis shows a significant negative relationship between option implied volatility and managers' decision to conclude M&A attempts.

[Table 3 about here]

To ensure that the above finding is not driven by the potential determinants of M&A deal completion, we conduct two-way conditional sorting. We first sort M&A attempts into quintiles based on one of the control characteristics including the acquirer's CAR, its square, the relative size of the transaction, and the acquirer's firm size; then, within each quintile, we group M&A attempts into quintiles based on option implied volatility. These implied volatility groups are then aggregated over each of the control characteristic quintiles. Panel B of Table 3 reports the results.

The differences in the average deal completion rate between the extreme implied volatility quintiles, controlling for various characteristics, range from 5.4% to 8.1%. These differentials are somewhat reduced in comparison to the raw differential of 10% in Panel A. However, they are still highly significant in both an economic and a statistical sense. Notably, the variation in the deal completion rate associated with the acquirer's option implied volatility remains substantial after controlling for the acquirer's squared CAR, which is often used as a proxy for realized volatility in the stock market.

Taken together, the results imply that acquiring managers' learning about riskiness from the options market is distinct from learning from the stock market and has a unique influence on the completion of the proposed acquisition.

### *4.1.2. Multivariate regression analysis*

We now investigate whether the differential likelihood of deal completion associated with different levels of option implied volatility is attributable to other characteristics using multivariate regression analysis. Specifically, we estimate four variants of the following probit model:

[11] If we exclude the financial crisis period during which the deal completion rate is exceptionally low, the standard deviation of the yearly deal completion rates is much lower, at roughly 2%.

$$Pr(Completed) = \Phi(\alpha + \beta\ Option\ implied\ voaltility + \gamma\ CAR + \delta\ Other\ controls + \eta\ Year\ dummies + \theta\ Industry\ dummies + \varepsilon), (1)$$

where the dependent variable is a dummy variable taking the value of one for completed M&A attempts and zero for abandoned attempts and Φ is the cumulative distribution function of the standard normal distribution. The acquiring firm's option implied volatility and CAR are measured over the trading window [-1, +7] around the announcement.[12] We include various control variables known to affect deal completion following Liu and McConnell (2013). We also include year and industry fixed effects. Industry fixed effects are defined using Fama and French's (1997) 17 industry groupings. We cluster standard errors at the firm level.

Table 4 reports the coefficient estimates and z-statistics from the probit model. We first examine the effects of the acquirer's option implied volatility and CAR separately. Column 1 shows that the coefficient of the acquirer's option implied volatility is -0.851 with a z-statistic of -3.60, which is negative and statistically significant. The coefficient estimate implies that if implied volatility increases from its first quintile value to the fifth one, the likelihood of acquisition completion decreases by 6.3%, which is an economically significant change.[13] This result is consistent with that in Table 3 that the higher risk the options market implies, the more likely the acquiring manager abandons the deal. In Column 2, the coefficient of the acquirer's CAR is significantly positive, corroborating the previous finding that the more negatively the stock market reacts to the announcement, the more likely the acquiring manager abandons the deal.

Next, in Column 3, we include both option implied volatility and CAR as independent variables at once. We find that the coefficient of option implied volatility remains significantly negative. The coefficient of CAR also remains significantly positive, although

[12] We repeated the analysis using option implied volatility and CAR measured over the trading window [-1, +1] around the announcement and found similar results.

[13] To provide a sense of the economic significance of the estimate, we estimate the marginal effect of implied volatility in the probit regression, defined as the change in the estimated probability of deal completion from changing implied volatility from zero to one, holding the other variables fixed at their sample mean. The marginal effect estimate of implied volatility is -0.116. Thus, the quintile difference in implied volatility, 54.5%, is associated with a decrease of 0.116×54.5%=6.3% in the probability of deal completion.

the magnitude is somewhat reduced. This finding indicates that option implied volatility contains unique information on deal completion that is not subsumed by CAR.

Moreover, when we include various control variables in Column 4, we still find a significantly negative coefficient of option implied volatility, but a marginally positive coefficient of CAR. The coefficients of the other control variables are consistent with the findings of previous studies; that is, acquisition attempts of a relatively smaller size with a larger acquirer, a higher target premium, and a more friendly attitude of the target as well as those in the form of tender offers are more likely to be completed.

[Table 4 about here]

Taken together, the results show that the negative relationship between an acquirer's option implied volatility and the likelihood of deal completion is substantial after we control for CAR and other characteristics known to affect deal completion. This finding suggests that the uncertainty information conveyed by the options market has a significant effect on acquiring managers' decision to complete or abandon the acquisition attempt.

### *4.2. Robustness tests*

To test the robustness of our results, we first conduct an instrumental variable approach to mitigate the endogeneity concern. Second, we examine whether alternative uncertainty proxies subsume the effect of option implied volatility. Third, we investigate whether the other moments of future stock returns implied by option prices influence acquiring managers' decision to complete the deal. All the methods provide similar results. We still find a significant negative relationship between the acquirer's option implied volatility and likelihood of acquisition completion.

#### *4.2.1. Instrumental variable approach*

A potential problem with our analysis is that the relationship between the likelihood of deal completion and level of option implied volatility is endogenous. In particular, the uncertainty captured by the acquirer's option implied volatility might be correlated with either the acquiring firm's alternative investment opportunities or firm managers' inside information about the deal. To alleviate this concern, we use an instrumental variable approach.

As an instrument for option implied volatility, we use the ratio of the ATM option open interest to the total open interest. We expect the ATM open interest ratio to be negatively associated with option implied volatility. That is, when the stock price is stable, options traders may prefer ATM options to OTM options because the latter are likely to be worthless when they expire. By contrast, when the stock price is volatile, options traders may prefer OTM options because they are likely to expire in-the-money soon. However, we do not expect acquiring managers to be more or less likely to complete their acquisition attempts depending on the level of the ATM option open interest.

Table 5 reports the estimation results from the probit model with the instrumented option implied volatility. Column 1 presents the results of the first-stage regression in which the acquirer's option implied volatility is the dependent variable. The coefficient of the ratio of the ATM option open interest is negative and statistically significant, indicating that the concentration of open interest in ATM options is associated with a low level of option implied volatility.

Column 2 shows the results of the second-stage probit regression of acquisition completion in which option implied volatility, our main independent variable of interest, is the predicted value of the first-stage regression. Importantly, the coefficient of the instrumented option implied volatility is negative and statistically significant. Thus, the result of the instrumental variable approach provides supportive evidence of the negative relationship between the acquirer's option implied volatility and likelihood of acquisition completion.

[Table 5 about here]

However, as a caveat, we acknowledge that the ATM open interest ratio is plausibly correlated with firm characteristics that might be linked to the likelihood of acquisition completion. We conduct the instrumental variable approach just to mitigate the possibility of alternative explanations.

*4.2.2. Alternative uncertainty proxies*

We argue that in deciding whether to conclude the acquisition attempt, acquiring managers learn about the riskiness of the attempt from the options market—specifically, from option implied volatility around the announcement—because the options market is especially suitable for conveying forward-looking information on uncertainty. However, option implied

volatility may be proxying for other uncertainty measures such as those already observable in the stock market. To address this possibility, we examine whether other uncertainty measures subsume the effect of option implied volatility on deal completion.

We consider three types of alternative uncertainty measures. First, we compute the acquiring firm's historical volatility as the standard deviation of its daily stock returns in the 250 trading days before the M&A announcement. Second, we measure realized volatility based on returns around the M&A announcement, using both the squared and the absolute values of the acquirer's CAR over the trading days [-1, +7] around the announcement. Third, we calculate past option implied volatility as an average of the option implied volatility over the trading days [-250, -50] before the announcement.

In Table 6, we first examine how each uncertainty measure is related to the likelihood of acquisition completion in a separate regression. The results from the univariate regressions in Columns 1–4 show that all these uncertainty measures are negatively associated with the likelihood of acquisition completion, confirming that higher uncertainty leads acquiring managers to abandon acquisition attempts. Next, we examine the explanatory power of each alternative uncertainty proxy in the presence of option implied volatility. The results from the bivariate regressions in Columns 5–8 show that the coefficient of option implied volatility is significantly negative, whereas the coefficients of the alternative uncertainty measures become insignificant and even positive. This finding is robust when we augment the regressions with the 10 control variables in Columns 9–12.

[Table 6 about here]

Thus, the results show that our finding of a strong negative relationship between option implied volatility and the likelihood of deal completion cannot be explained by the effect of other uncertainty proxies. Rather, option implied volatility subsumes all the explanatory powers of the alternative uncertainty proxies. This finding suggests that the options market serves as an important source of information on uncertainty from which acquiring managers can learn about the riskiness of the deal to decide whether to complete or abandon the acquisition attempt.

*4.2.3. Other moments implied by options*

In this study, we focus on the overall level of option implied volatility as a source of information about riskiness. However, the literature documents that the options market also

conveys information about future stock prices (so-called "directional information") as well as riskiness.[14] In particular, previous studies such as Cremers and Weinbaum (2010) and Xing, Zhang, and Zhao (2010) report that the structure of the option implied volatility curve, or the differences in option implied volatilities across puts and calls with different strike prices, contains information about the level and skewness of future stock returns. Moreover, Chan, Ge, and Lin (2015) show that the structure of the option implied volatility curve predicts acquirers' announcement returns. Given these findings, we investigate whether the documented negative relationship between option implied volatility and acquisition completion is attributable to the directional information contained in the structure of the option implied volatility curve.

We employ two options market variables for acquiring firms. First, the option volatility spread is computed as the average difference in the implied volatilities of a pair of call and put options with the same strike price and same maturity, as in Cremers and Weinbaum (2010). This volatility spread is regarded as a proxy for informed traders' net demand for call options relative to put options with the same contractual terms. Thus, a high volatility spread is expected to be related to a positive stock price movement.

Second, the option volatility skew is calculated as the average difference between the implied volatilities of OTM puts and ATM calls following Xing, Zhang, and Zhao (2010). A put option is defined as OTM when moneyness, defined as the strike price divided by the closing underlying stock price, is lower than 0.95 and a call option is defined as ATM when moneyness is between 0.95 and 1.05. Like the volatility spread, the volatility skew is seen as a proxy for informed traders' bet on future stock price movement, but in the reverse direction. That is, a high volatility skew is expected to be associated with a negative stock price movement. Both the volatility spread and the volatility skew are measured over the same trading window as the average level of option implied volatility.

In Table 7, we examine the relationship between the structure of the option implied volatility curve and likelihood of acquisition completion using probit regressions. In the univariate regressions of Columns 1 and 2, the coefficients of both the volatility spread and the volatility skew are positive but not statistically significant. This lack of significance

[14] The informational content of the options market has been examined in various contexts using different measures. Studies include Easley, O'Hara, and Srinivas (1998), Cao (1999), Cao, Chen, and Griffin (2005), Pan and Poteshman (2006), and Johnson and So (2012).

indicates that both the volatility spread and the volatility skew have little or no influence on the acquiring manager's decision on deal completion.

When we add option implied volatility into the regressions, as shown in Columns 3 and 4, the coefficients of the volatility spread and volatility skew are again not statistically different from zero. By contrast, the coefficients of option implied volatility are significantly negative. This negative relationship between option implied volatility and the likelihood of acquisition completion remains significant even after augmenting the regressions with the other control variables in Columns 5 and 6.

[Table 7 about here]

In sum, our results show that the volatility information conveyed by the options market is significantly negatively associated with the likelihood of acquisition completion, whereas the directional information conveyed by the options market is unrelated to deal completion. This finding implies that acquiring managers follow the options market to learn about the riskiness of the deal, rather than its valuation, when deciding whether to complete or abandon the acquisition attempt.

## 5. Additional tests

### *5.1. Economic channels*

Our finding of a negative relationship between option implied volatility and the likelihood of deal completion might be due to the predictability of option implied volatility instead of managerial learning. In other words, a potential bad shock, the high occurrence probability of which is reflected in high implied volatility, might occur after the M&A announcement, thereby reducing the initial appeal of the deal. The reduced deal value due to a bad shock will cause managers to abandon the deal. In this way, without learning, high option implied volatility can still be associated with a low likelihood of deal completion simply because high option implied volatility predicts bad events.

To weigh this nonlearning hypothesis against the learning hypothesis, we investigate the underlying economic channels through which option implied volatility affects the likelihood of deal completion. First, the irreversibility of investment may deter managers from succeeding in risky acquisition attempts ("*investment irreversibility channel*"). Second, acquiring managers might be risk averse, probably because they hold a large, undiversified share in the firm, thereby rejecting a risky attempt ("*risk attitude channel*"). Third, we expect

managers to be more likely to learn from the options market when they believe that it can provide more information ("*market informativeness channel*").

*5.1.1. Investment irreversibility channel*

One of the main implications of real option theory for firm value is that the volatility of an underlying process increases firm value (e.g., McDonald and Siegel, 1985, 1986; Carlson, Fisher, and Giammarino, 2004; Grullon, Lyandres, and Zhdanov, 2012). The premise for this positive effect of volatility on firm value is that firms can adapt their investment and operations flexibly to shocks, creating a convex relationship between firm value and an underlying process.

Put differently, real option theory implies that a lack of flexibility in firms' operating and investment decisions makes the increase in firms' cash flow volatility less attractive. Thus, managers who learn about the high riskiness of the acquisition attempt from the options market plausibly abandon the deal owing to the irreversibility of investment. If so, we expect the negative relationship between option implied volatility and the likelihood of acquisition completion to become stronger among acquirers with a greater degree of investment irreversibility.

To test this prediction, we use three alternative proxies for the degree of investment irreversibility employed by Panousi and Papanikolaou (2012). First, we consider how fast a firm's capital assets depreciate. If capital assets depreciate faster, it would be harder to reverse the investment. We measure capital depreciation as the ratio of depreciation expenses to total asset value. High depreciation expenses relative to asset value would mean fast capital depreciation and, therefore, a high degree of investment irreversibility.

Second, we assess the ratio of capital asset sales to total assets. The fact that a firm sells a relatively large proportion of assets indicates that it can easily dispose of used capital assets. Thus, a high ratio of capital sales to total assets would mean a low degree of investment irreversibility.

Third, we estimate the sensitivity of a firm's stock returns to the returns of its corresponding industry portfolio, or the so-called industry beta of the firm. We expect a firm with a higher industry beta to have more difficulty reversing the investment because when a firm must sell capital owing to disinvestment following a bad shock, other firms in the same

industry, which are potential buyers for the capital, would be unable to buy it (Shleifer and Vishny, 1992). Appendix B describes how we construct these measures.

In Table 8, we sort acquiring firms into two equal-sized groups based on one of these three investment irreversibility proxies. In each investment irreversibility group, we run the probit regression of the acquisition completion indicator on option implied volatility and the other control variables.

In Panel A, we divide the sample into two groups based on the capital depreciation of acquiring firms. Notably, the coefficient of option implied volatility is negative but insignificant among acquirers with relatively slow capital depreciation. However, the coefficient of option implied volatility is significantly negative among acquirers with relatively fast capital depreciation. Thus, the results indicate that acquiring managers are more likely to abandon risky acquisition attempts if firms' capital assets depreciate quickly.

[Table 8 about here]

In Panel B of Table 8, we divide the sample into acquirers with low and high capital sales ratios. For acquirers with a low capital sales ratio, option implied volatility is significantly negatively related to the likelihood of acquisition completion. However, this negative relationship disappears among acquirers with a high capital sales ratio. Therefore, when acquiring firms find it harder to sell used capital assets, acquiring managers are more likely to abandon risky acquisition attempts.

Panel C of Table 8 presents the results for acquirers with low and high industry betas. As expected, an acquirer's option implied volatility is significantly negatively associated with the likelihood of acquisition completion among acquirers with a high industry beta. This negative relationship, however, is no longer significant among acquirers with a low industry beta. Thus, acquiring managers are more likely to abandon risky acquisition attempts when the acquirer's stock returns covary strongly with those of its industry portfolio.

In summary, the results in Table 8 show that the negative relationship between the acquirer's option implied volatility and likelihood of acquisition completion is more pronounced among acquirers with a greater degree of investment irreversibility, specifically faster capital depreciation, a lower capital sales ratio, and a higher industry beta. This finding is consistent with the prediction that acquiring managers are more reluctant to carry on with risky acquisition attempts if disinvestment is costlier and more difficult, thus supporting the learning hypothesis as opposed to the nonlearning hypothesis.

*5.1.2. Risk attitude channel*

In theory, acquiring managers should determine whether to abandon risky acquisition attempts to maximize firm value, regardless of their risk preference. In practice, however, managers' attitudes toward risk may affect their investment decision. For example, Panousi and Papanikolaou (2012) report that managerial risk aversion causes firms to reduce capital expenditure.

In this subsection, we explore the possibility that the negative relationship between managers' learning about uncertainty and the likelihood of acquisition completion is driven by managers' risk aversion. Specifically, we investigate whether and how this relationship varies with acquiring managers' incentives for risk-taking by considering the following three aspects of managerial incentives.

First, managerial ownership affects acquiring managers' attitudes toward risk. Panousi and Papanikolaou (2012) argue that managers with a large proportion of their wealth tied to their own firms are likely to be poorly diversified and therefore forego a risky, though possibly value-increasing, investment. Thus, if acquiring managers hold a larger share of their firms' stocks, we would expect them to be more likely to abandon risky acquisition attempts. This causes a stronger negative relationship between option implied volatility and the likelihood of acquisition completion. We compute managerial ownership as a firm's shares held by firm insiders as a proportion of the shares outstanding in the firm as of the last filing date before the M&A announcement (see Appendix B for the details).

Second, executive compensation is important for determining managers' risk-taking behaviors (DeFusco, Johnson, and Zorn, 1990). Giving stock options to managers creates a convex compensation scheme that makes increasing the volatility of firm performance more attractive to managers, and therefore might induce them to undertake risky investments (Smith and Stulz, 1985; Ross, 2004). Accordingly, we expect a more convex compensation scheme for acquiring managers to attenuate the negative effect of option implied volatility on the likelihood of acquisition completion. We estimate the convexity of executive compensation (hereafter, vega) as the dollar change in executives' wealth with respect to a one percentage point change in the standard deviation of the firm's stock returns. We take the average of the vega estimates over all executives in the year before the M&A announcement.

Finally, institutional ownership is considered to be an effective governance mechanism for monitoring managers (Cremers and Nair, 2005). If the abandonment of a risky acquisition attempt is due to the risk aversion of under-diversified acquiring managers, monitoring by institutional investors would mitigate this agency problem. Therefore, to the extent that the abandonment of a risky acquisition attempt is aligned with shareholders' interests, we expect the negative relationship between option implied volatility and the likelihood of acquisition completion to be weaker for acquirers with higher institutional ownership. We define institutional ownership as a firm's shares held by all 13F institutions as a proportion of the outstanding shares of the firm at the last filing date before the M&A announcement.

Panel A of Table 9 shows the effect of insider ownership on the relationship between option implied volatility and the likelihood of acquisition completion. We divide the sample into acquirers with low and high insider ownership based on the median value and then estimate the probit regression of acquisition completion in each group. The coefficient of option implied volatility for acquirers with low insider ownership is negative but insignificant, whereas that for acquirers with high insider ownership is significantly negative. Thus, the sensitivity of acquisition abandonment to option implied volatility becomes stronger among acquirers with higher insider ownership, implying that managers who hold larger shares in their own firms tend to be more risk averse and thus abandon risky acquisition attempts.

[Table 9 about here]

In Panel B of Table 9, we group the sample into acquirers with low and high executive compensation vegas. The coefficient of option implied volatility for acquirers with a low compensation vega is negative and significant, whereas that for acquirers with a high compensation vega is not significant. Thus, the sensitivity of acquisition abandonment to option implied volatility is weaker among acquirers with higher compensation vegas, implying that greater stock option compensation helps mitigate managers' risk aversion to abandon risky acquisition attempts.

In Panel C of Table 9, we examine the interaction effect of insider ownership and executive compensation vega on the relationship between option implied volatility and the likelihood of acquisition completion. We first divide all acquirers into two groups based on the median value of insider ownership. Then, in each insider ownership group, we further sort acquirers into two groups based on executive compensation vega. The estimation results show that the coefficient of option implied volatility is significantly negative only among

acquirers with high insider ownership and a low compensation vega. Thus, the abandonment of risky acquisition attempts is concentrated in acquirers whose managers own a larger proportion of their firms and are less compensated for risk-taking. This finding is consistent with the view that acquirers with high insider ownership and a low executive compensation vega are most susceptible to managerial risk aversion.

Panel D of Table 9 shows the interaction effect of insider ownership and institutional ownership on the relationship between option implied volatility and the likelihood of acquisition completion. We divide our sample acquirers into four equal-sized groups using two-way conditional sorting: the first based on insider ownership and the second based on institutional ownership. We find that the coefficient of option implied volatility, although negative, is not significantly different from zero among acquirers with low insider ownership. However, the coefficient of option implied volatility is significantly negative among acquirers with high insider ownership but low institutional ownership. This finding suggests that acquiring managers are more likely to abandon risky attempts when they hold a larger equity stake in their firms, but are less monitored by institutional investors.

In sum, we find that the negative relationship between option implied volatility and the likelihood of acquisition completion becomes more pronounced among acquirers with higher insider ownership, a lower executive compensation vega, and lower institutional ownership. These findings are consistent with the idea that acquiring managers who hold larger shares in their firms, are compensated in a less convex way, and are less closely monitored by institutions are more risk averse and therefore more likely to abandon risky acquisition attempts. Again, this evidence supports the learning hypothesis instead of alternative explanations.

*5.1.3. Market informativeness channel*

In this section, we explore the effect of options market liquidity on the relationship between option implied volatility and the likelihood of acquisition completion. Previous studies document that informed traders prefer to trade in active markets with high trading volumes (Admati and Pfleiderer, 1988; Kyle, 1985). In particular, Roll, Schwartz, and Subrahmanyam (2009) report that benefits from the options market such as informational efficiency increase with the trading volume of options, implying that informed traders are more active in the high volume options market. This implies that an options market with

higher trading volume would incorporate information about riskiness more quickly and completely. In addition, Loureiro and Taboada (2015) state that an improvement in the information environment encourages managers to learn from financial markets. Specifically, they document that the relationship between the market reaction to M&A deal announcements and likelihood of deal completion becomes stronger after the adoption of International Financial Reporting Standards.

Following these studies, we expect that when the options market is more liquid, acquiring managers might be more motivated to learn about the riskiness of the deal from the options market. In particular, the negative effect of an acquirer's option implied volatility on the likelihood of acquisition completion would be stronger for acquirers with more actively traded options to the extent that the effect is driven by managerial learning.

We test this prediction using three measures of options market liquidity: volume, open interest, and bid/ask spreads. Higher volume and open interest as well as narrower spreads imply a more liquid options market. To measure an acquiring firm's option volume, we first compute the daily option volume by summing each option's contract volume multiplied by its delta over all traded options. We divide the daily total option volume by the acquirer's number of shares outstanding.[15] Then, we calculate the average of these daily option volumes over the trading days [-250, -1] around an M&A announcement. In a similar way, we compute the average open interest and bid/ask spread for acquirers' options over the 250-day trading window. We then divide acquiring firms into two groups based on their levels of each liquidity proxy. For each group, we run a separate probit regression of the deal completion indicator on option implied volatility and the other control variables, as shown in the last column of Table 4.

[Table 10 about here]

The estimation results in Panel A of Table 10 show that for acquirers with a low daily option volume, the coefficient of option implied volatility is negative but insignificant. For acquirers with a high daily option volume, however, the coefficient of option implied volatility is significantly negative. Notably, the magnitude of the coefficient of option implied volatility becomes much greater for the high volume group, -1.497, more than twice that

[15] To measure option volume and open interest, we follow Lakonishok et al. (2007) to adjust the difference in the delta among options and convert option volume and open interest into an equivalent number of shares of the underlying stock.

obtained from the baseline analysis using the full sample, -0.726, as reported in the last column of Table 4.

Similarly, when the sample is sorted based on acquirers' option open interest, the negative relationship between option implied volatility and the likelihood of acquisition completion is stronger for acquirers with higher open interest, as reported in Panel B. Option implied volatility for the low open interest group has a negative but insignificant coefficient of -0.297 (z-statistic=-0.63), whereas that for the high open interest group has a significantly negative coefficient of -1.090 (z-statistic=-2.24).

The results for acquirers' option bid/ask spreads reported in Panel C show that the coefficients of option implied volatility are -0.927 (z-statistic=-2.16) and -0.364 (z-statistic=-0.69) in the subsamples of low and high bid/ask spreads, respectively. Thus, the relationship between option implied volatility and the likelihood of acquisition completion is stronger when the bid/ask spread is narrower. This finding is consistent with managers being more likely to learn from a more liquid market.

In sum, we find that the sensitivity of acquisition completion to option implied volatility is greater for acquirers whose options market has a higher trading volume, higher open interest, and narrower bid/ask spreads. This finding supports the notion that when options are more actively traded and thus, their prices tend to be more informative, managers are more likely to learn from the options market when making their decision on deal completion.

*5.2. Sensitivity of investment to option implied volatility*

So far, we have focused on the effect of option implied volatility on a firm's acquisition decision. In this section, we investigate whether the option implied volatility effect can be extended to the general investment level of a firm. Given that the managerial awareness of riskiness is an important determinant of a firm's investment and that an options market is an apt place from which managers can learn about riskiness, we expect option implied volatility to be uniquely related to the investment level, subsuming the impacts of other risk proxies.

Following Chen, Goldstein, and Jiang (2007) and Panousi and Papanikolaou (2012), we estimate several variants of the following regression model of the investment level:

$$I_{i,t}/K_{i,t-1} = \alpha + \beta log(\sigma_{i,t-1}) + \gamma Z_{i,t-1} + \delta F_i + \lambda T_t + \varepsilon_{i,t}, \quad (2)$$

where $I_{i,t}$ is the capital expenditure of firm $i$ in year $t$ and $K_{i,t-1}$ is the book value of assets in the previous year. The volatility of firm $i$ in year $t$, $\sigma_{i,t}$, is measured in three ways: option implied volatility, $\sigma_{i,t}^{option\ implied}$, is computed as the average of the implied volatilities of all options traded on firm $i$'s stock in year $t$; the firm's idiosyncratic volatility, $\sigma_{i,t}^{idiosyncratic}$, is calculated as the standard deviation of the residuals from the regression in which weekly stock returns are regressed on the returns of the CRSP value-weighted index and corresponding Fama and French's (1997) 30-industry portfolio; and the stock market's systematic volatility, $\sigma_{i,t}^{systematic}$, is defined as the square root of the difference between the total variance of firm $i$'s stock returns and its idiosyncratic variance. $Z_{i,t-1}$ is a vector of control variables, including Tobin's Q, the operating cash flow ratio, firm size, stock returns, and leverage. $F_i$ and $T_t$ are dummies for firm and year fixed effects, respectively. These variables are defined in Appendix B.

For this analysis, our sample covers all public firms common to the CRSP/Compustat merged database and OptionMetrics database from 1996 to 2015. We require each firm to have a history of at least 200 daily options trading observations because our main independent variable of interest is option implied volatility. We exclude firms in the financial and utilities industries. Our sample consists of 35,858 firm-year observations.

Table 11 reports the estimation results of equation (2). The first two columns show the effect of option implied volatility on investment. Specifically, when we include only option implied volatility and firm fixed effects in Column 1, the coefficient of option implied volatility is -0.0045, which is statistically significant. In Column 2, we further include systematic volatility to address the concern that the negative impact of option implied volatility might capture the systematic risk premium. The coefficient of option implied volatility is still significantly negative at -0.0076 (*t*-statistic=-4.10). These results show that when managers learn about high riskiness from the options market, they tend to reduce investment.

[Table 11 about here]

In the next two columns, we use idiosyncratic volatility instead of option implied volatility. The results are mixed: idiosyncratic volatility has a positive coefficient when examined alone, whereas it has a negative coefficient when other firm characteristics are controlled for. The latter finding is consistent with that of Panousi and Papanikolaou (2012).Most importantly,

when we include both option implied volatility and idiosyncratic volatility as independent variables (see the last two columns), the coefficients of option implied volatility are significantly negative regardless of the model. However, the coefficients of idiosyncratic volatility are no longer significantly negative. These results indicate that the negative effect of idiosyncratic volatility on investment is subsumed by option implied volatility.

In sum, our results show that option implied volatility is strongly and negatively associated with a firm's investment, subsuming the impact of idiosyncratic volatility. This indicates that managers reduce investment when they learn about high riskiness from the options market. Thus, managerial learning about riskiness from the options market applies to general investment decisions as well as acquisition decisions.

## 6. Conclusion

Uncertainty is a ubiquitous concern of firm managers, especially when they make investment decisions. Despite the oft-cited role of the equity options market as a unique trading venue for volatility, its implications for firm managers have rarely been examined in prior studies. This study investigates whether managers learn about uncertainty from the equity options market when making investment decisions.

We find a robust negative relationship between an acquirer's option implied volatility and the likelihood of the acquisition attempt being completed, suggesting that when acquiring managers learn about the high riskiness of the acquisition attempt from the options market, they are more likely to abandon the deal. Moreover, we show that the negative relationship between option implied volatility and deal completion is more pronounced when disinvestment is harder, managers are more likely to be risk averse, or the options market is more liquid. This variation in the relationship is not explained by the nonlearning hypothesis that the realization of a bad shock foreseen by high option implied volatility leads to the abandonment of the acquisition attempt. We also find evidence that managers reduce firms' capital expenditure when they learn about high uncertainty from the options market.

Overall, our results suggest that the equity options market is a useful source of volatility information from which firm managers learn about riskiness when making investment decisions. Our study also adds to the understanding of the role of the equity options market in positively affecting the real economy.

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**Appendix A. Sample selection**

| No. of Obs. After Query | Query Description |
|---|---|
| | ***Machine search in SDC*** |
| | SDC domestic M&As announced: January 1, 1996 to June 30, 2015 |
| 74,002 | Deal type included: disclosed value M&As, leveraged buyouts, tender offers, and exchange offers |
| 71,559 | Percentage of shares the acquirer is seeking to own after the transaction: 50% or higher |
| 71,559 | Target nation: United States |
| 10,080 | Target is public |
| 8,850 | Acquirer nation: United States |
| 5,435 | Acquirer is public |
| 5,013 | Deal value is $10 million or higher |
| 4,667 | Exclude all deals with a hostile or unsolicited initial reception |
| 4,481 | Exclude all challenged deals |
| 4,357 | Percentage of the target firm's shares held by the proposed acquirer before the announcement of the acquisition attempt: less than 50% |
| | ***Match with the CRSP*** |
| 2,541 | Both the acquirer and the target are identified by the CRSP, matched by CUSIP, ticker, and/or company name. In addition, their stock prices one day before the announcement are available on the CRSP and are consistent with those reported by SDC. The stock price from SDC is between 90% and 110% of the closing price from the CRSP. |
| | ***Acquirers with exchange-traded equity options*** |
| 1,865 | Acquirer firms have exchange-traded equity options whose price information including implied volatilities is available from the Ivy OptionMetrics database. |

**Appendix B. Variable definitions**

| Variable | Definition |
|---|---|
| ***M&A attempt characteristics*** | |
| Completed dummy | One for completed M&A deals and zero for abandoned M&A attempts. |
| CAR | The cumulative abnormal returns of the acquirer company over the trading days [-1, +7] around the M&A announcement. We calculate the abnormal returns using the market model: we estimate the beta of the market model using the daily returns of the firm and CRSP value-weighted market portfolio over the trading days [-250, -50] before the announcement. |
| Acquirer/target size | The acquirer/target firm's market capitalization 41 trading days before the announcement day of the M&A attempt. |
| Relative deal value | The total value of the payments that the acquirer proposed to pay for the target firm divided by the acquirer's firm size. |
| 41-day premium | $\left(Offer\ price - P_{-41}^{Target}\right)/P_{-41}^{Target}$, where $P_{-41}^{Target}$ is the target firm's stock price 41 trading days before the announcement of the M&A attempt. |
| Target normalized price response (TNPR) | $\left(P_{0}^{Target} - P_{-41}^{Target}\right)/\left(Offer\ price - P_{-41}^{Target}\right)$, where $P_{0}^{Target}$ and $P_{-41}^{Target}$ are the target firm's stock prices on the announcement day and 41 trading days before the announcement of the M&A attempt, respectively. |
| Termination fee dummy | One if the attempt includes termination fees that the acquirer must pay to the target if the attempt is abandoned, and zero otherwise. |
| Tender offer dummy | One if the attempt is structured as a tender offer, and zero otherwise. |
| Stock dummy | One if the attempt is financed by the acquirer's common stock, and zero otherwise. |
| Lockup dummy | One if the attempt includes a lockup of target shares in which the potential acquirer is granted an option to purchase shares at a fixed price, and zero otherwise. |
| ***Options market variables*** | |
| Option implied volatility | Option implied volatility from Cox, Ross, and Rubinstein's (1979) binomial tree model. Daily implied volatility is obtained by averaging the implied volatilities of all options traded on the stock in a day. These daily option implied volatilities are averaged over the trading days [-1, +7] around the M&A announcement. |
| Option volume | Yearly aggregate delta-adjusted option volume as a percentage of the shares outstanding. As in Lakonishok, Lee, Pearson, and Poteshman (2007), the delta-adjusted volume of options for underlying stock $i$ on day $t$ is calculated by first multiplying the total trade volume in each option by the absolute value of the delta and then aggregating this number across all option contracts traded: |

$$Volume_{i,t} = \frac{\sum_{j=1}^{N_{i,t}} 100 \times (Option\ Contract\ Volume)_{i,j,t} \times |\Delta_{i,j,t}|}{(Shares\ Outstanding)_{i,t}} \times 100,$$

where $N_{i,t}$ is the number of call or put contracts traded on stock $i$ on day $t$ and $\Delta_{i,j,t}$ is the delta of the $j$th option contract on stock $i$ on day $t$. Since an option contract is for 100 shares of the underlying stock, the contract volume is multiplied by 100 in the numerator. This delta-adjusted option volume is expressed as a percentage of the number of the shares outstanding for the underlying stock. The yearly volume is the sum of the daily ones over the 250 trading days before an M&A announcement.

At-the-money (ATM) open interest ratio

The ratio of ATM options' open interest to the total open interest of all options traded for an acquirer's stock over the 250 trading days before an M&A announcement. An option is classified as ATM when moneyness, defined as the strike price divided by the underlying stock price, is between 0.95 and 1.05. Like the option volume, we adjust the delta by multiplying contract open interest by the absolute value of the delta and then summing it across the different options.

Option volatility spread

Each day, the option volatility spread is calculated as the difference in option implied volatility between a pair of call and put options with the same strike price and maturity following Cremers and Weinbaum (2010):

$$Volatility\ Spread_{i,d} = \sum_{j=1}^{N_{i,d}} w_{i,j,d}\left(IV_{i,j,d}^{Call} - IV_{i,j,d}^{Put}\right),$$

where $N_{i,d}$ is the number of call/put pairs on stock $i$ on day $d$ and $w_{i,j,d}$ is the weight based on the open interest of the call/put pair. $IV_{i,j,d}$ is option implied volatility. The daily volatility spread is averaged over the trading days [-1, +7] around the M&A announcement.

Option volatility skew

Each day, the option volatility skew is computed as the difference in option implied volatility between the OTM put option and ATM call option following Xing, Zhang, and Zhao (2010). A put option is classified as OTM when moneyness, defined as the strike price divided by the underlying stock price, is lower than 0.95. A call option is classified as ATM when moneyness is between 0.95 and 1.05. the daily volatility skew is averaged over the trading days [-1, +7] around the M&A announcement.

***Other firm characteristics***

Historical volatility

Annualized standard deviation of an acquirer firm's daily stock returns in the 250 trading days before the M&A announcement.

Insider ownership

A firm's shares held by firm officers as a proportion of the shares outstanding in the firm at the last filing date before the M&A announcement. We obtain managerial holdings data from the Thomson Financial Insider database of filings derived from Forms 3, 4, and 5. As in Panousi and Papanikolaou (2012), we include insiders with the following role classifications: O, OD, OE, OB, OP, OS, OT, OX, CEO, CFO, CI, CO, CT, H, GM, M, MD, P, EVP, VP, and SVP.

Institutional ownership

A firm's shares held by all 13F institutions as a proportion of the shares outstanding in the firm at the last filing date before the M&A announcement. We obtain the stock holdings of all reporting 13F

| | |
|---|---|
| | institutions from the Thomson Financial 13F database. |
| Convexity of executive compensation (vega) | Dollar change in executives' wealth associated with a 0.01 change in the standard deviation of the firm's stock returns, measured in the year before the M&A announcement. We compute the partial derivatives of an executive's wealth with respect to stock return volatility following Core and Guay (2002) and Coles, Daniel, and Naveen (2006). We calculate the firm-level vega by averaging across the executives in the firm. Data on managerial compensation including CEO option grants are from the Execucomp database. |
| Capital depreciation | The ratio of depreciation expenses to total assets. When depreciation expenses (Compustat item: xdp) are missing from the Compustat annual database, we calculate them as depreciation and amortization (Compustat item: dp) minus the amortization of intangibles (Compustat item: am). |
| Capital sales | The ratio of the sales of property, plant, and equipment (Compustat item: sppe) to total assets. |
| Firm industry beta | We estimate the beta of a firm with its corresponding industry portfolio by running the following yearly regression of weekly returns: $$R_{i,w} = \alpha_i + \beta_i^{MKT} R_{MKT,w} + \beta_i^{IND} R_{IND,w} + \varepsilon_w,$$ where $R_{i,w}$ is the weekly return of firm $i$ in week $w$, $R_{MKT,w}$ is the weekly return of the market portfolio, and $R_{IND,w}$ is the weekly return of firm $i$'s industry portfolio. We use the CRSP value-weighted returns and value-weighted returns of Fama and French's (1997) 30-industry portfolio as proxies for market and industry returns, respectively. $\beta_i^{IND}$ represents the industry beta of firm $i$. |

**Appendix C. Distribution of M&A attempts across years and industries**

The table presents the distribution of M&A attempts across years in Panel A and across industries in Panel B. The sample consists of the 1,865 M&A attempts in the United States announced between January 1, 1996 and June 30, 2015 obtained from the Thomson Financial SDC M&A database. We apply a series of data filters, which are described in detail in Appendix A. The primary requirement is that acquirer firms have exchange-traded equity options. The table reports the frequencies of M&A attempts and completed M&A deals. The industry classification in Panel B is based on Fama and French's (1997) 17 groupings.

Panel A: Distribution of acquisition attempts across years

| Year | Number of attempts | % of total | Number of completed attempts | % completed |
|---|---|---|---|---|
| 1996 | 120 | 6.4 | 111 | 92.5 |
| 1997 | 182 | 9.8 | 171 | 94.0 |
| 1998 | 187 | 10.0 | 173 | 92.5 |
| 1999 | 206 | 11.0 | 189 | 91.7 |
| 2000 | 136 | 7.3 | 123 | 90.4 |
| 2001 | 100 | 5.4 | 90 | 90.0 |
| 2002 | 68 | 3.6 | 62 | 91.2 |
| 2003 | 81 | 4.3 | 76 | 93.8 |
| 2004 | 86 | 4.6 | 80 | 93.0 |
| 2005 | 80 | 4.3 | 77 | 96.3 |
| 2006 | 90 | 4.8 | 88 | 97.8 |
| 2007 | 105 | 5.6 | 98 | 93.3 |
| 2008 | 62 | 3.3 | 45 | 72.6 |
| 2009 | 49 | 2.6 | 47 | 95.9 |
| 2010 | 58 | 3.1 | 52 | 89.7 |
| 2011 | 39 | 2.1 | 35 | 89.7 |
| 2012 | 67 | 3.6 | 64 | 95.5 |
| 2013 | 50 | 2.7 | 46 | 92.0 |
| 2014 | 66 | 3.5 | 62 | 93.9 |
| 2015 | 33 | 1.8 | 30 | 90.9 |
| Total | 1,865 | 100 | 1,719 | 92.2 |

Panel B: Distribution of acquisition attempts across industries

| Industry description | Number of attempts | % of total | Number of completed attempts | % completed |
|---|---|---|---|---|
| Food | 31 | 1.7 | 30 | 96.8 |
| Mining and Minerals | 11 | 0.6 | 10 | 90.9 |
| Oil and Petroleum Products | 81 | 4.3 | 76 | 93.8 |
| Textiles, Apparel, and Footwear | 14 | 0.8 | 12 | 85.7 |
| Consumer Durables | 23 | 1.2 | 20 | 87.0 |
| Chemicals | 26 | 1.4 | 23 | 88.5 |
| Drugs, Soap, Perfumes, and Tobacco | 91 | 4.9 | 86 | 94.5 |
| Construction and Construction Materials | 30 | 1.6 | 28 | 93.3 |
| Steel Works etc. | 17 | 0.9 | 15 | 88.2 |
| Fabricated Products | 6 | 0.3 | 6 | 100.0 |
| Machinery and Business Equipment | 288 | 15.4 | 264 | 91.7 |
| Automobiles | 10 | 0.5 | 9 | 90.0 |
| Transportation | 41 | 2.2 | 32 | 78.0 |
| Utilities | 72 | 3.9 | 64 | 88.9 |
| Retail Stores | 68 | 3.6 | 57 | 83.8 |
| Banks, Insurance Companies, and Other Financials | 429 | 23.0 | 411 | 95.8 |
| Other | 627 | 33.6 | 576 | 91.9 |

| | | | | |
|---|---|---|---|---|
| Total | 1,865 | 100 | 1,719 | 92.2 |

**Table 1. Descriptive statistics**

The table presents the descriptive statistics for a sample of the 1,865 US M&A attempts announced between January 1, 1996 and June 30, 2015 obtained from the Thomson Financial SDC M&A database. The table reports the means and medians of various firm and M&A attempt characteristics for the full sample as well as separately for completed and abandoned acquisition attempts. All the variables are defined in Appendix C. The last two columns report the differences in means and medians for each variable for completed and abandoned M&A attempts. *T*-tests and Wilcoxon tests are conducted for the differences in the means and medians, respectively. $^{***}$, $^{**}$, and $^{*}$ indicate significance at the 1%, 5%, and 10% levels, respectively.

| | Full (N=1,865) | | Completed (N=1,719) | | Abandoned (N=146) | | Difference | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Median | Mean | Median | Mean | Median | Mean | Median |
| ***Panel A: Acquirer and M&A attempt characteristics*** | | | | | | | | |
| Acquirer size (in $ millions) | 17,808 | 3,476 | 18,236 | 3,568 | 12,763 | 1,898 | 5,473 | 1,670$^{***}$ |
| Target size (in $ millions) | 1,369 | 274 | 1,262 | 266 | 2,630 | 391 | -1,369$^{***}$ | -126$^{***}$ |
| Transaction value (in $ millions) | 2,014 | 441 | 1,886 | 434 | 3,524 | 520 | -1,638$^{***}$ | -87$^{***}$ |
| Relative transaction value (%) | 34.7 | 14.5 | 32.8 | 13.3 | 57.3 | 36.6 | -24.6$^{***}$ | -23.3$^{***}$ |
| 41-day premium (%) | 46.1 | 36.0 | 47.0 | 36.4 | 35.4 | 29.7 | 11.6$^{**}$ | 6.7$^{***}$ |
| TNPR (%) | 67.2 | 75.7 | 67.9 | 76.3 | 58.2 | 66.2 | 9.7 | 10.1$^{**}$ |
| ***Panel B: Proportion of M&A attempts with the following features*** | | | | | | | | |
| Friendly dummy | 0.962 | | 0.990 | | 0.630 | | 0.360$^{***}$ | |
| Termination fee dummy | 0.213 | | 0.217 | | 0.164 | | 0.053 | |
| Tender offer dummy | 0.166 | | 0.169 | | 0.130 | | 0.039 | |
| Stock dummy | 0.008 | | 0.007 | | 0.021 | | -0.014$^{*}$ | |
| Lockup dummy | 0.130 | | 0.131 | | 0.110 | | 0.022 | |

**Table 2. M&A deal completion, option implied volatility, and announcement returns**

The table presents an acquirer's option implied volatility and announcement returns for a sample of the 1,865 US M&A attempts announced between January 1, 1996 and June 30, 2015 obtained from the Thomson Financial SDC M&A database. An acquirer's option implied volatility and CAR are measured over two event windows: the trading days [-1, +1] and [-1, +7] around the M&A announcement. Option implied volatility is calculated as the average of the option implied volatilities of all traded options during the event window. We calculate the abnormal returns using the market model. We estimate the beta of the market model using the daily returns of the firm and CRSP value-weighted market portfolio over the trading days [-250, -50] before the announcement. The table reports the means and medians of option implied volatility and CAR for the full sample as well as separately for completed and abandoned acquisition attempts. The last two columns report the differences in means and medians for each variable for completed and abandoned M&A attempts. *T*-tests and Wilcoxon tests are conducted for the differences in means and medians, respectively. $^{***}$, $^{**}$, and $^{*}$ indicate significance at the 1%, 5%, and 10% levels, respectively.

| | Completed (N=1,719) | | Abandoned (N=146) | | Difference | |
|---|---|---|---|---|---|---|
| | Mean | Median | Mean | Median | Mean | Median |
| Option implied volatility [-1, +1] | 0.436 | 0.385 | 0.516 | 0.444 | -0.080$^{***}$ | -0.059$^{***}$ |
| Option implied volatility [-1, +7] | 0.436 | 0.387 | 0.511 | 0.446 | -0.075$^{***}$ | -0.059$^{***}$ |
| | | | | | | |
| CAR [-1, +1] (%) | -1.4 | -0.8 | -2.7 | -1.5 | 1.3$^{**}$ | 0.7$^{*}$ |
| CAR [-1, +7] (%) | -1.3 | -0.8 | -3.9 | -3.2 | 2.6$^{***}$ | 2.5$^{***}$ |

**Table 3. Likelihood of M&A deal completion sorted by option implied volatility**

The table reports the proportion of completed M&A deals across quintiles based on option implied volatility. The sample consists of the 1,865 M&A attempts in the United States announced between January 1, 1996 and June 30, 2015. Panel A presents mean option implied volatility and the percentage of completed M&A deals for each quintile into which M&A attempts are grouped based on option implied volatility. Panel B presents the proportion of completed M&A deals across the option implied volatility quintiles controlling for the other M&A attempt characteristics. We first sort M&A attempts into quintiles based on one of the control characteristics (i.e., CAR, squared CAR, relative deal value, and acquirer firm size). Then, in each quintile, we group M&A attempts into quintiles based on option implied volatility. The implied volatility groups are then aggregated over each of the control characteristic quintiles. The last column reports the differences between the lowest (Q1) and highest (Q5) implied volatility groups. Option implied volatility and CAR are measured over the [-1, +7] window around an M&A announcement. Relative deal value is defined as the total value of payments that an acquirer firm proposes to pay for a target firm divided by the acquirer's firm size. $^{***}$, $^{**}$, and $^{*}$ indicate significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Univariate analysis

| | Quintiles sorted by option implied volatility | | | | | |
|---|---|---|---|---|---|---|
| | Q1 (Low) | Q2 | Q3 | Q4 | Q5 (High) | Q1-Q5 |
| Implied volatility | 0.234 | 0.315 | 0.391 | 0.492 | 0.778 | 0.545 |
| % completed M&A deals | 96.2 | 92.2 | 94.4 | 91.7 | 86.3 | 9.9$^{***}$ |

Panel B: Double-sorting analysis

| | Quintiles sorted by option implied volatility | | | | | |
|---|---|---|---|---|---|---|
| Controlled characteristics | Q1 (Low) | Q2 | Q3 | Q4 | Q5 (High) | Q1-Q5 |
| CAR | 95.7 | 91.7 | 94.4 | 90.4 | 88.7 | 7.0$^{***}$ |
| Squared CAR | 95.1 | 92.0 | 93.9 | 92.0 | 87.8 | 7.3$^{***}$ |
| Relative deal value | 94.9 | 92.8 | 93.3 | 93.1 | 86.8 | 8.1$^{***}$ |
| Acquirer firm size | 95.4 | 92.5 | 92.3 | 90.7 | 90.0 | 5.4$^{***}$ |

**Table 4. Probit analysis of M&A deal completion on option implied volatility**

The table presents the estimated coefficients from the probit regression of M&A deal completion. The sample consists of the 1,865 US M&A attempts announced between January 1, 1996 and June 30, 2015 obtained from the Thomson Financial SDC M&A database. The dependent variable is a dummy variable taking the value of one for completed M&A attempts and zero for abandoned attempts. Option implied volatility and CAR are measured over the [-1, +7] window around an M&A announcement. The variables are defined in Appendix C. All the regressions control for year and industry fixed effects. The industry classification is based on Fama and French's (1997) 17 groupings. The coefficients of the constant and the year and industry dummies are omitted for brevity. Z-statistics are reported in parentheses. $^{***}$, $^{**}$, and $^{*}$ indicate significance at the 1%, 5%, and 10% levels, respectively.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Option implied volatility | **-0.851$^{***}$** | | **-0.706$^{***}$** | **-0.726$^{**}$** |
| | **(-3.60)** | | **(-2.87)** | **(-2.43)** |
| CAR | | 1.384$^{***}$ | 1.022$^{**}$ | 0.927$^{*}$ |
| | | (3.18) | (2.31) | (1.91) |
| Relative deal value | | | | -0.233$^{***}$ |
| | | | | (-2.61) |
| Ln (acquirer size) | | | | 0.097$^{**}$ |
| | | | | (2.49) |
| 41-day premium | | | | 0.260$^{**}$ |
| | | | | (2.08) |
| TNPR | | | | 0.000 |
| | | | | (0.04) |
| Friendly dummy | | | | 2.540$^{***}$ |
| | | | | (12.66) |
| Termination fee dummy | | | | 0.206 |
| | | | | (1.52) |
| Tender offer dummy | | | | 0.401$^{**}$ |
| | | | | (2.33) |
| Stock dummy | | | | -0.272 |
| | | | | (-0.62) |
| Lockup dummy | | | | -0.203 |
| | | | | (-1.22) |
| Year fixed effect | Yes | Yes | Yes | Yes |
| Industry fixed effect | Yes | Yes | Yes | Yes |
| N | 1,859 | 1,859 | 1,859 | 1,852 |
| Psuedo-$R^2$ | 0.070 | 0.068 | 0.076 | 0.317 |

**Table 5. Instrumental variable approach**

This table presents the estimation results from the probit model with endogenous option implied volatility. The first column reports the coefficients and z-statistics of the first-stage regressions in which option implied volatility is the dependent variable. The second column reports the coefficients and z-statistics of the second-stage regressions in which the dependent variable is a dummy variable taking the value of one for completed M&A attempts and zero for abandoned attempts. The model is estimated using the maximum likelihood method. The ratio of ATM open interest is the ratio of ATM options' open interest to the total open interest of all options traded for an acquirer's stock over the 250 trading days before the M&A announcement. An option is defined as an ATM option when the strike price divided by the underlying stock price is between 0.95 and 1.05. All the other variables are defined in Appendix C. All the regressions control for year and industry fixed effects. The coefficients of the constant, year, and industry dummies are omitted for brevity. $^{***}$, $^{**}$, and $^{*}$ indicate significance at the 1%, 5%, and 10% levels, respectively.

| | First-stage Dep. Var = option implied volatility | Second-stage Dep. Var = completed |
|---|---|---|
| **Ratio of ATM open interest** | **-0.194$^{***}$** | |
| | **(-10.74)** | |
| **Instrumented option implied volatility** | | **-2.430$^{*}$** |
| | | **(-1.85)** |
| CAR | -0.339$^{***}$ | 0.279 |
| | (-9.41) | (0.40) |
| Relative deal value | 0.010 | -0.220$^{**}$ |
| | (1.28) | (-2.38) |
| Ln (acquirer size) | -0.045$^{***}$ | 0.028 |
| | (-19.58) | (0.42) |
| 41-day premium | 0.008 | 0.271$^{**}$ |
| | (1.32) | (2.22) |
| TNPR | -0.000 | 0.000 |
| | (-0.69) | (0.04) |
| Friendly dummy | 0.026 | 2.496$^{***}$ |
| | (1.44) | (11.36) |
| Termination fee dummy | 0.019$^{**}$ | 0.236$^{*}$ |
| | (2.09) | (1.78) |
| Tender offer dummy | -0.032$^{***}$ | 0.323$^{*}$ |
| | (-3.31) | (1.79) |
| Stock dummy | -0.029 | -0.285 |
| | (-0.75) | (-0.66) |
| Lockup dummy | 0.011 | -0.154 |
| | (0.95) | (-0.93) |
| Year fixed effect | Yes | Yes |
| Industry fixed effect | Yes | Yes |
| N | 1,849 | 1,849 |

**Table 6. Option implied volatility vs. other uncertainty proxies**

The table presents the estimated coefficients from the probit regression of M&A deal completion on various uncertainty proxies and control variables. The dependent variable is a dummy variable taking the value of one for completed M&A attempts and zero for abandoned attempts. Historical volatility is measured as the standard deviation of daily stock returns in the 250 trading days before the M&A announcement. Current option implied volatility and CAR are measured over the [-1, +7] window around the announcement. Past implied volatility is the average of the option implied volatilities over the trading days [-250, -50] before the announcement. The other variables are defined in Appendix C. All the regressions control for year and industry fixed effects. The industry classification is based on Fama and French's (1997) 17 groupings. The coefficients of the constant and the year and industry dummies are omitted for brevity. Z-statistics are reported in parentheses. $^{***}$, $^{**}$, and $^{*}$ indicate significance at the 1%, 5%, and 10% levels, respectively.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Historical volatility | **-0.585**$^{***}$ | | | | **0.288** | | | | **0.261** | | | |
| | **(-2.62)** | | | | **(0.69)** | | | | **(0.56)** | | | |
| Squared CAR | | **-2.300** | | | | **0.273** | | | | **1.975** | | |
| | | **(-1.45)** | | | | **(0.15)** | | | | **(0.93)** | | |
| Absolute CAR | | | **-1.310**$^{**}$ | | | | **-0.452** | | | | **0.258** | |
| | | | **(-2.26)** | | | | **(-0.69)** | | | | **(0.32)** | |
| Past implied volatility | | | | **-0.827**$^{***}$ | | | | **0.075** | | | | **0.130** |
| | | | | **(-3.13)** | | | | **(0.16)** | | | | **(0.24)** |
| Option implied volatility | | | | | **-1.102**$^{**}$ | **-0.868**$^{***}$ | **-0.769**$^{***}$ | **-1.006**$^{**}$ | **-0.945**$^{*}$ | **-0.830**$^{***}$ | **-0.761**$^{**}$ | **-0.903**$^{*}$ |
| | | | | | **(-2.56)** | **(-3.32)** | **(-2.90)** | **(-2.37)** | **(-1.93)** | **(-2.61)** | **(-2.40)** | **(-1.86)** |
| CAR | | | | | | | | | 0.946$^{*}$ | 1.148$^{**}$ | 0.997$^{*}$ | 0.914$^{*}$ |
| | | | | | | | | | (1.94) | (2.08) | (1.86) | (1.87) |
| Relative deal value | | | | | | | | | -0.227$^{**}$ | -0.239$^{***}$ | -0.237$^{***}$ | -0.239$^{***}$ |
| | | | | | | | | | (-2.52) | (-2.67) | (-2.63) | (-2.62) |
| Ln (acquirer size) | | | | | | | | | 0.100$^{**}$ | 0.097$^{**}$ | 0.097$^{**}$ | 0.100$^{**}$ |
| | | | | | | | | | (2.55) | (2.50) | (2.50) | (2.47) |
| 41-day premium | | | | | | | | | 0.260$^{**}$ | 0.257$^{**}$ | 0.260$^{**}$ | 0.268$^{**}$ |
| | | | | | | | | | (2.08) | (2.06) | (2.08) | (2.10) |
| TNPR | | | | | | | | | 0.000 | 0.000 | 0.000 | 0.000 |
| | | | | | | | | | (0.04) | (0.04) | (0.04) | (0.04) |
| Friendly dummy | | | | | | | | | 2.540$^{***}$ | 2.536$^{***}$ | 2.538$^{***}$ | 2.493$^{***}$ |
| | | | | | | | | | (12.65) | (12.63) | (12.64) | (12.28) |
| Termination fee dummy | | | | | | | | | 0.207 | 0.206 | 0.205 | 0.221 |
| | | | | | | | | | (1.52) | (1.52) | (1.51) | (1.62) |
| Tender offer dummy | | | | | | | | | 0.407$^{**}$ | 0.399$^{**}$ | 0.400$^{**}$ | 0.411$^{**}$ |
| | | | | | | | | | (2.36) | (2.32) | (2.32) | (2.35) |
| Stock dummy | | | | | | | | | -0.270 | -0.274 | -0.272 | -0.272 |
| | | | | | | | | | (-0.61) | (-0.62) | (-0.61) | (-0.61) |
| Lockup dummy | | | | | | | | | -0.211 | -0.206 | -0.205 | -0.197 |
| | | | | | | | | | (-1.27) | (-1.24) | (-1.23) | (-1.18) |
| Year fixed effect | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Industry fixed effect | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 1,859 | 1,859 | 1,859 | 1,808 | 1,859 | 1,859 | 1,859 | 1,808 | 1,852 | 1,852 | 1,852 | 1,801 |
| Psuedo-$R^2$ | 0.064 | 0.060 | 0.063 | 0.068 | 0.071 | 0.070 | 0.071 | 0.074 | 0.317 | 0.318 | 0.317 | 0.313 |

**Table 7. Option implied volatility vs. directional information**

The table presents the estimated coefficients from the probit regression of M&A deal completion on the option volatility spread or skew, option implied volatility, and the other control variables. The dependent variable is a dummy variable taking the value of one for completed M&A attempts and zero for abandoned attempts. The option volatility spread is the difference in implied volatility between a pair of call and put options. The option volatility skew is the difference in implied volatility between an OTM put option and an ATM call option. All option variables and CAR are measured over the [-1, +7] window around the M&A announcement. The variables are defined in Appendix C. All the regressions control for year and industry fixed effects. The industry classification is based on Fama and French's (1997) 17 groupings. The coefficients of the constant and the year and industry dummies are omitted for brevity. Z-statistics are reported in parentheses. $^{***}$, $^{**}$, and $^{*}$ indicate significance at the 1%, 5%, and 10% levels, respectively.

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Option volatility spread | **0.026** | | **-0.215** | | **-0.424** | |
| | **(0.02)** | | **(-0.18)** | | **(-0.32)** | |
| Option volatility skew | | **0.396** | | **0.571** | | **1.075** |
| | | **(0.36)** | | **(0.53)** | | **(0.82)** |
| Option implied volatility | | | **-0.923$^{***}$** | **-1.127$^{***}$** | **-1.122$^{**}$** | **-1.593$^{**}$** |
| | | | **(-3.69)** | **(-3.75)** | **(-2.08)** | **(-2.48)** |
| CAR | | | | | 1.072$^{**}$ | 1.167$^{*}$ |
| | | | | | (2.11) | (1.95) |
| Historical volatility | | | | | 0.479 | 0.739 |
| | | | | | (0.92) | (1.18) |
| Relative deal value | | | | | -0.253$^{***}$ | -0.293$^{**}$ |
| | | | | | (-2.64) | (-2.14) |
| Ln (acquirer size) | | | | | 0.131$^{***}$ | 0.117$^{**}$ |
| | | | | | (3.09) | (2.26) |
| 41-day premium | | | | | 0.243$^{*}$ | 0.264$^{*}$ |
| | | | | | (1.86) | (1.69) |
| TNPR | | | | | 0.000 | 0.000 |
| | | | | | (0.04) | (0.05) |
| Friendly dummy | | | | | 2.531$^{***}$ | 2.653$^{***}$ |
| | | | | | (11.78) | (10.60) |
| Termination fee dummy | | | | | 0.248$^{*}$ | 0.102 |
| | | | | | (1.75) | (0.61) |
| Tender offer dummy | | | | | 0.343$^{*}$ | 0.178 |
| | | | | | (1.95) | (0.93) |
| Stock dummy | | | | | -0.226 | -0.140 |
| | | | | | (-0.50) | (-0.24) |
| Lockup dummy | | | | | -0.204 | -0.336$^{*}$ |
| | | | | | (-1.18) | (-1.68) |
| Year fixed effect | Yes | Yes | Yes | Yes | Yes | Yes |
| Industry fixed effect | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 1,688 | 1,266 | 1,688 | 1,266 | 1,683 | 1,261 |
| Psuedo-$R^2$ | 0.053 | 0.063 | 0.067 | 0.084 | 0.313 | 0.349 |

**Table 8. Economic channels: Investment irreversibility channel**

The table presents the estimated coefficients and z-statistics from the probit regression of M&A deal completion, which is run separately for firms with different levels of investment irreversibility. The dependent variable is a dummy variable taking the value of one for completed M&A attempts and zero for abandoned attempts. In each panel, we sort M&A attempts into two groups (Low, High) based on the sample median of several proxies for investment irreversibility: *capital depreciation* is measured as the ratio of depreciation expenses to total assets; *capital sales* is measured as the ratio of sales of property, plant, and equipment to the total asset value; and *firm industry beta* is the firm's return sensitivity to its corresponding industry portfolio. All the other variables are defined in Appendix C. $^{***}$, $^{**}$, and $^{*}$ indicate significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Capital depreciation

| | Low capital depreciation | High capital depreciation |
|---|---|---|
| **Option implied volatility** | **-0.521** | **-1.331$^{***}$** |
| | **(-1.09)** | **(-2.89)** |
| CAR | 0.888 | 1.454$^{**}$ |
| | (1.12) | (2.02) |
| Relative deal value | -0.417$^{***}$ | -0.058 |
| | (-3.02) | (-0.41) |
| Ln (acquirer size) | 0.034 | 0.130$^{**}$ |
| | (0.54) | (2.34) |
| 41-day premium | 0.538$^{**}$ | 0.146 |
| | (2.46) | (0.89) |
| TNPR | -0.010 | 0.000 |
| | (-0.34) | (0.06) |
| Friendly dummy | 2.940$^{***}$ | 2.315$^{***}$ |
| | (8.11) | (8.46) |
| Termination fee dummy | 0.143 | 0.335$^{*}$ |
| | (0.65) | (1.69) |
| Tender offer dummy | 0.093 | 0.368$^{*}$ |
| | (0.31) | (1.66) |
| Stock dummy | | -0.492 |
| | | (-1.00) |
| Lockup dummy | -0.099 | -0.395 |
| | (-0.43) | (-1.45) |
| N | 753 | 826 |
| Psuedo-$R^2$ | 0.350 | 0.346 |

**Table 8. Economic channels: Investment irreversibility channel – continued**

Panel B: Capital sales

| | Low capital sales | High capital sales |
|---|---|---|
| **Option implied volatility** | **-0.776**$^{**}$ | **0.011** |
| | **(-2.16)** | **(0.01)** |
| CAR | 0.816 | 2.237$^{*}$ |
| | (1.41) | (1.84) |
| Relative deal value | -0.213$^{**}$ | -0.199 |
| | (-2.03) | (-0.85) |
| Ln (acquirer size) | 0.089$^{*}$ | 0.200$^{**}$ |
| | (1.83) | (2.20) |
| 41-day premium | 0.352$^{**}$ | 0.161 |
| | (2.23) | (0.59) |
| TNPR | 0.000 | -0.017 |
| | (0.04) | (-0.42) |
| Friendly dummy | 2.997$^{***}$ | 3.104$^{***}$ |
| | (9.62) | (6.61) |
| Termination fee dummy | 0.240 | 0.173 |
| | (1.44) | (0.55) |
| Tender offer dummy | 0.206 | 2.266$^{***}$ |
| | (1.00) | (3.34) |
| Stock dummy | -0.752 | |
| | (-1.50) | |
| Lockup dummy | -0.162 | -0.567 |
| | (-0.82) | (-1.51) |
| N | 1224 | 519 |
| Psuedo-$R^2$ | 0.320 | 0.465 |

**Table 8. Economic channels: Investment irreversibility channel – continued**

Panel C: Firm industry betas

| | Low industry beta | High industry beta |
|---|---|---|
| **Option implied volatility** | **-0.610** | **-1.402**$^{**}$ |
| | **(-1.18)** | **(-2.42)** |
| CAR | 1.288 | 0.902 |
| | (1.54) | (1.09) |
| Relative deal value | -0.335$^{**}$ | -0.317$^{**}$ |
| | (-2.33) | (-2.07) |
| Ln (acquirer size) | 0.147$^{**}$ | 0.076 |
| | (2.20) | (1.20) |
| 41-day premium | 0.076 | 0.234 |
| | (0.42) | (1.19) |
| TNPR | 0.005 | -0.014 |
| | (0.30) | (-0.27) |
| Friendly dummy | 2.824$^{***}$ | 2.851$^{***}$ |
| | (9.59) | (7.28) |
| Termination fee dummy | 0.331 | 0.261 |
| | (1.61) | (1.08) |
| Tender offer dummy | 0.355 | 0.613$^{*}$ |
| | (1.36) | (1.92) |
| Stock dummy | 0.307 | -1.648$^{*}$ |
| | (0.51) | (-1.70) |
| Lockup dummy | -0.270 | -0.243 |
| | (-1.06) | (-0.91) |
| N | 865 | 842 |
| Psuedo-$R^2$ | 0.398 | 0.371 |

**Table 9. Economic channels: Risk attitude channel**

The table presents the estimated coefficients and z-statistics from the probit regression of M&A deal completion, which is run separately for firms with different levels of managerial incentives. The dependent variable is a dummy variable taking the value of one for completed M&A attempts and zero for abandoned attempts. We sort M&A attempts into two equal-sized groups (Low, High) based on ownership by insiders in Panel A and the sensitivity of executive compensation to volatility, vega, in Panel B. In Panel C, we first sort M&A attempts into two equal-sized groups based on insider ownership and then into two groups based on the executive compensation vegas in each insider ownership group. In Panel D, we first sort M&A attempts into two equal-sized groups based on insider ownership and then into two groups based on the institutional ownership in each insider ownership group. All the variables are defined in Appendix C. $^{***}$, $^{**}$, and $^{*}$ indicate significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Effect of insider ownership

| | Low insider ownership | High insider ownership |
|---|---|---|
| **Option implied volatility** | **-0.623** | **-0.875$^{**}$** |
| | **(-1.30)** | **(-2.30)** |
| CAR | -0.000 | 1.843$^{**}$ |
| | (-0.00) | (2.20) |
| Relative deal value | -0.236 | -0.271$^{**}$ |
| | (-1.02) | (-2.18) |
| Ln (acquirer size) | 0.072 | 0.146$^{**}$ |
| | (1.15) | (2.09) |
| 41-day premium | 0.153 | 0.152 |
| | (0.68) | (0.83) |
| TNPR | -0.005 | 0.011 |
| | (-0.28) | (0.60) |
| Friendly dummy | 2.447$^{***}$ | 2.624$^{***}$ |
| | (7.17) | (8.08) |
| Termination fee dummy | -0.102 | 0.182 |
| | (-0.43) | (0.82) |
| Tender offer dummy | 0.165 | 0.327 |
| | (0.64) | (1.12) |
| Stock dummy | -1.558$^{**}$ | |
| | (-2.56) | |
| Lockup dummy | 0.318 | -0.279 |
| | (0.78) | (-1.22) |
| N | 634 | 627 |
| Psuedo-$R^2$ | 0.286 | 0.319 |

**Table 9. Economic channels: Risk attitude channel – continued**

Panel B: Effect of executive compensation vegas

| | Low compensation vega | High compensation vega |
|---|---|---|
| **Option implied volatility** | **-1.085**$^{**}$ | **-0.304** |
| | **(-2.57)** | **(-0.54)** |
| CAR | 0.314 | 2.418$^{*}$ |
| | (0.39) | (1.87) |
| Relative deal value | -0.204 | -0.250 |
| | (-1.44) | (-1.37) |
| Ln (acquirer size) | 0.135$^{*}$ | 0.064 |
| | (1.67) | (0.87) |
| 41-day premium | 0.205 | 0.291 |
| | (1.03) | (1.12) |
| TNPR | 0.000 | 0.051 |
| | (0.03) | (1.23) |
| Friendly dummy | 2.483$^{***}$ | 2.383$^{***}$ |
| | (8.14) | (8.23) |
| Termination fee dummy | 0.680$^{**}$ | -0.111 |
| | (2.45) | (-0.46) |
| Tender offer dummy | 0.546$^{*}$ | 0.136 |
| | (1.85) | (0.53) |
| Stock dummy | -0.751 | |
| | (-1.59) | |
| Lockup dummy | 0.063 | -0.508$^{*}$ |
| | (0.26) | (-1.95) |
| N | 710 | 708 |
| Psuedo-$R^2$ | 0.324 | 0.346 |

**Table 9. Economic channels: Risk attitude channel – continued**

Panel C: Effect of executive compensation vegas by level of insider ownership

| | Low insider ownership | | High insider ownership | |
|---|---|---|---|---|
| | Low vega | High vega | Low vega | High vega |
| **Option implied volatility** | **0.247** | **1.400** | **-1.607**$^{**}$ | **-0.768** |
| | **(0.28)** | **(0.80)** | **(-2.09)** | **(-0.83)** |
| CAR | -0.926 | 0.401 | 1.751 | 2.645 |
| | (-0.61) | (0.12) | (1.17) | (1.44) |
| Relative deal value | -0.609 | 1.048 | -0.109 | -0.816$^{**}$ |
| | (-1.59) | (1.53) | (-0.55) | (-2.40) |
| Ln (acquirer size) | 0.305$^{**}$ | 0.159 | 0.140 | 0.134 |
| | (2.05) | (1.02) | (0.85) | (0.88) |
| 41-day premium | 0.165 | 0.150 | 0.424 | -0.077 |
| | (0.40) | (0.26) | (1.12) | (-0.22) |
| TNPR | -0.122 | 0.287$^{**}$ | -0.038 | 0.017 |
| | (-1.06) | (2.32) | (-0.44) | (0.50) |
| Friendly dummy | 2.994$^{***}$ | 3.115$^{***}$ | 3.126$^{***}$ | 2.376$^{***}$ |
| | (4.75) | (4.40) | (4.78) | (4.98) |
| Termination fee dummy | 0.614 | -0.946$^{*}$ | 0.532 | 0.377 |
| | (1.39) | (-1.95) | (1.04) | (0.84) |
| Tender offer dummy | 0.410 | 0.678 | 1.622$^{*}$ | -0.215 |
| | (1.01) | (0.92) | (1.69) | (-0.54) |
| Stock dummy | -1.969$^{***}$ | | | |
| | (-2.76) | | | |
| Lockup dummy | | -0.915 | -0.230 | -0.279 |
| | | (-1.52) | (-0.60) | (-0.58) |
| N | 231 | 265 | 260 | 264 |
| Psuedo-$R^2$ | 0.423 | 0.383 | 0.402 | 0.411 |

**Table 9. Economic channels: Risk attitude channel – continued**

Panel D: Effect of insider ownership by level of institutional ownership

| | Low insider ownership | | High insider ownership | |
|---|---|---|---|---|
| | Low institutional ownership | High institutional ownership | Low institutional ownership | High institutional ownership |
| **Option implied volatility** | **-0.048** | **-1.014** | **-1.885*****| **-0.825** |
| | **(-0.06)** | **(-1.36)** | **(-3.19)** | **(-1.16)** |
| CAR | -1.147 | 1.180 | 1.448 | 1.301 |
| | (-0.67) | (0.79) | (1.15) | (0.99) |
| Relative deal value | -0.116 | -0.244 | -0.773** | -0.433** |
| | (-0.29) | (-0.58) | (-2.25) | (-2.10) |
| Ln (acquirer size) | 0.030 | 0.202* | 0.094 | 0.184 |
| | (0.35) | (1.67) | (0.90) | (1.53) |
| 41-day premium | 0.933** | 0.029 | 0.167 | 0.265 |
| | (1.99) | (0.25) | (0.49) | (1.01) |
| TNPR | 0.049 | -0.031 | 0.083 | 0.008 |
| | (0.79) | (-0.55) | (1.28) | (0.44) |
| Friendly dummy | 2.002*** | | 2.939*** | 2.495*** |
| | (3.95) | | (5.58) | (5.34) |
| Termination fee dummy | -0.160 | 0.243 | 1.279** | 0.032 |
| | (-0.38) | (0.62) | (2.09) | (0.11) |
| Tender offer dummy | 0.294 | 0.209 | -0.216 | 0.633 |
| | (0.61) | (0.51) | (-0.48) | (1.42) |
| Stock dummy | | -1.791** | | |
| | | (-2.48) | | |
| Lockup dummy | -0.040 | | -0.587* | -0.203 |
| | (-0.08) | | (-1.79) | (-0.48) |
| N | 300 | 264 | 301 | 294 |
| Psuedo-$R^2$ | 0.210 | 0.170 | 0.430 | 0.323 |

**Table 10. Economic channels: Market informativeness channel**

The table presents the estimation results from the probit regression of M&A deal completion after splitting M&A attempts into two equal-sized groups (Low, High) based on the levels of option volume, open interest, and bid/ask spread in Panels A, B, and C, respectively. In all the panels, the dependent variable is a dummy variable taking the value of one for completed M&A attempts and zero for abandoned attempts. We measure the option liquidity variables by aggregating over all traded options each day and then averaging over the trading days [-250, -1]. All the regressions control for year and industry fixed effects. The industry classification is based on Fama and French's (1997) 17 groupings. The coefficients of the constant and the year and industry dummies are omitted for brevity. All the variables are defined in Appendix B. Z-statistics are reported in parentheses. $^{***}$, $^{**}$, and $^{*}$ indicate significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Effect of option volume

| | Low option volume | High option volume |
|---|---|---|
| **Option implied volatility** | **-0.020** | **-1.497$^{***}$** |
| | **(-0.04)** | **(-3.25)** |
| CAR | 0.664 | 1.025 |
| | (0.75) | (1.60) |
| Relative deal value | -0.301$^{**}$ | -0.282$^{**}$ |
| | (-2.05) | (-2.16) |
| Ln (acquirer size) | 0.132$^{*}$ | 0.068 |
| | (1.87) | (1.19) |
| 41-day premium | 0.591$^{**}$ | 0.061 |
| | (2.34) | (0.41) |
| TNPR | -0.002 | 0.000 |
| | (-0.07) | (0.04) |
| Friendly dummy | 3.666$^{***}$ | 2.134$^{***}$ |
| | (7.70) | (7.71) |
| Termination fee dummy | 0.180 | 0.339$^{*}$ |
| | (0.87) | (1.69) |
| Tender offer dummy | 0.984$^{**}$ | 0.189 |
| | (2.48) | (0.87) |
| Stock dummy | | -0.874$^{*}$ |
| | | (-1.71) |
| Lockup dummy | -0.240 | -0.211 |
| | (-1.01) | (-0.85) |
| Year fixed effect | Yes | Yes |
| Industry fixed effect | Yes | Yes |
| N | 874 | 892 |
| Psuedo-$R^2$ | 0.383 | 0.326 |

**Table 10. Economic channels: Market informativeness channel – continued**

Panel B: Effect of option open interest

| | Low option open interest | High option open interest |
|---|---|---|
| **Option implied volatility** | **-0.297** | **-1.090**$^{**}$ |
| | **(-0.63)** | **(-2.24)** |
| CAR | 1.097 | 0.985 |
| | (1.49) | (1.34) |
| Relative deal value | -0.201 | -0.284$^{**}$ |
| | (-1.58) | (-2.04) |
| Ln (acquirer size) | 0.189$^{**}$ | 0.096 |
| | (2.24) | (1.45) |
| 41-day premium | 0.389$^{**}$ | 0.221 |
| | (1.98) | (1.20) |
| TNPR | 0.000 | 0.006 |
| | (0.03) | (0.36) |
| Friendly dummy | 3.129$^{***}$ | 2.330$^{***}$ |
| | (8.76) | (8.03) |
| Termination fee dummy | 0.300 | 0.161 |
| | (1.52) | (0.76) |
| Tender offer dummy | 1.190$^{***}$ | 0.121 |
| | (2.81) | (0.55) |
| Stock dummy | -1.239$^{*}$ | -0.255 |
| | (-1.90) | (-0.41) |
| Lockup dummy | -0.079 | -0.463$^{*}$ |
| | (-0.35) | (-1.76) |
| Year fixed effect | Yes | Yes |
| Industry fixed effect | Yes | Yes |
| N | 894 | 897 |
| Psuedo-$R^2$ | 0.360 | 0.339 |

**Table 10. Economic channels: Market informativeness channel – continued**

Panel C: Effect of the option bid/ask spread

| | Low option bid/ask spread | High option bid/ask spread |
|---|---|---|
| **Option implied volatility** | **-0.927**$^{**}$ | **-0.364** |
| | **(-2.16)** | **(-0.69)** |
| CAR | 1.143 | 0.804 |
| | (1.62) | (1.05) |
| Relative deal value | -0.288$^{*}$ | -0.230$^{*}$ |
| | (-1.85) | (-1.88) |
| Ln (acquirer size) | 0.075 | 0.135$^{*}$ |
| | (1.20) | (1.85) |
| 41-day premium | 0.213 | 0.514$^{**}$ |
| | (1.20) | (2.22) |
| TNPR | 0.000 | 0.000 |
| | (0.03) | (0.02) |
| Friendly dummy | 2.491$^{***}$ | 3.075$^{***}$ |
| | (7.24) | (9.31) |
| Termination fee dummy | 0.173 | 0.217 |
| | (0.80) | (1.15) |
| Tender offer dummy | 0.115 | 1.023$^{***}$ |
| | (0.50) | (2.87) |
| Stock dummy | -0.599 | -0.500 |
| | (-0.91) | (-0.75) |
| Lockup dummy | -0.317 | -0.064 |
| | (-1.39) | (-0.24) |
| Year fixed effect | Yes | Yes |
| Industry fixed effect | Yes | Yes |
| N | 839 | 900 |
| Psuedo-$R^2$ | 0.299 | 0.380 |

**Table 11. Option implied volatility and investment**

The table presents the estimated coefficients and t-statistics from the following regression of the investment rate:

$$I_{i,t}/K_{i,t-1} = \alpha + \beta log(\sigma_{i,t-1}) + \gamma Z_{i,t-1} + \delta F_i + \lambda T_t + \varepsilon_{i,t},$$

where $I_{i,t}$ is the capital expenditure of firm $i$ in year $t$ and $K_{i,t-1}$ is the book value of the asset. Option implied volatility, $\sigma_{i,t}^{option\ implied}$, is computed as the average of the implied volatilities of all the options traded on firm $i$'s stock in year $t$. The stock market's idiosyncratic volatility, $\sigma_{i,t}^{idiosyncratic}$, is computed as the standard deviation of residuals from the regression in which weekly stock returns are regressed on the returns of the CRSP value-weighted index and corresponding Fama and French's (1997) 30-industry portfolio. The stock market's systematic volatility, $\sigma_{i,t}^{systematic}$, is defined as the square root of the difference between the total variance of firm $i$'s stock returns and its idiosyncratic variance. Tobin's Q, $Q_t$, is defined as the ratio of the market value of total assets to their book value. The operating cash flow ratios, $CF_t/K_{t-1}$, is measured as the ratio of operating income to book assets. $R_t$ is firm $i$'s stock return in year $t$. Leverage, $E_t/A_t$, is defined as the ratio of book equity to book assets. The sample consists of all public firms common to the CRSP/Compustat merged database and OptionMetrics database from January 1996 to June 2015. We exclude firms in the financial and utilities industries. *t*-statistics are reported in parentheses. $^{***}$, $^{**}$, and $^{*}$ indicate significance at the 1%, 5%, and 10% levels, respectively.

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| $\mathbf{log(\sigma_{t-1}^{option\ implied})}$ | **-0.0045**$^{***}$ | **-0.0076**$^{***}$ | | | **-0.0188**$^{***}$ | **-0.0073**$^{***}$ |
| | **(-3.81)** | **(-4.10)** | | | **(-9.91)** | **(-3.29)** |
| $\mathbf{log(\sigma_{t-1}^{idiosyncratic})}$ | | | **0.0025**$^{***}$ | **-0.0029**$^{**}$ | **0.0132**$^{***}$ | **-0.0004** |
| | | | **(2.95)** | **(-2.46)** | **(9.61)** | **(-0.26)** |
| $\log(\sigma_{t-1}^{systematic})$ | | 0.0020$^{**}$ | | 0.0011 | | 0.0020$^{**}$ |
| | | (2.21) | | (1.23) | | (2.22) |
| $\log(Q_{t-1})$ | | 0.0359$^{***}$ | | 0.0359$^{***}$ | | 0.0359$^{***}$ |
| | | (33.82) | | (33.75) | | (33.71) |
| $CF_{t-1}/K_{t-2}$ | | 0.0362$^{***}$ | | 0.0367$^{***}$ | | 0.0362$^{***}$ |
| | | (9.61) | | (9.72) | | (9.59) |
| $\log(K_{t-1})$ | | -0.0168$^{***}$ | | -0.0165$^{***}$ | | -0.0168$^{***}$ |
| | | (-22.63) | | (-22.34) | | (-22.58) |
| $R_{t-1}$ | | 0.0015$^{***}$ | | 0.0016$^{***}$ | | 0.0015$^{***}$ |
| | | (3.10) | | (3.24) | | (3.11) |
| $\log(E_{t-1}/A_{t-1})$ | | 0.0141$^{***}$ | | 0.0143$^{***}$ | | 0.0141$^{***}$ |
| | | (12.57) | | (12.68) | | (12.51) |
| *N* | 35,858 | 35,828 | 35,858 | 35,828 | 35,858 | 35,828 |
| $R^2$ | 0.675 | 0.725 | 0.675 | 0.725 | 0.676 | 0.725 |
| Firm fixed effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Time fixed effects | No | Yes | No | Yes | No | Yes |