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May 6, 2009

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The market implied volatilities for target stocks during the period between an acquisition announcement and the transaction resolution were examined for differences between samples of successful and failed transactions. By constructing volatility ratios for all cash and pure stock swap transactions, I find that market implied volatilities for successful and failed transactions diverge over time for cash bids but not stock bids.

Introduction:

Risk arbitrage, also known as merger arbitrage, is part of a broader category of investment strategies aimed at generating returns from event risk as opposed to market risk. Made famous by Ivan Boesky, the 1980s king of the arbitrageurs, and his large team of traders, lawyers, and informants, this traditional strategy is still pursued by hundreds of hedge funds, attempting to make bets on the success or failure of an announced transaction (Russell, 1986). In risk arbitrage situations, investors, primarily hedge funds and institutions, attempt to profit from the spread between the anticipated purchase price and current trading price of the target company in an acquisition or merger scenario. In cash bids, the arbitrageur will try to profit by owning the stock of the target firm, which generally trades lower than the agreed upon acquisition price in the absence of competing bids. In stock swaps, the arbitrageur will generally buy stock in the target firm and short stock in the acquiring firm in a ratio corresponding to the exchange ratio enumerated in the merger agreement. At the completion of the transaction, the arbitrageur receives shares in the acquirer firm which is then used to settle the short side of the trade. The returns from risk arbitrage, however, are often asymmetrical. Empirically, small gains are realized from completed mergers but large losses accumulate from withdrawn transactions because the target firm’s stock price returns to a level which no longer incorporates the control premium inherent in the bid price (Branch & Yang, 2006). In this paper, I aim to examine the differences in options implied volatilities between successful (completed) and failed (withdrawn) takeover attempts and utilize these implied volatilities to understand how markets reflect potential success or failure. Results surrounding these implied volatilities may be useful in predicting the outcome of transactions for risk arbitrageurs.

Option Mechanics in Merger Situations:

Before discussing the previous literature, it is useful to explore the effect of successful merger transactions on the legal delivery obligations of target firm options contracts as set by the Options Clearing Corporation. At the close of an all cash transaction, the rules stipulate that the options contract will be cash settled in the amount of the acquisition share price times the number of shares in the contract, usually 100 (Options Clearing Corporation, 2009). As of January 2, 2008, the Options Cleaning Corporation made exercising the target company's options in an all cash transaction at the date of deal closure mandatory. Because it would have been ideal to exercise early on the date of closure rather than wait until expiration, this new rule is merely procedural and has no material effect on the economics of the contract. For all stock transactions, option contracts expiring after the close of the transaction are adjusted by the transaction exchange ratio to deliver the acquirer firm's stock in lieu of the target firm's stock. Fractional shares are cash settled (Options Clearing Corporation, 2009). In a mixed transaction, the cash settlement and stock conversion portions are prorated according to the merger agreement. In some cases, the target company shareholders are given the choice of cash or stock, up to a fixed proportion determined by the acquiring company. In these cases, the options holder receives a proration based on the non-electing shareholders' consideration[1] (Options Clearing Corporation, 2009).

In order to reduce the complexity involving different forms of transactions and their effects on options settlement, I choose here to focus on two types of transactions, the all cash and the all stock transaction.

[1] This scenario occurs when shareholders are given the choice between receiving all cash or all stock in a mixed consideration transaction and the company has set a fixed percentage to be distributed in cash and stock. Non-electing shareholders are shareholders who do not specify their preference. Those who specify their preferences are given priority, and non-electing shareholders receive a proration of the remaining consideration such that the company achieves its previously determined cash and stock payout percentages.

Previous Literature:

With the rise in popularity of merger arbitrage in the 1980s, academics began to analyze the information contained in stock and options markets during merger situations. However, the majority of the options research has focused on the time period surrounding the initial bid announcement, particularly with regards to informed trading, rumors, and information leakage. Jayaraman, Frye, and Sabherwal (2001) conclude that call and put option volume and open interest increase prior to transaction announcements, which is followed by unusual activity in the equity markets. Cao, Chen, and Griffin (2005) find that before a bid announcement there is an increase in call option volume imbalances, i.e. purchases initiated by call buyers. They also find a strong correlation between the imbalance in call volume and the bid premium. Comparing these results to the equity markets, they conclude that the options market provides a better signaling mechanism in takeover scenarios. Levy and Yoder (1993) and Jayaraman, Mandelker, and Shastri (1991) conclude that target firm implied volatilities increase significantly in advance of a transaction announcement and decline after that announcement.

Analyses around the bid period, the interval between the transaction announcement and resolution, have generally been more limited in scope. Studying equity prices, Brown and Raymond (1986) utilize expectation calculations to determine the market implied probability of success or failure, showing that the market differentiates between successful and failed transactions. Hutson (2000) expands on this work by looking at standardized prices[2] as opposed to probabilities and finds that Australian stock prices do not fully converge to the offer price due to lower liquidity and stale last trade prices. Hutson and Kearney (2001) show declines in bid period conditional and unconditional volatility of target companies' stock prices. They find that post-bid betas are much lower than pre-bid betas for cash transactions and that unconditional and conditional price volatility declines most drastically for cash bids and less so for stock

[2] Standardized share price on day d of the bid period, denoted x_d, is defined as $x_d = (P_d - P_I)/(P_T - P_I)$, where P_d is the actual stock price on day d, P_T is the bid price, and P_I is the price 1 month prior to the bid announcement.

swap offers. Price volatility declines are also statistically significant for successful bids and insignificant for unsuccessful bids.

Turning to the options market, Barone-Adesi, Brown, and Harlow (1994) conclude that options implied volatilities in all cash transactions reflect information regarding the outcome of the transaction. Using call options at the same strike and different maturities, they show that implied volatilities of options expiring after the proposed transaction completion date are lower than implied volatilities of options expiring before the proposed date reflecting the accelerated maturity of the long dated option upon deal closure. They also see in their data that this effect is much more pronounced in successful offers versus failed offers. Subramanian (2004) develops an arbitrage-free model for pricing options of target firms in stock swap transactions by incorporating jump diffusions for the possibility of transaction withdrawals. Subramanian also empirically confirms the assumption that the price volatilities of target and acquirer stocks converge for stock swaps, and further develops a measure of success probability based on his model. Hutson and Kearney (2005) similarly find significant interaction between target and acquirer stock prices in stock swap transactions.

Hypothesis Development:

While Barone-Adesi, Brown, and Harlow (1994) focus on acceleration of options maturities and their effects on implied volatilities for all cash transactions, I analyze implied volatility from a different perspective. Hutson and Kearney (2001) show that unconditional price volatilities decline for target companies during the bid period. Hutson and Kearney (2001) attribute the price volatility declines to a converging of market expectations or as they put it: “the reduction in price volatility can be explained by a reduction in the dispersion of traders’ beliefs regarding value, as it becomes apparent that the takeover will succeed.” I predict that this ex-post analysis of declines in price volatility should be manifested in forward indicators as well. Thus implied volatilities, a market driven indicator of future volatility, should decrease. These implied volatilities should also reflect the probability of bid success or failure as perceived by the market.

To test this outcome on all cash transactions, I utilize a normalized volatility ratio for the target company, $\frac{\sigma_T}{\sigma_F}$ where σ_T is the implied volatility of the target's option at a point in time during the bid period and σ_F is the implied volatility of a target's option in the absence of the transaction, denoted as the fallback volatility. Thus the expectation for successful cash transactions is that implied volatilities should converge to zero, meaning $\frac{\sigma_T}{\sigma_F} \rightarrow 0$. For failed cash transactions, the target's implied volatility should revert back to σ_F as the normal price determining processes return and dispersion in traders' beliefs about the outcomes again manifest themselves in the options price. Thus $\frac{\sigma_T}{\sigma_F} \rightarrow 1$ for failed transactions.

For pure stock-swap transactions, a different outcome should be expected. Subramanian (2004)'s conclusion that the price volatilities of the target and acquirer show high correlation and Hutson and Kearney (2005)'s conclusion that there is significant interaction in target and bidder stock prices during the bid period for all stock transactions confirm that the price formation process changes in stock-swap transactions. If correlations in stock prices are high and options of the target firm are merely converted to options on the acquirer's stock in completed transactions, similar trends should manifest themselves in the implied volatilities of the two companies' options. Thus, σ_T should converge to σ_A, the implied volatility of the acquirer's stock, for a successful transaction, and σ_T should converge to σ_F for a failed transaction. Here, I test a few ratio constructions. First, I expect to see $\frac{\sigma_T}{\sigma_A} \rightarrow 1$ for successful transactions and $\frac{\sigma_T}{\sigma_A} \neq 1$ for failed transactions. Second, to magnify the effect of the differences between target and acquirer implied volatilities, I construct the ratio $\frac{|\sigma_T - \sigma_A|}{\sigma_A}$ which also has the benefit of being directionally indifferent to the target implied volatility being higher or lower than the acquirer implied volatility. I expect this ratio to trend to zero for successful transactions and some number different from zero for failed transactions.

Data:

Transactions data was collected from Thomson ONE Banker Deal Module, including announcement date, completion date, withdrawal date, and terms of the merger. Deals had to have been announced between January 1, 2003 and August 1, 2008 and resolved (either completed or withdrawn) by August 1, 2008. Eligible transactions were limited to only those in which the targets were publicly listed companies in the U.S with over $100MM in equity value and where all of the outstanding common equity was acquired. Complex transaction structures like collars and multiple tiered purchase agreements were excluded as well. Multiple bids and private equity involvement were coded into the data, and multiple bid transactions were consolidated into one entry, using the date of the first bid announcement as the start date for the transaction. All other information was retained based on the values for the final successful or failed bid.

The best bid and ask prices on close for options and final trade price for stocks were collected from OptionsMetrics. Implied volatilities were taken from OptionsMetrics, which utilizes a proprietary modification of the Cox-Ross-Rubenstein binomial tree model to account for discrete dividends. These implied volatilities were calculated based on the midpoint between the best bid and ask prices on close. In order to maintain consistency while maximizing the size of my transactions data set, I utilized the implied volatilities from the front month contract (nearest to expiration) but with more than one week remaining before expiration keeping only the values for the nearest in-the-money call and put options. To be consistent with previous studies, fallback implied volatilities were taken to be the implied volatility of the front month contract four weeks prior to the first bid announcement only in cases where that contract had at least one week left until expiration. Otherwise, the implied volatility of the next month contract was used. Furthermore, not all dates in the bid period had calculable implied volatilities, and so I utilized the last available implied volatility as a substitute for that date. This generated some data problems that will be discussed later.

Transactions which did not have options data were removed. To evaluate target implied volatilities in stock-swap agreements, acquirer implied volatilities were also needed so eligible stock-swap transactions were further limited to those with U.S. publicly traded acquirer firms with options data.

Among all 1597 transactions in that time period, 437 of them were retained, of which 56 were all stock transactions and 381 were all cash transactions. Among the 381 cash transactions, 346 were successes and 35 were failures. 29 involved multiple bids and 132 involved private equity companies. The average days to resolution for successes and failures from the announcement of the first bid were 88 and 102 days respectively. Among the 56 stock-swap transactions, 46 were successes and 10 were failures. None involved multiple bids and three involved private equity companies. The average days to resolution for successes and failures among this subset were 108 and 132 days respectively.

In addition, the data was viewed using three time frames: days after announcement, days before resolution, and standardized transaction length, the last of which was calculated by rescaling all transactions to a constant 100 day period. The former two frames had data points drop out based on the actual length of deal.

Results and Discussion:

Cash Bids:

The following two graphs (Fig. 1 and 2) display the median ratio $\frac{\sigma_T}{\sigma_F}$ for calls and puts for each day separately in the bid period.

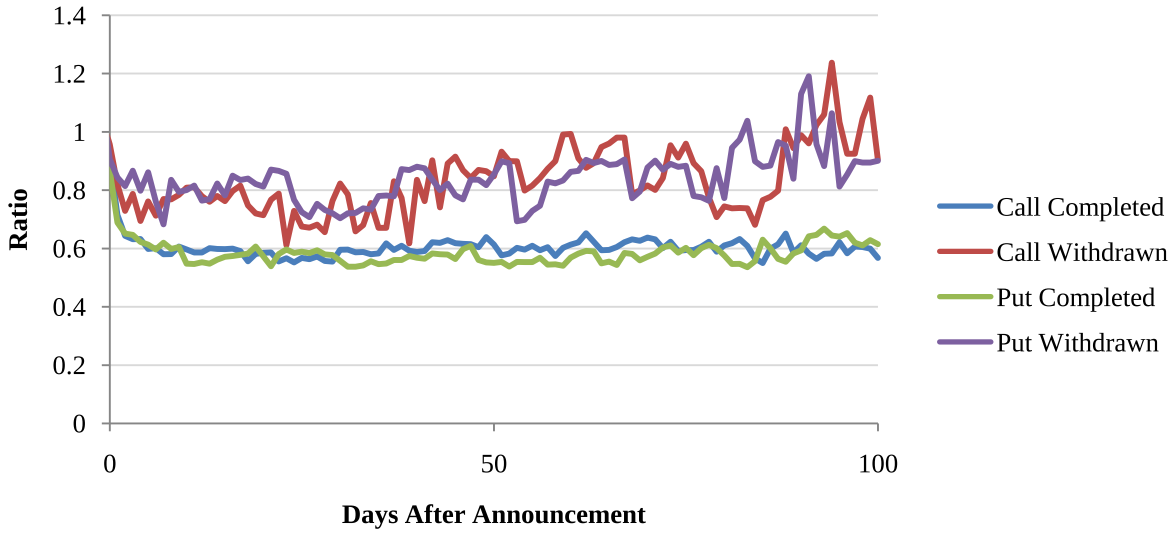

Fig. 1: Median volatility ratio σ_T/σ_F for calls and puts separated by completed and withdrawn all cash transactions each day after the transaction announcement. The volatility ratio is calculated as the current target implied volatility divided by the fallback implied volatility taken 4 weeks prior to the transaction announcement. Transactions which were resolved within 100 days are included in the data and are removed from the median calculation the day after they were resolved.

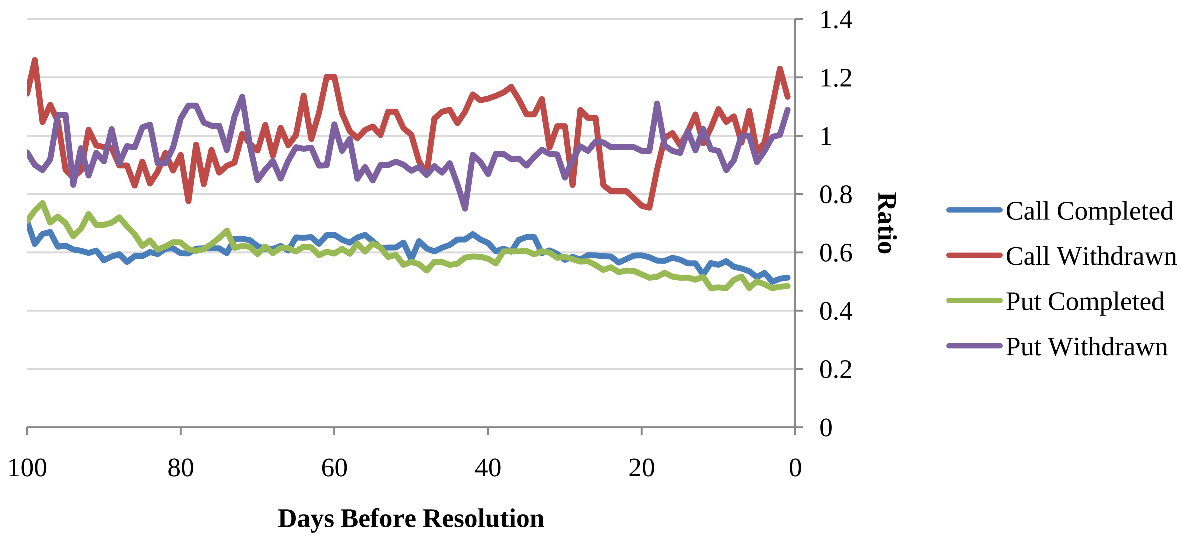

Fig. 2: Median volatility ratio σ_T/σ_F for calls and puts separated by completed and withdrawn all cash transactions each day before resolution. The volatility ratio is calculated as the current target implied volatility divided by the fallback implied volatility taken 4 weeks prior to the transaction announcement. Transactions which were resolved within 100 days are included in the data and are introduced into the sample the day they were announced.

In the announcement time frame, the median ratio declines shortly after announcement, and it seems the market is able to differentiate between successful (completed) and failed (withdrawn) transactions as the resolution date nears. To test this, I utilize a Wilcoxon Signed Rank Test, consistent with the methodology utilized by Barone-Adesi et al. (1994), by comparing the median value of the call volatility ratio for completed transactions versus withdrawn transactions in both weeks after announcement and weeks before resolution time frames. The results are in Table 1. Data is computed when available at that exact time point.

Table 1: Median volatility ratio σ_T/σ_F for all cash transactions and number of observations for each week after announcement (left panel) and each week before resolution (right panel). Wicoxon Signed-Rank Test p-value displayed below. Note: Week 0 refers to the day of announcement.

Weeks After Announcement	Median Ratio		Number of Observations	
	Completed	Withdrawn	Completed	Withdrawn
0	91.10%	95.72%	346	35
1	59.83%	76.13%	345	35
2	59.66%	80.89%	345	32
3	59.75%	76.24%	346	31
4	58.52%	71.44%	347	31
5	56.74%	67.54%	344	31
6	59.55%	82.27%	322	30
7	58.29%	67.07%	301	30
8	58.77%	83.53%	281	29
9	61.79%	91.51%	265	27
10	61.35%	84.76%	243	27
-1	102.87%	99.82%	346	35

Wilcoxon Signed-Rank Test
$p<0.001$

Weeks Before Resolution	Median Ratio		Number of Observations	
	Completed	Withdrawn	Completed	Withdrawn
0	51.33%	113.35%	345	35
1	51.49%	94.53%	346	35
2	55.73%	109.17%	345	32
3	57.50%	96.81%	346	31
4	58.96%	76.04%	346	30
5	58.68%	83.10%	343	31
6	57.46%	103.28%	333	29
7	65.24%	107.33%	306	29
8	63.25%	112.76%	287	30
9	62.56%	108.95%	271	28
10	57.64%	100.38%	244	27

Wilcoxon Signed-Rank Test
$p<0.001$

Both tests show that the market effectively separates successful and failed transactions in the weeks after announcement and preceding resolution. Furthermore, similar outcomes are seen on a standardized transaction timescale in Fig. 3.

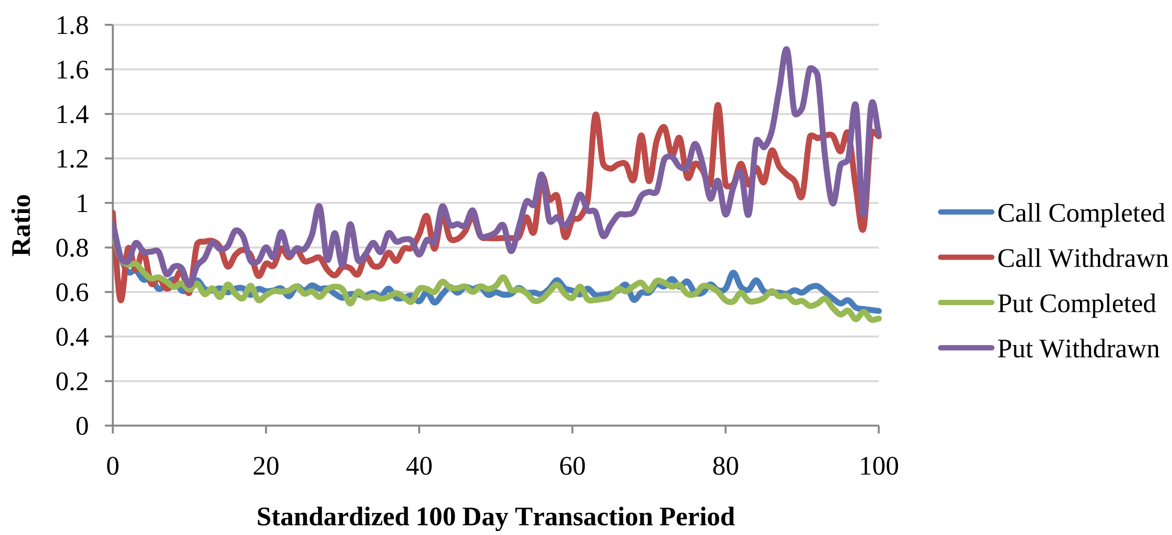

Fig. 3: Median volatility ratio σ_T/σ_F for calls and puts separated by completed and withdrawn all cash transactions in a standardized 100 day transaction period. The volatility ratio is calculated as the current target implied volatility divided by the fallback implied volatility taken 4 weeks prior to the transaction announcement. Each target company's bid period is scaled to 100 days and each data point is attributed to the nearest rescaled day. Data is included where available.

When all transactions are rescaled to a standardized 100 day period, the data indicates a divergence between the median ratios for successful and failed transactions. Ordinary least squares regression on the standardized 100 day period data shows a statistically significant difference between the slopes of the ratios for withdrawn and failed transactions over time. The equation used to model the regression is as follows:

$$\frac{\sigma_T}{\sigma_F} = \beta_1(time\ to\ resolution) + \beta_2(time\ to\ resolution * failure) + \beta_3(Multiple\ Bids) + \beta_4(PE) + C$$

The β_2 term models the additional slope for failed transactions, where failure is an indicator variable with value one for failed transactions and zero for completed transactions. In cases where there are multiple bids or private equity involvement, Multiple Bids and PE are used respectively as indicator variables. The results of the regression are listed in Table 2 with both regression coefficients calculated from call and put data displayed separately.

Table 2: Regression coefficient estimates and p-values for separate call and put all cash transaction data on a standardized 100 day transaction period. The regression equation is $\sigma_T/\sigma_F = \beta_1(time\ to\ resolution) + \beta_2(time\ to\ resolution * failure) + \beta_3(Multiple\ Bids) + \beta_4(PE) + C$ where σ_T is the implied volatility on a particular day, σ_F is the fallback implied volatility taken 4 weeks prior to the announcement date, time to resolution is the days after announcement in the standardized 100 day transaction period, and failure, multiple bids, and PE (private equity) are indicator variables for those scenarios.

		Call Data		**Put Data**	
	Description	**Estimate**	**P-value**	**Estimate**	**P-value**
C	Intercept	0.66618	<.0001	0.68040	<.0001
β_1	Time to Resolution	0.0008633	<.0001	-0.0006614	<.0001
β_2	Time to Resolution * Failure	0.0061368	<.0001	0.0095949	<.0001
β_3	Multiple Bids (Y/N)	0.02800	<.0001	0.14709	.0173
β_4	Private Equity Participation (Y/N)	0.10049	<.0001	0.07463	<.0001

The regression along a standardized 100 day time frame shows a very weak correlation, with an R^2 value of 0.0346 and 0.0871 for call and put data respectively. The slopes for both completed (β_1) and failed ($\beta_1 + \beta_2$) transactions are statistically significant. The regression data also shows statistically significant and rather large coefficients to the private equity term implying higher risks for private equity transactions.

The magnitude of the slopes for completed and failed transactions is also quite different. For completed transactions, the slope is approximately zero while the magnitude of the slopes for failed transactions is positive, with the ratio increasing notionally by 0.9% and 0.7% for call and put implied volatilities respectively for every incremental standardized day out of 100. Thus, at the end of the standardized time period, call volatility ratios for failed transactions would be 0.9 higher than successful transactions. The fact that the slope of successful transactions is not negative with any discernable magnitude may be due to the use of last calculated implied volatilities in some instances. For completed transactions, as the completion date approaches, some options do not have current period implied volatilities because the midpoint of the options data is outside the allowable range. In these cases, I substitute the last calculated implied volatility, leading to stale volatilities which may have artificially kept the median volatility ratio higher. These stale volatilities may be due to decreased liquidity as the resolution date nears for completed transactions. Empirically, Hutson (2000), studying Australian transaction data, notices a reduction in liquidity as transactions approach completion. I find that this also occurs in my data set.

To analyze this, I first determined the normal options volume and open interest experienced in a particular target stock in the absence of the deal by finding the average daily volume and average daily open interest in the period four to eight weeks prior to the transaction announcement date, denoted as the fallback volume and fallback open interest. I then total the option volume and open interest across all strikes for each date and divide by its fallback counterpart to calculate the volume ratio and open interest ratio for that day. Thus a volume ratio of 1 signifies a normal level of options volume. By dividing the bid period into ten equal time segments, I standardize the time length of the transaction across all companies. I then calculate the average volume and open interest ratio in each of the time segments to obtain Fig. 4.

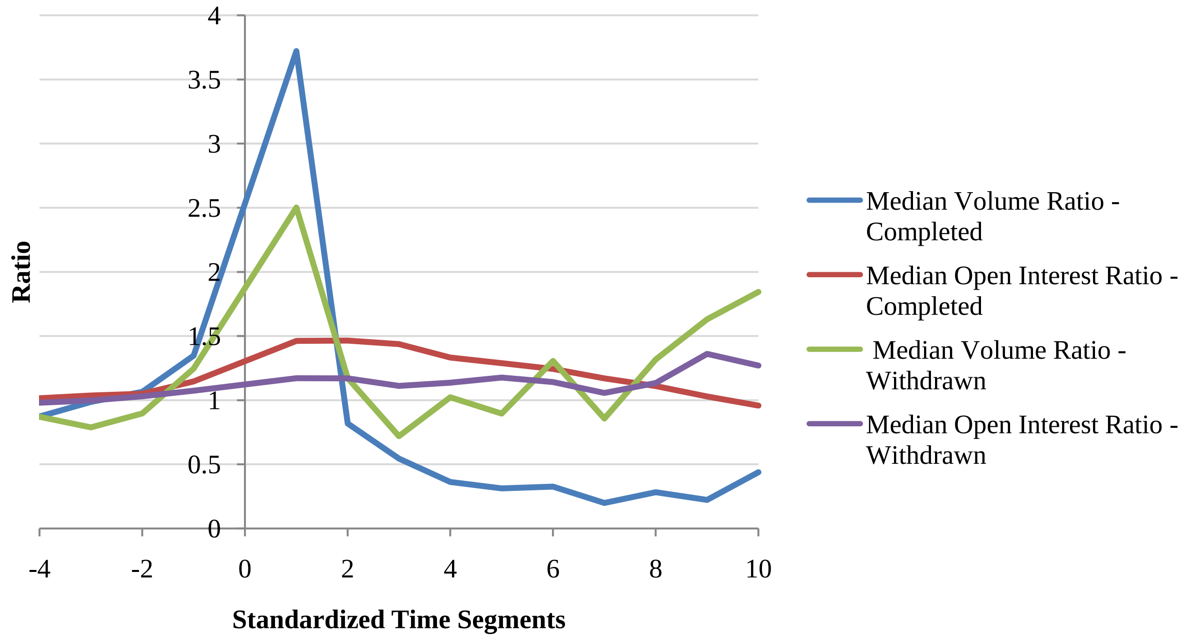

Fig. 4: Median volume and open interest ratio over a standardized time period for all cash transactions. The volume and open interest ratio for each company is calculated by dividing the total daily volume and open interest for the company's options by the average daily volume and open interest in the period four to eight weeks prior to the transaction announcement date. Standardized time segments are obtained by dividing each company's transaction period into 10 time segments reflecting the 1-10 time periods, and the median volume and open interest ratios are taken within each period. -1 though -4 time periods reflect similarly rescaled time segments before the announcement. Data is included where available.

The graph shows a decrease in the median volume ratio for completed cash transactions from the pre-bid period (-1 to -4 time segments before announcement) of ~1.0 to less than 0.5 (starting 4 time segments after announcement). In the last two time periods (last fifth of the bid period), 46% of companies involved in completed all cash transactions show average options volume of less than ¼ of normal volume, as compared to 23% in withdrawn transactions. Because open interest remains at normal levels throughout the bid period but options volume decreases, liquidity in completed all cash transactions appears to decrease over time.

Analyzing the volatility ratios a day after announcement using a two-tailed t-test with unequal variances, I find no significant difference between successful and failed transactions at a 1% level. Analyzing the data set for the day before resolution using the same test, I find a statistical difference in volatility ratios between successful and failed transactions at the 1% level. Some data points drop out due to differences in the timing of the transactions.

Table 3: Results from a two-tailed t-test for differences in means between the volatility ratio σ_T/σ_F for completed and withdrawn all cash transactions both one day after announcement and one day before resolution. The volatility ratio is calculated as the current target implied volatility divided by the fallback implied volatility taken 4 weeks prior to the transaction announcement.

	All Cash Transaction IV 1 Day After Announcement (Call Data)		*All Cash Transaction IV 1 Day Before Resolution (Call Data)*	
	Completed	*Withdrawn*	*Completed*	*Withdrawn*
Mean	0.791	0.819	0.671	1.505
Variance	0.297	0.227	0.383	0.976
Observations	325	33	324	31
Hypothesized Mean Difference	0		0	
P(T<=t) two-tail	0.75		0.00	

Table 3 shows that the market is initially unable to discern to-be-successful transactions from to-be-withdrawn transactions, but is able to make this differentiation by the resolution date. This result is consistent with the differences in slope for successful and withdrawn transactions over the standardized time scale.

Stock Swap Bids:

Stock swap bids using the $\frac{\sigma_T}{\sigma_A}$ ratio in both the days after announcement and days to resolution time frame are shown in Figures 5 and 6.

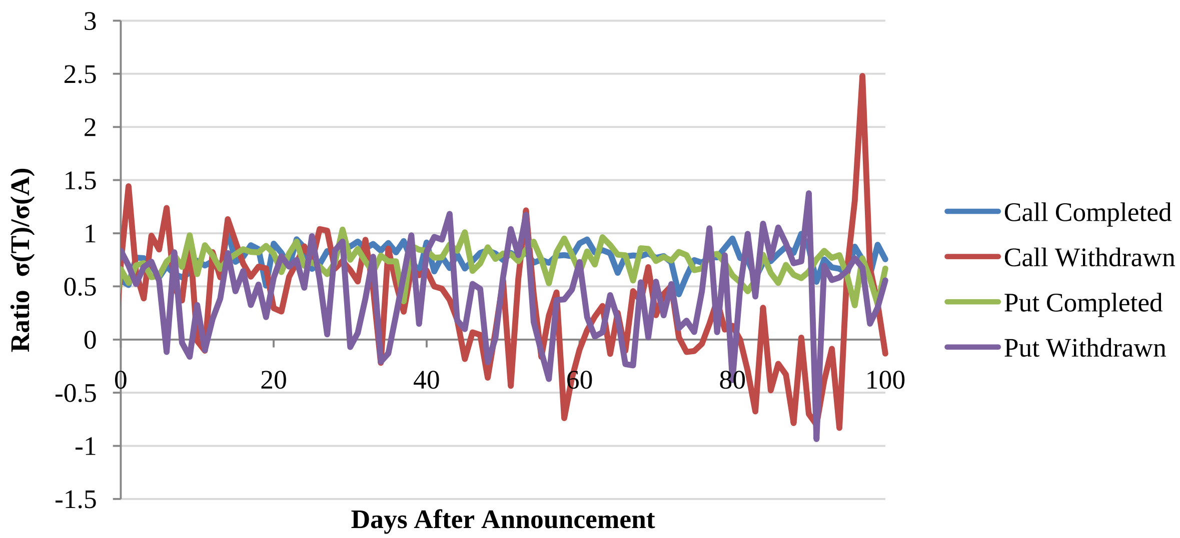

Fig. 5: Median volatility ratio σ_T/σ_A for calls and puts separated by completed and withdrawn stock swap transactions for each day after the transaction announcement. The volatility ratio is calculated as the current target implied volatility divided by the current acquirer implied volatility. Transactions which were resolved within 100 days are included in the data and are removed for the median calculation the day after they were resolved.

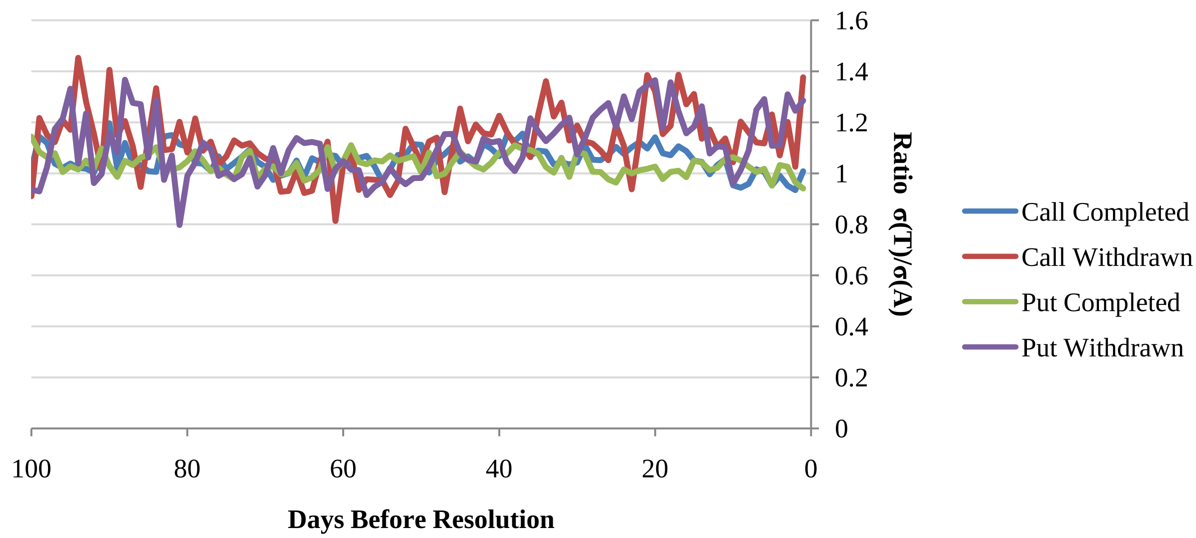

Fig. 6: Median volatility ratio σ_T/σ_A for calls and puts separated by completed and withdrawn stock swap transactions for each day before resolution. The volatility ratio is calculated as the current target implied volatility divided by the current acquirer implied volatility. Transactions which were resolved within 100 days are included in the data and are introduced into the sample the day they were announced.

The Wilcoxon signed rank tests in Table 4 show that the market displays a significant difference in the median implied volatilities only in the weeks to completion time frame at a 1% level.

Table 4: Median volatility ratio σ_T/σ_A for stock swap transactions and number of observations for each week after announcement (left panel) and each week before resolution (right panel). Wicoxon Signed-Rank Test p-value displayed below. Note: Week 0 refers to the day of announcement.

Weeks After Announcement	Median Ratio Completed	Median Ratio Withdrawn	Number of Observations Completed	Number of Observations Withdrawn
0	99.85%	92.83%	45	10
1	105.48%	100.90%	46	10
2	104.47%	92.57%	46	10
3	96.71%	110.59%	46	10
4	101.01%	110.56%	46	10
5	104.37%	98.95%	46	10
6	99.46%	108.73%	46	10
7	101.68%	111.85%	46	10
8	97.79%	104.74%	46	9
9	106.97%	107.94%	44	9
10	105.96%	97.10%	41	9
-1	131.31%	101.74%	45	10

Wilcoxon Signed-Rank Test
p>0.2

Weeks Before Resolution	Median Ratio Completed	Median Ratio Withdrawn	Number of Observations Completed	Number of Observations Withdrawn
0	100.81%	137.63%	45	10
1	95.27%	123.12%	46	10
2	95.32%	104.32%	45	10
3	105.02%	131.09%	46	10
4	114.13%	132.15%	45	10
5	110.35%	118.97%	45	10
6	104.29%	118.73%	45	10
7	108.91%	122.75%	45	10
8	106.72%	122.56%	45	9
9	104.58%	125.38%	44	9
10	111.21%	104.31%	41	9

Wilcoxon Signed-Rank Test
0.001<p<0.005

Figure 7 uses the directionally indifferent ratio $\frac{|\sigma_T - \sigma_A|}{\sigma_A}$ and charts median values across a rescaled time frame to stretch all transactions to exactly 100 days. I hypothesize that this ratio should approach zero for successful transactions. This graph shows a sharp spike upwards in the median value for failed transactions towards the resolution date but no spike for completed transactions.

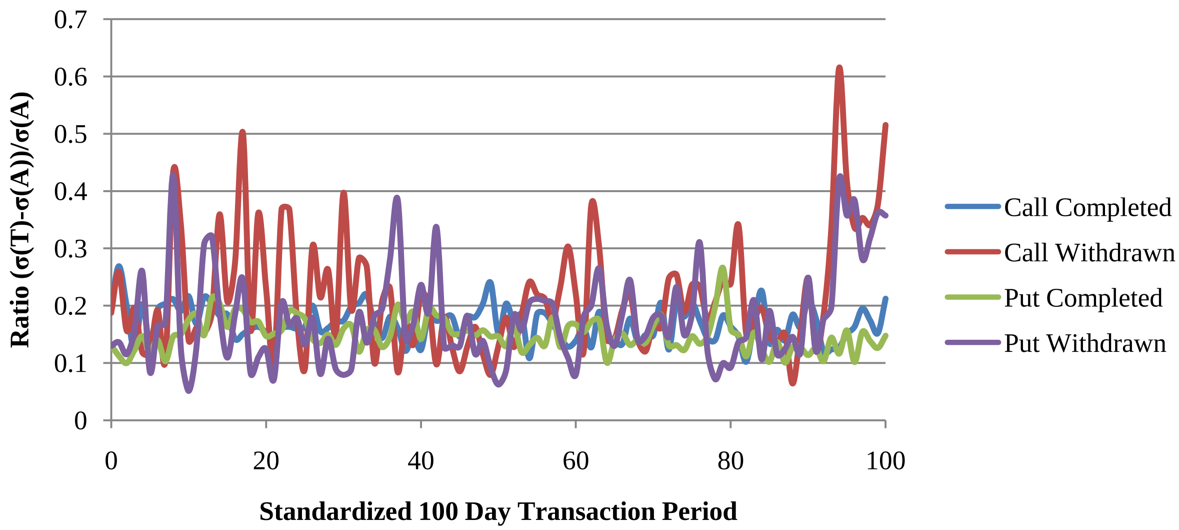

Figure 7: Median volatility ratio $|\sigma_T - \sigma_A|/\sigma_A$ for calls and puts separated by completed and withdrawn stock swap transactions in a standardized 100 day transaction period. The volatility ratio is calculated as the current target implied volatility minus the current acquirer implied volatility all divided by the current acquirer implied volatility. Each target company's bid period is scaled to 100 days and each data point is attributed to the nearest rescaled day. Data is included where available.

Ordinary least squares regression shows a statistically significant slope parameter for the completed versus withdrawn transactions. Using call data, the parameters are estimated in Table 5.

Table 5: Regression coefficient estimates and p-values for separate call and put stock swap transaction data on a standardized 100 day transaction period. The regression equation is $|\sigma_T - \sigma_A|/\sigma_A \ = \beta_1(time\ to\ resolution) + \beta_2(time\ to\ resolution * failure) + \beta_3(PE) + C$ where σ_T is the target's implied volatility on a particular day, σ_A is the acquirer's implied volatility, time to resolution is the days after announcement in the standardized 100 day transaction period, and failure and PE (private equity) are indicator variables for those scenarios.

		Call Data		**Put Data**	
	Description	**Estimate**	**P-value**	**Estimate**	**P-value**
C	Intercept	0.29359	<.0001	0.28914	<.0001
β_1	Time to Resolution	-0.000446	.0057	-0.000701	<.0001
β_2	Time to Resolution * Failure	0.001183	<.0001	0.000669	.0007
β_3	Private Equity Participation (Y/N)	0.00929	.6209	-0.0406	0.0223

The regression along a standardized 100 day time period for stock swap transactions shows very weak correlation with r-squared values of .0065 and .0051 for call and put data respectively. The slopes for both completed (β_1) and failed ($\beta_1 + \beta_2$) transactions are statistically significant. The magnitude is however not particularly notable, showing essentially a flat slope over the course of the transaction for both successful and failed transactions when looking at both call and put data.

Furthermore, the results of the two-tailed t-test for means assuming unequal variances for both one day after announcement and one day before resolution are shown in Table 6.

Table 6: Results from a two-tailed t-test for difference in means between the volatility ratio $|\sigma_T - \sigma_A|/\sigma_A$ for completed and withdrawn stock swap transactions both one day after announcement and one day before resolution. The volatility ratio is calculated as the current target implied volatility minus the current acquirer implied volatility all divided by the current acquirer implied volatility.

	Stock Swap Transactions 1 Day After Announcement (Call Data)		*Stock Swap Transactions 1 Day Before Resolution (Call Data)*	
	Completed	*Withdrawn*	*Completed*	*Withdrawn*
Mean	0.412	0.193	0.268	0.510
Variance	0.797	0.015	0.055	0.173
Observations	41	10	45	10
Hypothesized Mean Difference	0		0	
P(T<=t) two-tail	0.14		0.10	

The data for one day after announcement shows that the mean ratio is actually higher for completed transactions than for withdrawn transactions. This is partially a result of large outliers entering into the mean calculation. The two samples are not statistically significant at the 1% level at either time point.

Decreases in liquidity also exist in the stock transaction data for completed transactions. Figure 8 shows the median volume and open interest ratios for stock transactions. Like with cash transactions, the median volume ratio for completed cash transactions goes from ~1.0 in the pre-bid period to ~ 0.5 as the transaction proceeds. The median open interest does not fall from the pre-bid time segments. Because open interest remains at normal levels but options volume decreases, liquidity in completed all cash transactions decreases over time. Furthermore, for withdrawn transactions, the median volume ratio shows liquidity increasing in the last few time segments.

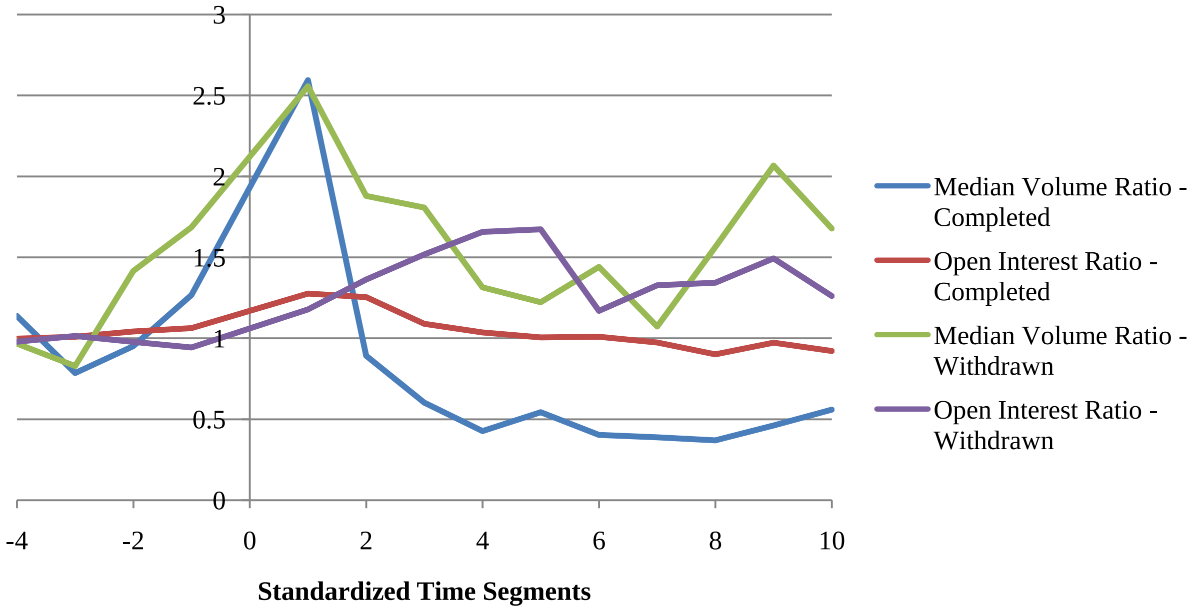

Figure 8: Median volume and open interest ratio over a standardized time period for stock swap transactions. The volume and open interest ratio for each company was calculated by dividing the total daily volume and open interest for the company's options by the average daily volume and open interest in the period four to eight weeks prior to the transaction announcement. Standardized time segments are obtained by dividing each company's transaction period into 10 time segments reflecting the 1-10 time periods, and the median volume and open interest ratios are taken within each period. -1 though -4 time periods reflect similarly rescaled time segments before the announcement. Data is included where available.

In the last two time periods (last fifth of the bid period), 31% of companies involved in completed all-stock transactions show average options volume of less than ¼ of normal volume, as compared to 0% in withdrawn transactions.

Summary and Conclusion:

This study examined the differences in implied volatilities between successful and failed transactions for cash and stock swap transactions during the bid period. From the analysis, I conclude that the ability of the market to distinguish between successful and failed transactions is different for all cash and all stock transactions.

For cash bids, the implied volatilities for successful and failed transactions separated over time. As the bid period progressed, only the median volatility ratio for failed transactions increased. While initially, the data showed no statistical significance between samples a day after announcement, the market's ability to discern differences increased as the target company approached the resolution date. The regression of the all cash volatility ratio over time exhibited weak correlation, but the statistically significant slope coefficients showed differences between successful and failed transactions.

The data for stock swap transactions pointed to a different outcome. Nominally small regression coefficients for the time variable and a weak ability of the market to categorize transactions as successful or failed on the basis of the constructed ratios were evident at both the day after announcement and the day before resolution. This may be due in part to the relatively small differences between intrinsic acquirer and target implied volatilities. The small data set may have reduced the ability to draw conclusions from the data.

Further complicating the cash and stock swap studies was the existence of stale volatilities, as liquidity tended to dry up as to-be completed transactions went to resolution for both all stock and all cash transactions. Conversely, liquidity issues were not observed for withdrawn transactions. These stale volatilities would likely skew the data to bring the means between completed and failed transactions closer together. It may be useful in the future to examine how these conclusions extend to mixed consideration transactions and to analyze within company changes in implied volatilities instead of addressing the completed and withdrawn samples in aggregate.

With further refinement, these conclusions may lend themselves to being tested in a merger arbitrage strategy which would utilize implied volatility ratios or changes in the ratios to select potential winners and losers, particularly for cash bids. Future analysis in the field is needed to identify opportunities in which to utilize implied volatilities to generate trading strategies among more commonly arbitraged transactions, as many of the successful transactions in this data set offered very low returns even starting a few days after the transaction announcement. Such low return transactions are not particularly applicable to hedge funds as the risk-reward is unattractive and the potential premium is too marginal to capture even with leverage. Because hedge funds focus on only a few transactions at a given time, a more realistic representation of the merger arbitrage universe for hedge funds would likely be found in fund disclosures, which discuss a reduced set of popular transactions as opposed to the commonly studied data set of all announced transactions.

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