# ON THE USE OF IMPLIED STOCK VOLATILITIES IN THE PREDICTION OF SUCCESSFUL CORPORATE TAKEOVERS

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## On the Use of Implied Stock Volatilities in the Prediction of Successful Corporate Takeovers


### Abstract

This paper develops and tests the notion that it is possible to use the post-announcement prices from the stock and option markets to infer both the probability of success and timing of an attempted takeover. Using a sample of 65 cash tender offers from the period January 1980 to July 1989, we demonstrate that the sequence of implied stock volatilities generated from the options of the target firm expiring both before and after the resolution date of the proposed deal exhibit a pattern strongly consistent with the hypothesis that prices are set in anticipation of the eventual outcome. We conclude that traders in the market for takeover candidates behave in a rational manner, although with less-than-perfect foresight.


## 1. Introduction

One of the more interesting consequences to arise from the resurgence in corporate merger and acquisition activity during the past decade has been the creation of a new class of financial intermediary: the risk arbitrageur. As the expression is most commonly employed, risk arbitrage refers to the process of purchasing the stock of firms targeted for acquisition during the period after the terms of the deal have been announced publicly. By speculating that the takeover will ultimately be successful, the risk arbitrageur stands to gain the fixed spread that typically exists between the tender offer price and the post-announcement price of the target firm. Of course, because the deal may fall through, this spread is properly viewed as compensation for allowing other holders of the targeted firm's stock to transfer their merger-specific risk to an investment professional. In this context, it is clear that the livelihood of the arbitrageur depends critically on the ability to establish accurate forecasts of the probability that the proposed takeover will succeed. Larcker and Lys (1987) showed that arbitrageurs are indeed able to form superior forecasts by acquiring costly information, for which they appear to be adequately compensated.

Although recent scandals have diminished the prestige of those in the risk arbitrage community, it is still the case that the there is a considerable mystique surrounding the activities of these investors. Part of this mystery is attributable, no doubt, to an attitude best expressed by Boesky (1985), who maintained that "... risk arbitrage itself is a craft that borders on an art." While this statement may be defensible on heuristic grounds, it nevertheless misses the point that the actions of any sizable group of investors will inevitably be reflected in market prices. In fact, both Samuelson and Rosenthal (1986) and Brown and Raymond (1986) demonstrated that while speculating on takeovers may well be an arcane art at the individual level, competition among investors is such that the overall market for takeover stocks is quite efficient. More precisely, both articles developed similar techniques for inferring a market consensus probability for the likelihood that the proposed deal will be completed based on the stock prices set in the post-announcement period. It was then shown that these probabilities were capable of discriminating between those deals that would ultimately succeed and those that would ultimately fail as far as three months in advance of the final resolution.

These prediction methods are notable in that they allow for the calculation of a sequence of success probabilities using market-generated price data during the time between the takeover announcement and its ultimate resolution. In this sense they can be contrasted with the more involved multivariate technique of Walkling (1985) created for the purpose of calculating a single prediction around the time of the announcement itself. What Samuelson and Rosenthal as well as Brown and Raymond ignore, however, is that the stock market is not the only capital market affected by a proposed takeover. Generally speaking, any market for securities whose values are contingent on movements in stock prices will also contain information about investor beliefs. Of course, this classification could include both the market for stock index options and futures and the market for individual equity options. Given the firm-specific (i.e., diversifiable) nature of the event in question, though, it is likely that only an examination of the latter will offer a substantive supplement to the forecasts inferred by post-announcement stock price movements.

The purpose of this article is to extend previous work on the efficiency of the market for takeover candidates by examining the information implicit in option prices for firms targeted for acquisition. Specifically, we select a sample of publicly announced takeover attempts for which the target firm has exchange-traded call options. Rather than refining the existing stock-based prediction models, the premise of the present research is that any acquisition-specific information embedded in call option prices will be reflected by differences in the underlying stock volatility implied by instruments alike in all respects except maturity. We argue that an informationally efficient option market would predict that the volatilities implied for a target firm must decline for options with successively longer expiration dates if the market ultimately expects the deal to be consummated. This will be the case because efficient option prices must be set in such a way as to effectively shorten the maturity date of the longer-term instrument relative to that of the shorter-term.[1]

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[1] Upon the successful completion of an announced takeover, all outstanding options of the target firm have their expiration dates accelerated to the acquisition date. Thus, in a rational option market, any instrument with a maturity falling after the expected merger completion date will have to be priced relatively lower than it ordinarily would *if* the market thinks the takeover is likely to be successful. However, when current prices are analyzed in conjunction with a static valuation formula using the original expiration dates, this will lead to the appearance of the longer-term instruments having lower volatilities, a point supported by Figlewski's (1989) view that implied volatilities impound information about *every* factor that affects option supply and demand.

Further, we demonstrate a technique for exploiting the extent to which these implied volatilities decline as a means of predicting *when* the takeover will be completed. When coupled with earlier work, this latter point has the potential to be extremely important in that it will allow risk arbitrageurs to make more precise speculations against the market as to both the probability of success *and* the timing of a proposed takeover. This approach is fully consistent with the work of Cox and Rubinstein (1985), who suggested that different options on the same underlying stock may have different implied volatilities in response to different economic events.

There are four sections in the remainder of this paper. Section 2 outlines the predicted reactions of an efficient option market in the face of a publicly announced takeover attempt. In section 3, we describe our data sample as well as the research methodology in more detail while the empirical results are presented in section 4. Lastly, the overall findings of the study are summarized in section 5.

## 2. Rational Responses in the Option Market for Takeover Targets

### *2.1 Notation*

Consider two call options in the post-announcement period for a firm that has been targeted for acquisition.[2] If the instruments are selected so that they expire at different points in time, their values can be expressed as $C_1(S,K,RF_1,T_1,\sigma_1,D_1)$ and $C_2(S,K,RF_2,T_2,\sigma_2,D_2)$, where the functional arguments represent the current stock price, exercise price, risk-free rate, time to maturity, volatility, and dividend payments, respectively. Assume that $T_1 < T_2$ and that at an arbitrary date t in the post-announcement period all of the variables involved in the valuation function have been established with the exception of $\sigma_t$ (that is, sufficient proxies can be established for both risk-free rates and the sequence of dividend payments). Without loss of generality assume further that the resolution date (R) of the announced takeover attempt falls between $T_1$ and $T_2$ and that the present date t falls between the announcement date (A) and $T_1$. With these definitions, at date t we have: $(A \leq t < T_1 < R < T_2)$.[3] To aid in the chronological interpretation of these values, all subsequent references to the announcement date will be as date 0.

[2] The use of call options in this discussion is done for simplicity only. A similar set of conclusions could be drawn for the rationality of investors in the put option market using the same implied standard deviations arguments developed below.

[3] The assumption that $T_1 < R < T_2$ is a convenient stylization. The empirical predictions outlined below will be equally valid if both options expire after the resolution date (i.e., if $R < T_1 < T_2$).

*2.2 Hypotheses*

This study concentrates on two aspects of the manner in which investors in the option market respond to a publicly announced takeover. First, without developing any specific predictions, it is possible to make inferences about whether risk arbitrageurs are rational in pricing options so as to discriminate between acquisitions attempts that will eventually succeed or fail. That is, given the sequence of events defined above, the implied volatility of any option expiring prior to the anticipated resolution date of the deal (i.e., $\sigma_1$) can be considered the "true" volatility in the sense that investors in the risk arbitrage market will not have priced the instrument so as to shorten its effective maturity.[4] On the other hand, to the extent that arbitrageurs feel that the deal will be successful, they will price the long-dated option so as to expire at date R rather than the nominal expiration date, $T_2$. However, if the date t market price for this option is assumed to be generated by the function $C_2(\cdot)$, then retaining $T_2$ as a functional argument will force the only non-determinant variable (i.e., $\sigma_2$) to decline. Consequently, on average, an option market in which traders are making efficient predictions about the eventual fate of the announced deal would make the following predictions: (i) $(\sigma_1 - \sigma_2) > 0$ for all takeovers which are eventually completed; and (ii) $(\sigma_1 - \sigma_2) = 0$ for all "failed" mergers.[5]

Our second goal in this study concerns predictions about the timing of the resolution date. Extending the previous analysis, since traders in the market for the longer-term option set prices at date t in anticipation of the possibility that its expiration date may be shortened by the takeover, it is possible to use the information contained in the implied volatilities to generate forecasts of date R. That is, the value of $\sigma_2$, which is derived from $C_2(\cdot)$ based on the nominal expiration date $T_2$, can be used to develop an estimate of R*, the predicted effective maturity (i.e., resolution) date. To see this, recognize that at date t,

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4 This does not mean, however, that $\sigma_1$ is unaffected by the prospective takeover. In fact, it is likely that investor uncertainty over the deal's outcome, as well as the asymmetric nature of the attendant cash flows, are enough to alter the "normal" level of the target stock's volatility (i.e., $\sigma$). The difference between $\sigma$ and $\sigma_1$ will be made explicit shortly.

5 One assumption implicit in the design of these hypotheses is that in the absence of any takeover-related activity, the volatilities of the options maturing at $T_1$ and $T_2$ are identical. That is, we assume initially that under normal circumstances the "term structure" of implied standard deviations is flat. If, however, the true volatility for the long-dated option exceeds $\sigma_1$ then the finding that $\sigma_1 = \sigma_2$ for successful takeovers may not be inconsistent with the notion of rational behavior among risk arbitrage investors. In such a case, the presumption of a flat term structure for implied volatilities serves as a bias *against* our underlying premise. On the other hand, if $\sigma_1 > \sigma_2$ under ordinary circumstances--as suggested by the findings of Rubinstein (1985)--then the preceding predictions would have to be modified to focus on incremental shifts in the normal implied volatility term structure. The tendency for the progression of implied volatilities to be mean-reverting documented by Stein (1989) suggests that either of these latter two cases are possible. The empirical relevance of this issue to the problem at hand is considered in a subsequent section.

investors will price the option expiring at $T_2$ with a volatility measure which takes into account both the information available for the option expiring at $T_1$ *and* the subjective probability that the deal will be resolved by R. Therefore, recalling that the valuation date t precedes the maturity of the shorter-term option and the actual resolution date precedes the maturity of the longer term option (i.e., $t < T_1 < R < T_2$), the level of $\sigma_2$ set at date t can be viewed as an expected value of $\sigma_1$ and the volatility that will obtain if the deal either succeeds or fails.

The calculation of this expectation function is best seen in two steps. First, notice that the date t forecast for the value of $\sigma_2$ at date R will be governed by the following probability distribution:

$$\sigma_{2R} = \begin{cases} \sigma \text{ with probability } [1-p_t] \\ 0 \text{ with probability } p_t \end{cases}$$

where $\sigma$ is the normal, or non-takeover influenced, level to which the target stock's volatility will revert if the deal falls through. Notice here that $\sigma_2$ is reduced to zero if the takeover is successful since the option maturity date will be accelerated from $T_2$ to R. Second, since it is also the case that $t < R$, the information implicit in the shorter-term option must also be incorporated. That is, the date t value for $\sigma_2$ implied by option prices set at date t can be represented as the following weighted average:

$$\begin{aligned} \sigma_2 &= \sigma_1 \cdot [R \div T_2] + \sigma_{2R} \cdot [(T_2 - R) \div T_2] \\ &= \sigma_1 \cdot [R \div T_2] + (1 - p_t) \cdot \sigma \cdot [(T_2 - R) \div T_2] \qquad (1) \end{aligned}$$

By way of interpreting the form of (1), notice that if risk arbitrageurs are perfectly certain at time t that the proposed takeover will be successful, $\sigma_2$ will simply be $\sigma_1$ scaled down by the ratio $[R \div T_2]$. That is, in accordance with our earlier prediction, when $p_t = 1$ we have $\sigma_2 < \sigma_1$ by an amount proportional to the extent which $R < T_2$. Conversely, if $p_t = 0$, $\sigma_2$ will be a simple weighted average of $\sigma_1$ and $\sigma$. Obviously, if $\sigma_1 = \sigma$, a flat term structure of normal volatilities obtains. However, if as suggested earlier $\sigma_1 \neq \sigma$, then $\sigma_2 \neq \sigma_1$ even though investors feel the deal will ultimately fail. The empirical work associated with the initial hypotheses that we present in a subsequent section will address this issue.

Once values for $\sigma$, $\sigma_1$, and $\sigma_2$ have been generated, a period t prediction of the date of resolution can be computed by rewriting (1) as:

$$R_t^* = [(T_2)(\sigma_2) - (1-p_t)(\sigma)(T_2)] \div [(\sigma_1) - (1-p_t)(\sigma)]. \qquad (2)$$

For the purposes of this investigation it is assumed that $p_t$, the probability of success, is a market-generated measure. Following Brown and Raymond (1986) and Larcker and Lys (1987), this can be calculated as:

$$p_t^* = [1 - (P_F \div P_{mt})] \div [(P_{Tt} \div P_{mt}) - (P_F \div P_{mt})]$$
$$= (P_{mt} - P_F) \div (P_{Tt} - P_F). \quad (3)$$

Here $P_{mt}$ and $P_{Tt}$ are the current market stock price for the target firm and prevailing tender offer, respectively, and are known with certainty at date t. On the other hand, $P_F$ represents what the target firm's stock price will become in the aftermath of an unsuccessful, or "failed," takeover bid. Of course, this value--like that of $\sigma$--is not known with certainty at date t and therefore both must be estimated.[6]

## 3. Data Selection & Methodology

### *3.1 Data Sample*

To test the hypotheses outlined above, we assembled a collection of announced takeover attempts using an information base provided by Security Data Corporation. Our sample included every deal proposed within the sample period spanning January 1980 to July 1989 which also met the following criteria: (i) the method of payment for the acquisition attempt had to be a single-tiered cash tender offer for at least 90% of the outstanding shares in the target firm; (ii) the market value of the proposed offer had to be at least \$100 million; (iii) the takeover target had to be a U.S.-based firm; (iv) the target company had to have stock options trading on at least one organized exchange; and (v) the event had a clearly defined resolution date. With these criteria we were able to identify a sample of 65 proposed deals, 56 of which were ultimately successful.

Once the sample of takeover events was identified, the calculation of implied volatilities demanded that we also gather data for target firm stock prices, option prices, Treasury bill yields, and dividends paid within the time period extending to the expiration date of the long-dated option. As detailed below, we obtained the information necessary to

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6 Typically, the "failure" price is approximated by the target firm's stock price at some point prior to the takeover announcement. For example, Larcker and Lys used the price four weeks before the announcement as a proxy. It is possible that such an approach can be somewhat misleading given that Bradley, Desai, and Kim (1983) have shown that the post-failure price of the target is usually substantially higher (albeit temporarily) than $P_F$. Importantly, however, Brown and Raymond demonstrated that any such discrepancies between the true and estimated values of $P_F$ have little practical impact on the inferences made about $p_t^*$ in equation (3). The estimation of $\sigma$ is discussed below.

test both predictions for each proposed deal on a weekly basis from the time of the initial announcement until the final resolution date. To focus our empirical work, we limited our analysis for each event to the closest-to-the-money options available on a given date t. Call option prices were gathered from various issues of *Barron's* while the source for all other data was once again Security Data Corporation.

### *3.2 Methodology*

Starting with the day falling four weeks prior to the initial announcement of the deal and continuing through the resolution date, option prices were collected on each Friday within the interval for every proposed takeover. On each of these weekly data collection dates, we gathered prices according to a two-step selection procedure. First, the shortest-term and the longest-term instruments having the same strike price were chosen, where the short-dated option expired at least two weeks after the collection date.[7] As the data permitted, we always chose expiration dates to fall on either side of the resolution date (i.e., $T_1 < R < T_2$). Second, whenever they were collectively available, the closest-to-the-money options were chosen as a means of identifying the most liquid instruments in the market. Given the length of the post-announcement periods in our sample of takeover events, these criteria indicated the collection of a total of 1,682 separate option positions.[8] Data was available from the reported sources in about 70% of the cases.

On each Friday in the data collection period, we also acquired data for the following variables: target firm stock price, current level of the outstanding cash tender offer, current dividend yield, and Treasury bill yields. Dividend yields, rather than the actual dividend payments during the life of the option, were used in accordance with specifications of the valuation model we employed. Treasury bill yields were selected for instruments maturing on (when available) the expiration dates of the shorter- and longer-term options. When these dates did not match the maturity of a listed T-bill, an average yield was estimated using bills with contiguous maturities.

Using this information, for each option of every target firm, an implied volatility measure was calculated on each collection day using the Newton-Raphson iterative search procedure under the assumption that option prices had been generated by the valuation

[7] The constraint of a common exercise price was imposed in recognition of the well-established result that implied volatilities vary with strike prices (see, for instance, MacBeth and Merville (1979)). In a few cases, data availability problems made it necessary to chose short-dated and long-dated options having adjacent, rather than similar, exercise prices.

[8] Across the sample of 65 proposed takeovers, the average length between the announcement and resolution dates was 128 days, with a maximum of 500 days and a minimum of 11.

model of Barone-Adesi and Whaley [BAW] (1987) adapted to stock options. Two points should be made in support of this estimation procedure. First, the use of a single option price to estimate the implied volatility--rather than the weighted average approach suggested by Latane and Rendleman (1976)--can be justified by the findings of Beckers (1981). Specifically, he demonstrated that it was the implied standard deviation of the closest-to-the-money option, and not one generated by a more involved weighting across strike prices, that offered the best forecast of the actual standard deviation of stock returns during the option's life. Second, the BAW valuation model we employed, unlike the traditional Black-Scholes (1973) closed-form equation for European-style option pricing, is based on a quadratic approximation algorithm. The advantage of this for our purposes is that it is sufficiently flexible to allow for the valuation of American-style call options for dividend-paying securities.

Finally, calculation of the resolution date prediction model of equation (2) required two additional pieces of information. Using closing stock prices on each of the data collection dates in conjunction with the outstanding tender offer, a series of "success" probabilities was computed for the entire sample of proposed deals. According to the form of $p_t^*$ in (3), this computation also necessitated selecting a proxy for $P_F$. To be consistent with previous work in this area, the price of the target firm's stock four weeks prior to the announcement date was used. The second additional variable needed to estimate (3) is a proxy for the normal level of firm volatility, or $\sigma$. According to the theoretical development of the preceding section, $\sigma$ should represent the single volatility level to which the firm will revert if the attempted takeover is unsuccessful. However, such a specification does not allow for the possibility of a non-flat term structure of volatilities. As a consequence, different proxies for $\sigma$ were tried, each being based on estimates obtained four weeks prior to the announcement date. After collecting data on the shortest- and longest-term at-the-money option available at that date, three natural proxies suggested themselves: the implied standard deviation on the short-dated option, the implied standard deviation on the long-dated option, and a weighted average of the two, where the weight on the shorter-term contract was determined by $(T_1 - t) \div (T_2 - t)$. Whenever data availability permitted, the latter proxy was used.

## 4. Empirical Results

### *4.1 The Influence of Takeover Announcements on Implied Volatilities*

The primary prediction we investigated was whether investors in the risk arbitrage market set prices so as to effectively shorten the life of any option expiring beyond the expected successful resolution of an announced takeover. As outlined above, this supposition can be summarized by the hypothesis that $(\sigma_1 - \sigma_2) > 0$. To facilitate the empirical analysis to follow, however, we rewrite this hypothesis in ratio form; that is, $(\sigma_1 \div \sigma_2) > 1$. In all subsequent work, this form of the hypothesis will be referred to as the "volatility ratio." Table 1 summarizes the sequence of weekly volatility ratios leading up to the resolution date for the call option pairs. The display is segmented into those proposed takeovers that ultimately succeeded (N = 56) and those that failed (N = 9) and reports the median volatility ratio at various points in the post-announcement interval, along with the median volatility ratio calculated four weeks prior to the deal's initial announcement.[9] The median probability measure of equation (3) is also listed so as to juxtapose investor reactions in the stock and option markets.[10]

[Insert Table 1 About Here]

The evidence provided in the display is largely consistent with the fundamental proposition. For instance, from an inspection of Panel A it is clear that as far as four months in advance of a successful tender offer's resolution, traders are pricing the long-dated option in anticipation of the eventual outcome. This conclusion can be supported by noting that for each of the sixteen weeks leading up to the resolution date, the median volatility ratio exceeds both the value 1.00 *and* its median pre-announcement level of 1.10. This latter comparison is particularly relevant when it is recalled that the value of the volatility ratio established four weeks prior to the announcement is used to proxy for the normal level of this statistic. Further, as indicated by the fourth column of Table 1, the percentage of volatility ratios greater than 1.00 for any particular week is typically in the range of 85-90%. These findings are quite complementary to the uniformly high probability predictions inferred from stock market data, which are listed in the last column.

The data from the unsuccessful tender offer sample in Panel B is somewhat less supportive of this conclusion. Although the extremely small sample size makes meaningful

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9 The use of the median (rather than the arithmetic mean) to indicate the central tendency is justified by both the relatively small sample size and the generally skewed nature of the individual volatility ratios. Given the way in which the volatility ratio is defined, calculating the sample mean in the presence of any such skewness would bias the findings toward the conclusion that $(\sigma_1 \div \sigma_2) > 1$. Thus, for our purposes, the median is a more conservative statistic.

10 One potential analytical problem with the statistic in equation (3) is that it can exceed unity. As Bhagat, Brickley and Loewenstein (1987) observed, such would be the case if the value of "put option" implicit in post-announcement stock price is out-of-the-money (i.e., $P_{mt} > P_{Tt}$). Consequently, to embellish its interpretation as a probability measure, (3) was constrained to remain within the [0,1] interval by the following modification: $p_t^* = \text{Min}\{[\text{Max}\{P_{mt} - P_F, 0\} + (P_{Tt} - P_F), 1\}$. See Brown and Raymond (1986) for more discussion on this point.

## Table 1

**Volatility ratios generated by call option data in the post-announcement period of a sample of 65 proposed tender offers, January 1980 - July 1989**

This table reports the cross-sectional median ratio of the short-term implied standard deviation ($\sigma_1$) to the long-term implied standard deviation ($\sigma_2$) for a number of dates in the post-announcement period of a proposed takeover. Under the assumption that at least one of the paired call options used to compute $\sigma_1$ and $\sigma_2$ expire after the resolution date (R), this data is used to test the rationality hypothesis that the "volatility ratio" exceeds unity. Also reported are the percentage of individual "date t" ratios which exceed unity as well as the "success" probability inferred from coincident stock prices.

| Weeks Prior to Resolution | Number of Observations | Median ($\sigma_1/\sigma_2$) | % of ($\sigma_1/\sigma_2$) > 1 | Probability of Success[a] |
|---|---|---|---|---|
| | | Panel A. Successful Tender Offers (N = 56) | | |
| 1 | 5 | 2.50 | 1.00 | 0.94 |
| 2 | 4 | 1.23 | 0.75 | 0.96 |
| 3 | 9 | 2.14 | 0.89 | 0.95 |
| 4 | 12 | 2.04 | 0.92 | 0.94 |
| 5 | 10 | 2.56 | 1.00 | 0.92 |
| 6 | 19 | 1.72 | 0.95 | 0.85 |
| 7 | 13 | 1.44 | 0.77 | 0.84 |
| 8 | 11 | 1.85 | 0.91 | 0.78 |
| 9 | 9 | 1.51 | 0.89 | 0.86 |
| 10 | 14 | 1.58 | 0.71 | 0.86 |
| 11 | 14 | 1.72 | 0.93 | 0.86 |
| 12 | 14 | 1.57 | 0.86 | 0.86 |
| 13 | 14 | 1.44 | 0.86 | 0.90 |
| 14 | 12 | 1.57 | 0.75 | 0.88 |
| 15 | 11 | 1.48 | 0.82 | 0.90 |
| 16 | 13 | 1.37 | 0.85 | 0.74 |
| <u>Pre-Announcement</u> | | | | |
| -4 | 30 | 1.10 | 0.80 | --- |
| | | Panel B. Failed Tender Offers (N = 9) | | |
| 1 | 6 | 1.70 | 1.00 | 0.94 |
| 2 | 6 | 1.43 | 1.00 | 0.88 |
| 3 | 3 | 1.47 | 1.00 | 0.84 |
| 4 | 3 | 1.27 | 1.00 | 0.75 |
| 5 | 3 | 1.36 | 1.00 | 0.68 |
| 6 | 4 | 1.49 | 1.00 | 0.62 |
| 7 | 4 | 1.16 | 1.00 | 0.52 |
| 8 | 2 | 1.23 | 1.00 | 0.77 |
| 9 | 2 | 1.20 | 0.50 | 0.62 |
| 10 | 3 | 1.51 | 1.00 | 0.94 |
| 11 | 2 | 1.14 | 1.00 | 0.70 |
| 12 | 2 | 1.40 | 1.00 | 0.75 |
| 13 | 2 | 1.50 | 1.00 | 0.69 |
| 14 | 1 | 1.07 | 1.00 | 0.67 |
| 15 | 1 | 0.93 | 0.00 | 0.31 |
| 16 | 0 | --- | --- | 0.26 |
| <u>Pre-Announcement</u> | | | | |
| -4 | 7 | 1.11 | 0.86 | --- |

[a] Calculated as a cross-sectional median figure according to equation (3), as modified in footnote 10.

inference difficult, it is nevertheless the case that neither the stock- nor option-based indicators appear to accurately presage the failure of the proposed deal. With respect to the median stock-based probabilities generated by equation (3), this is particularly surprising in the light of the consistently strong results to the contrary established in the literature. As to the behavior of the volatility ratios which form the motivation for the present investigation, although they seem to display the same pattern as the successful subsample, one important mitigating fact must be recognized. Specifically, in comparing the median volatility ratios for the successful and failed subgroups on a weekly basis, it is apparent that in only two cases (i.e., Weeks 2 and 13) does the latter exceed the former. To formalize this statistically, we performed a sign test between the weekly medians from the two subsamples under the null hypothesis that there was no detectable difference between them. The non-parametric test statistic for this hypothesis (with the correction for continuity suggested by Snedecor and Cochran (1973)) is calculated as $([13 - 2] - 1)^2 \div 15 = 6.67$. This is well in excess of the 5% critical value applicable to chi-squared variables with one degree of freedom. Thus, while the data are too noisy to allow a more precise parametric comparison, there is an indication that investors in the option market for takeover targets do indeed differentiate between deals that will ultimately succeed or fail.[11]

As another means of analyzing the discriminating power of the post-announcement volatility ratios, the subsample of successful tender offers was further delineated by assessing whether or not the proposal was initiated with the target firm management's approval. Accordingly, after reviewing the 14D-1 filing with the Security and Exchange Commission for each tender offer, a proposed deal was classified as either "hostile" ($N_H$ = 18) or "friendly" ($N_F$ = 38). It is reasonable to expect that takeover attempts that are considered hostile to the target firm's existing management are likely to be less successful than those attempted with mutual cooperation. (As evidence of this, all nine of the failed tender offers were classified as hostile.) In the present context, to the extent that stock and option prices in risk arbitrage market support this hypothesis, there should be two consequences. First, for at least some dates t in the sample period, the median success probability (i.e., $p_t$*) measured for hostile proposals should be discernibly lower than that for friendly deals. Second, the median volatility ratio (i.e., $\sigma_1 \div \sigma_2$) calculated for the sample of hostile takeover attempts should be lower than that for amicable ones during the pre-resolution period.

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[11] Another interesting facet of the results contained in Table 1 is that for both the successful and unsuccessful subgroups the median pre-announcement volatility ratio exceeds 1.00. This suggests that the non-takeover influenced implied volatility term structure is downward sloping. In the analysis to follow, we make an explicit allowance for this dimension.

[Insert Table 2 About Here]

Table 2 lists the findings for hostile and friendly subsamples in a fashion comparable to the previous display. While nothing is revealed that undermines the fundamental hypothesis about relationship between $\sigma_1$ and $\sigma_2$, it is nevertheless surprising to see that there are no substantive differences between these two subgroups of successful tender offers. Certainly, given the striking similarity of both the median volatility ratios and probability forecasts, it would be difficult to argue that investors in the market for hostile and friendly takeover targets price their respective options with appreciably different assessments of the deal's ultimate outcome. Using the same non-parametric sign test employed above, this conclusion is supported by the insignificance of the calculated statistic (i.e., 0.06). Of course, given that all of the tender offers examined *were* eventually successful, this may reflect little more than the market's ability to see beyond the defensive tactics of the target firm's management. Thus, an apparent inability to discriminate between hostile and friendly tender offers need not imply anything about the rationality of the risk arbitrage investor.

### *4.2 Regression Results*

Although the preceding analysis strongly suggests the conclusion that risk arbitrage investors set options prices in anticipation of the eventual deal resolution, it is difficult to tell from the descriptive nature of the reported findings how strong this tendency actually is and how it changes as the actual resolution date approaches. In order to establish the relationship between the volatility ratio and the time to resolution more precisely, we also ran several variations of the following cross-sectional regression using the entire sample:

$$(\sigma_1 \div \sigma_2)_j = \alpha_0 + \alpha_1(R)_j + \alpha_2(T_2 - T_1)_j + u_j \qquad (4)$$

where, in addition to the variables already defined, $(T_2 - T_1)_j$ represents the number of days separating the expiration dates for short- and long-term option used in the calculation of the j-th volatility ratio. We included this variable as an explicit control for the possibility that the underlying term structure of implied volatilities was not flat. Further, equation (4) was reestimated as a logarithmic transformation. This was done in order to reduce the influence of outliers in the original population of volatility ratios. The statistics associated with all of these forms are listed in Table 3.

[Insert Table 3 About Here]

## Table 2

**Volatility ratios generated by call option data in the post-announcement period of a sample of 56 hostile and friendly successful tender offers, January 1980 - July 1989**

This table reports the cross-sectional median ratio of the short-term implied standard deviation ($\sigma_1$) to the long-term implied standard deviation ($\sigma_2$) for a number of dates in the post-announcement period of proposed takeover segmented as either hostile or friendly to the target firm's management. Under the assumption that at least one of the paired call options used to compute $\sigma_1$ and $\sigma_2$ expire after the resolution date (R), this data is used to test the rationality hypothesis that the "volatility ratio" exceeds unity. Also reported are the percentage of individual "date t" ratios which exceed unity as well as the "success" probability inferred from coincident stock prices.

| Weeks Prior to Resolution | Number of Observations | Median ($\sigma_1/\sigma_2$) | % of ($\sigma_1/\sigma_2$) > 1 | Probability of Success[a] |
|---|---|---|---|---|
| | | Panel A. Friendly Tender Offers ($N_F$ = 38) | | |
| 1 | 4 | 4.33 | 1.00 | 0.82 |
| 2 | 1 | 0.58 | 0.00 | 0.92 |
| 3 | 4 | 2.40 | 1.00 | 0.94 |
| 4 | 7 | 2.61 | 1.00 | 0.94 |
| 5 | 6 | 2.38 | 1.00 | 0.92 |
| 6 | 12 | 1.72 | 0.92 | 0.86 |
| 7 | 7 | 2.41 | 1.00 | 0.89 |
| 8 | 8 | 1.55 | 0.87 | 0.63 |
| 9 | 6 | 1.51 | 1.00 | 0.74 |
| 10 | 11 | 1.50 | 0.73 | 0.92 |
| 11 | 11 | 2.00 | 0.91 | 0.72 |
| 12 | 10 | 1.40 | 0.80 | 0.71 |
| 13 | 10 | 2.03 | 0.90 | 0.90 |
| 14 | 6 | 1.27 | 0.67 | 0.94 |
| 15 | 7 | 1.39 | 0.71 | 0.94 |
| 16 | 8 | 1.38 | 0.87 | 0.92 |
| Pre-Announcement | | | | |
| -4 | 20 | 1.10 | 0.85 | --- |
| | | Panel B. Hostile Tender Offers ($N_H$ = 18) | | |
| 1 | 1 | 1.10 | 1.00 | 0.98 |
| 2 | 3 | 1.40 | 1.00 | 0.98 |
| 3 | 5 | 1.52 | 0.80 | 0.97 |
| 4 | 5 | 1.46 | 0.80 | 0.94 |
| 5 | 4 | 3.37 | 1.00 | 0.91 |
| 6 | 7 | 1.72 | 1.00 | 0.80 |
| 7 | 6 | 1.06 | 0.50 | 0.79 |
| 8 | 3 | 3.89 | 1.00 | 0.87 |
| 9 | 3 | 1.51 | 0.67 | 0.86 |
| 10 | 3 | 1.95 | 0.67 | 0.84 |
| 11 | 3 | 1.47 | 1.00 | 0.88 |
| 12 | 4 | 1.87 | 1.00 | 0.89 |
| 13 | 4 | 1.18 | 0.75 | 0.86 |
| 14 | 6 | 1.77 | 0.83 | 0.77 |
| 15 | 4 | 1.55 | 1.00 | 0.74 |
| 16 | 5 | 1.22 | 0.80 | 0.66 |
| Pre-Announcement | | | | |
| -4 | 10 | 1.04 | 0.70 | --- |

[a] Calculated as a cross-sectional median figure according to equation (3), as modified in footnote 10.

## Table 3

**Regression statistics summarizing the relationship between investor-generated volatility ratios and the days to resolution for a sample of 65 proposed tender offers, January 1980 - July 1989**

This table reports cross-sectional regression results using the volatility ratios ($\sigma_1 + \sigma_2$) as the dependent variable and the actual days to resolution (R) and the difference between the expiration dates of the short- and long-dated options ($T_2$-$T_1$) as explanatory variables. Under the assumptions of the model, the coefficient on R should have a negative sign, which indicates that value of the volatility ratio is increasing as the resolution date approaches. The variable ($T_2$-$T_1$) controls for term structure effects in the sequence of calculated implied volatilities. Regressions are reported in both unadjusted and logarithmic forms.

Panel A. Unadjusted Form

| Dependent Variable | Intercept | R | ($T_2$-$T_1$) | Coefficient of Determination |
|---|---|---|---|---|
| ($\sigma_1+\sigma_2$) | 2.25<br>(8.79)[a] | -0.0047<br>(-1.21) | | 0.01 |
| ($\sigma_1+\sigma_2$) | 1.48<br>(3.64)[a] | -0.0034<br>(-0.87) | 0.0060<br>(2.44)[a] | 0.03 |

Panel B. Logarithmic Transformation

| Dependent Variable | Intercept | ln(R) | ln($T_2$-$T_1$) | Coefficient of Determination |
|---|---|---|---|---|
| ln($\sigma_1+\sigma_2$) | 1.34<br>(4.41)[a] | -0.2058<br>(-2.71)[a] | | 0.04 |
| ln($\sigma_1+\sigma_2$) | -0.33<br>(-0.54) | -0.1934<br>(-2.61)[a] | 0.3534<br>(3.08)[a] | 0.09 |

[a] Significant at the 5% critical level in a two-sided test.

The most relevant characteristic of the tabulated findings is that the investor-generated volatility ratios appear to increase in value as the actual resolution date of the proposed deal draws closer. This result is indicated by the consistently negative coefficient on the R variable and is to be expected for a sample so heavily weighted with successful tender offers. Equally interesting, though, is the finding that this relationship is only significant when the logarithm-adjusted form of the regression is employed, a fact which indicates the degree to which skewness in the underlying volatility ratio series is a factor. Further, the correlation between these variables remains significant even when the normal difference between $\sigma_1$ and $\sigma_2$ was controlled with the inclusion of $(T_2 - T_1)$. Said differently, after accounting for what is a naturally downward sloping term structure of implied volatilities, the level of $\sigma_2$ (relative to $\sigma_1$) is significantly revised downward as the resolution date draws closer.[12] This finding is entirely consistent with the notion that investors are pricing the long-dated option so as to shorten its life in anticipation of a successful takeover.

### *4.3 Predicting the Resolution Date*

The second general goal of this study was to examine the accuracy of the resolution date predictions that are implied by the way in which risk arbitrage traders set option prices. To this end, the prediction formula in (2) was estimated for any proposed deal satisfying the condition that on a given date t in the sample period an option pair existed so that $(T_1 < R < T_2)$. For simplicity, only the 56 successful takeover proposals were used in the analysis. Further, to ensure empirical tractability, values generated by equation (2) were constrained by two boundary conditions: (i) Max(t, R*) and (ii) Min($T_2$, R*).[13] The results of these calculations are displayed in Table 4, which lists weekly summary statistics for both the predicted and actual days to resolution in the post-announcement period.

[Insert Table 4 About Here]

Perhaps the most consistent implication of the reported findings is the tendency for investors to underestimate the number of days to the tender offer resolution date. This conclusion can be established in a number of ways. First, and most immediately, the percentage of predicted dates which exceed the actual dates listed in the final column is only

[12] The conclusion of a downward sloping term structure of implied volatilities is based on the significantly positive parameter on the $(T_2 - T_1)$ variable, which suggests that the longer the time between option expiration dates, the greater the extent to which $\sigma_1 > \sigma_2$.

[13] These constraints are analogous to a trading rule which holds that the prediction formula will only be acted upon if it forecasts a resolution date falling in an interval bounded by the present date (t) and the date of the last piece of available information ($T_2$).

**Table 4**

**Resolution date prediction accuracy for a sample of 56 successful tender offers, January 1980 - July 1989.**

Summary statistics are reported for the resolution date predictions implied by option prices set in the post-announcement period of a sample of completed takeover attempts. For each week t in the sample period, the display compares the mean actual resolution date for a given event (R) with its predicted counterpart ($R_t$*).[a] Also listed are the percentage of predicted resolution dates which exceed the actual date.

| Week Prior to Resolution | Number of Observations | Actual: Mean R | Predicted: Mean $R_t$* | Predicted: Median $R_t$* | % of $R_t^* > R$ |
|---|---|---|---|---|---|
| 1 | 5 | 5.36 | 15.46 | 0.00 | 14.29 |
| 2 | 4 | 12.36 | 21.12 | 0.00 | 15.79 |
| 3 | 9 | 19.36 | 40.33 | 0.00 | 33.33 |
| 4 | 12 | 26.36 | 35.67 | 0.00 | 24.14 |
| 5 | 10 | 33.36 | 28.67 | 0.00 | 24.00 |
| 6 | 19 | 40.30 | 38.42 | 0.00 | 36.67 |
| 7 | 13 | 47.20 | 40.21 | 0.00 | 38.10 |
| 8 | 11 | 54.17 | 23.39 | 0.00 | 20.69 |
| 9 | 9 | 61.18 | 39.69 | 0.00 | 27.27 |
| 10 | 14 | 68.26 | 52.99 | 29.20 | 39.13 |
| 11 | 14 | 75.22 | 40.23 | 0.00 | 20.83 |
| 12 | 14 | 82.23 | 48.80 | 16.74 | 22.73 |
| 13 | 14 | 89.23 | 51.42 | 13.62 | 29.17 |
| 14 | 12 | 96.23 | 58.59 | 0.00 | 20.00 |
| 15 | 11 | 103.30 | 60.16 | 46.16 | 27.78 |
| 16 | 13 | 110.35 | 81.30 | 52.47 | 35.29 |

[a] Predicted resolution date (R*) calculated according to equation (2), as modified by the following boundary conditions: (i) Max(t, R*) and (ii) Min($T_2$, R*) where $T_2$ is the expiration date of the long-dated option.

occasionally greater than 30% in any of the post-announcement weeks. This alone indicates that a substantial number of the predictions generated by equation (2) fall short of their targeted goals. Further, from the relatively small number of non-zero median values for $R_t$* shown in the fifth column of Table 4, it is clear that a sizable number of the predictions were truncated at date t. This would occur, for instance, any time risk arbitrage traders reduce the implied volatility of the long-dated option ($\sigma_2$) too severely relative to the normal level ($\sigma$) so as to force the unconstrained prediction model to yield a *negative* forecast. Finally, a comparison of the mean values for both the actual and predicted days to resolution indicates that the former exceeds the latter in twelve of the sixteen weeks during the sample period. Using the non-parametric sign test employed in the last section (once again in light of the non-symmetric nature of the data), this difference can be formalized in the statistic $([12 - 4] - 1)^2 \div 16 = 3.06$, which is significant at the 10% critical level.

Although the preceding analysis suggests that the predictions built into market prices tend to understate the ultimate tender offer resolution date, a point that should not be overlooked is that the *direction* of the relationship between R and R* appears to be quite well behaved. To establish this trend more convincingly, Table 5 reports the findings of a cross-sectional regression of R* on the actual number of days to resolution. As with the earlier regression results in Table 3, this comparison was performed both with and without an explicit control for the term structure of implied volatilities (which, of course, is built into the prediction equation in (2)). The display indicates that, despite the partially flawed nature of the set of predictions revealed above, there is a significant and positive correlation between forecast and fact. It is also interesting to note that this relationship is once again strong enough to transcend the inclusion of $(T_2 - T_1)$ variable. Consequently, while they appear to be considerably less than perfect prognosticators, it does appear that investors in the option market for takeover targets set prices with a reasonable degree of insight about the future.

[Insert Table 5 About Here]

## 5. Summary and Conclusions

This study has investigated the proposition that through the collective actions of the arbitrage community it is possible to use the post-announcement prices from the stock and option markets to infer both the probability of success and timing of a proposed acquisition. While the former notion is well established in the literature, the latter is not. Through our analysis of a sample of 65 tender offers in the period spanning January 1980

**Table 5**

**Regression statistics summarizing the relationship between predicted and actual days to resolution for a sample of 65 proposed tender offers, January 1980 - July 1989**

This table reports cross-sectional regression results using the predicted days to resolution (R*) generated from equation (2) as the dependent variable and the actual days to resolution (R) and the difference between the expiration dates of the short- and long-dated options ($T_2$-$T_1$) as explanatory variables. Under the assumptions of the model, the coefficient on R should have a positive sign, indicating a direct correlation between predicted and actual resolution dates. The variable ($T_2$-$T_1$) controls for term structure effects in the sequence of calculated implied volatilities.

| Dependent Variable | Intercept | R | ($T_2$-$T_1$) | Coefficient of Determination |
|---|---|---|---|---|
| R* | 17.65<br>(2.50)[a] | 0.4181<br>(3.80)[a] | | 0.04 |
| R* | -6.60<br>(-0.63) | 0.4290<br>(3.95)[a] | 0.2103<br>(3.10)[a] | 0.06 |

[a] Significant at the 5% critical level in a two-sided test

to July 1989, we have provided considerable evidence to suggest that investors do indeed price the options of firms targeted for a takeover in anticipation of deal's ultimate outcome.

Specifically, we showed that traders effectively shorten the life of options scheduled to expire beyond the resolution date of the tender offer by setting their prices so as to reduce the implied stock volatility below its normal level. Further, we also demonstrated that this reduction became significantly greater as the time to the actual resolution date drew shorter. What we cannot conclude, however, is that risk arbitrage traders are able to make accurate predictions of the resolution date with any consistency. Of course, given that we were only able to test this proposition jointly with the form of our prediction model, it is always possible that any apparent shortcomings are entirely ours.

When taken together with the earlier results on the behavior of post-tender offer stock prices, these findings represent a potentially significant extension of the literature concerned with the efficiency of the market for takeover targets. Certainly, it is hoped that this research provides further evidence to support the notion that the risk arbitrage market is most properly thought of as an insurance market, a point apparently missed by Hetherington (1983). In any case, it appears once again that, when judged by its end product, the risk arbitrage investment process is far less mysterious than the its practitioners would like to believe.

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