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Volatility in stocks subject to takeover bids: Australian evidence using daily data[☆]

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Abstract

Using daily price and volume data on 112 of the largest takeover targets in Australia during the period from 1985 to 1993, we find that conditional price volatility declines after the takeover announcement. This decline is greatest for targets of cash bids and smallest for targets of share-exchange bids. We argue that the phenomenon is due to convergence of trader opinion regarding the value of the target stock, and reflects a change in the price formation process that has not hitherto been recognised. Our findings have implications for event studies of takeovers that inappropriately assume a time-invariant risk-return relation, and also for regulatory policies in the market for corporate control. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

Enduring interest in the market for corporate control stems from its importance in ensuring that assets are managed as efficiently as possible, in generating output from the economy's stock of productive resources. A plethora of empirical studies examining the efficiency of this market in many countries has provided evidence

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that firms subject to takeover bids experience substantial revaluation. The emphasis of this research has been on the behaviour of the *level* of prices around the announcement of takeover offers, with very few studies examining the price *volatility* of target companies, and no studies to date examining the conditional price volatility of target stocks. This constitutes a significant gap in the literature to which this paper is addressed. Using a comprehensive database comprising daily price and volume data on 112 of the largest takeover targets in Australia during the period from January 1985 to June 1993, our results show a strong tendency for the conditional price volatility of target stocks to decline after the announcement of the takeover bid. At first glance, this may appear counterintuitive insofar as target shareholders consistently earn positive excess returns. We explain this apparent anomaly in terms of a post-announcement change in the price formation process that has not hitherto been made explicit. By applying the mixture of distributions model (MDM) to the market for corporate control, we argue that the reduction in conditional price volatility after a takeover announcement reflects a convergence of trader opinion regarding target stock value. Our findings have implications for event studies of takeovers that inappropriately assume a time-invariant risk–return relation, and they also have implications for regulatory policies in the market for corporate control.

Our analysis contains four novel features. *First*, previous studies of target price volatility (Levy and Yoder, 1993; Lee et al., 1994; Smith et al., 1997) have considered only the change in unconditional volatility, and have examined only the hours, or at most the few days around the takeover announcement. By contrast, we formally model the conditional price volatility of target stocks over the full bid period, from the announcement of the bid to its conclusion as specified by the bidder. *Second*, we provide a new setting for the application of the MDM, which has become popular in the microstructure literature to explain the positive relation between asset price volatility and trading volume. In addition to corroborating the findings of related work on equity, foreign exchange and futures markets, our application of the MDM to takeover targets has a particularly appealing intuition. Using a variance components model (a la Tauchen and Pitts, 1983), in which changes in traders' reservation prices result from informational events that are either common to all traders or specific to individual traders, we interpret the bid price as the former, and the perceived likelihood of success of the bid as the latter. Our model predicts that for targets of takeover bids that are ultimately successful, the dispersion in traders' beliefs about the value of the stock will diminish during the course of the bid, and the conditional price volatility will consequently decline. *Third*, previous models of target price behaviour have focussed largely on cash bids, and models of target price volatility (Bhagat et al., 1987) have focussed on partial bids. Our model applies more generally to targets of full bids, and it distinguishes between bids for which the method of payment is cash-only, share-exchange, and mixed bids (that is, a choice between cash and shares, or a combination of the two). In particular, it allows us to explain why the reduction in post-announcement conditional price volatility is greatest for cash bids, followed by mixed bids and share-exchange bids. *Fourth*, we use the Davidian and Carroll (1987) autoregressive conditional heteroscedasticity (ARCH) model of conditional volatility and the general-to-specific dynamic estimation strategy together with generalised least squares (GLS) in order to arrive at our parsimonious models. This overcomes the generated regressors problem (see inter alia, Pagan, 1984, 1986; McAleer and McKenzie, 1991; Oxley and McAleer, 1993), which yields inefficient estimates, introduces bias into a number of diagnostic test statistics and generates potentially invalid inferences.

The paper is structured as follows: Section 2 reviews the relevant literature and presents the theoretical rationale for the empirical analysis. Section 3 discusses the methodology and describes the hypotheses to be tested. Section 4 introduces the data set and presents preliminary results including summary statistics and betas for the sample of target stocks. Section 5 presents the results of the econometric modelling. The final section summarises the main arguments of the paper and draws together the conclusions.

2. Previous research and theoretical background

There is a large body of evidence demonstrating that target company shareholders earn substantial excess returns around takeover announcements.[1] This raises an important question that has attracted comparatively little attention in the literature. Do target shareholders experience significantly higher risk commensurate with the higher returns they earn? Bhagat et al. (1987) found that the unconditional standard deviation of post-announcement target returns is actually lower than during the pre-bid period. They explained this reduction in risk in terms of the target stock becoming a portfolio of the share, plus a put option on the bidding firm. More recent studies, however, have found evidence of higher volatility immediately after takeover announcements. Levy and Yoder (1993) found significantly higher option-implied standard deviations for target stocks from 3 days before the announcement up to and including, but not after the announcement day. Lee et al. (1994) and Smith et al. (1997) found that intra-day trading volume and unconditional stock price volatility is abnormally high, but decreasing, on the day of a takeover announcement. It appears, therefore, that after an initial increase, target stock price volatility—and hence risk—is actually lower than before the takeover announcement.

[1] See Jensen and Ruback (1983) for a review of the US evidence. The most comprehensive study in Australia is Bishop et al. (1987).

How can the reduction in target price volatility be explained? We argue that there is a fundamental change in the price formation process for target stocks.[2] This view is implicit in the model developed by Brown and Raymond (1986) and Samuelson and Rosenthal (1986), which has also been applied by Larcker and Lys (1987) and Barone-Adesi et al. (1994). In this model, the target share price is determined by three factors: the offer price, the probability of the bid's success, and the expected post-takeover price if it fails. For targets of successful bids, these studies found that the average implied probability of success drifts upward during the course of the offer period, to converge with the offer price by the conclusion of the period. They also found that the average implied probability of success for targets of failed bids remains much lower throughout the bid period.

The existence of a positive relation between price volatility and trading volume is well documented in studies of equity, foreign exchange and futures markets (Karpoff, 1987 reviews the evidence). In the course of his explanation of leptokurtic price changes, Clark (1973) argued that this occurs because of randomness in the number of intra-day transactions. Epps and Epps (1976) subsequently argued that the intra-day price changes reflect the average of changes in traders' reservation prices. An increase in the extent to which traders disagree is associated with a larger absolute price change. The positive volatility–volume relation arises because the volume of trading is positively related to the degree of dispersion in traders' reservation prices. Tauchen and Pitts (1983) extended this work by specifying two components of informational events: those common to all traders and those specific to individual traders. Their model predicts that price volatility is influenced by both components, but volume is determined only by the dispersion in the trader-specific events. Subsequent models of the price volatility–volume relation have similar implications; see inter alia Jang and Ro (1989), Holthausen and Verrecchia (1990), Harris and Raviv (1993), Shalen (1993) and Wang (1993, 1994).

Tauchen and Pitts' (1983) model of speculative trading assumes that an asset with price p is traded by $j = 1 \ldots J$ traders who transact at irregular intervals of time. The intra-day demand for this asset by trader j at time i is written as,

$$Q_i^{Dj} = \alpha\left[\, p_i^j - p_i \right], \tag{1}$$

where Q_i^{Dj} is the trader's demand for the asset, p_i^j is his/her reservation price, p_i is the current market price, $\alpha > 0$ and Q_i^{Dj} can be positive or negative depending

[2] The combination of excess returns and lower price volatility for target stocks may appear, at first glance, to be anomalous with the capital asset pricing model (CAPM) and the mean–variance efficiency theory, more generally. This, however, is not the case. *First*, the target pricing process represents a temporary departure from the normal stock pricing process described by the CAPM. *Second*, the movement of stocks upward and to the left in mean–variance space after they become takeover targets is simply an interesting example of stocks being repositioned in it.

upon whether a long or short position is required. Traders possess different reservation prices because they differ in their expectations about the future prospects of the asset. Equilibrium is reached in the market at each point in time when the market's price is the average of the traders' reservation prices. It follows that price changes and trading volume are written as in Eqs. (2) and (3) below.

$$\Delta p_i = \frac{1}{J}\sum_{j=1}^{J}\Delta p_i^j, \tag{2}$$

$$V_i \equiv \frac{1}{2}\sum_{j=1}^{J}|Q_i^{D^j} - Q_{i-1}^{D^j}| = \frac{\alpha}{2}\sum_{j=1}^{J}|\Delta p_i^j - \Delta p_i|. \tag{3}$$

A variance components model describes the change at time i in trader j's reservation price for the asset, Δp_i^j as,

$$\Delta p_i^j = \phi_i + \varphi_i^j, \tag{4}$$

where ϕ_i and φ_i^j denote, respectively, informational events that are common to all market traders and those that are specific to individual traders, with $E(\phi_i) = E(\varphi_i^j) = 0$, $\mathrm{Var}(\phi_i) = \sigma_\phi^2$ and $\mathrm{Var}(\varphi_i^j) = \sigma_\varphi^2$. The expressions for the change in price and volume at time i consequently become

$$\Delta p_i = \phi_i + \overline{\varphi}_i, \qquad \overline{\varphi}_i = \frac{1}{J}\sum_{j=1}^{J}\varphi_i^j, \tag{5}$$

$$V_i = \frac{\alpha}{2}\sum_{j=1}^{J}|\Delta p_i^j - \Delta p_i| = \frac{\alpha}{2}\sum_{j=1}^{J}|\varphi_i^j - \overline{\varphi}_i|. \tag{6}$$

In moving from transactions time to daily data, the intra-day transactions are aggregated to obtain $\Delta p_t = \sum_{i=1}^{I}\Delta p_i$ and $V_t = \sum_{i=1}^{I}V_i$. These are mixtures of independent normals with the same mixing variable, I, which represents the flow of information to the market. This is the MDM, which has become popular in the volatility–volume literature. It arises because although the random variables, Δp_i and V_i, are stochastically independent, their common dependence on the assumed normally distributed ϕ_i and φ_i^j causes functional dependence in their moments. Inspection of Eqs. (5) and (6) reveals that price volatility is determined by the common informational component, ϕ_i, and by the average change in price resulting from trader-specific information, $\overline{\varphi_i^j}$. Volume is determined by the dispersion of traders' opinion around the average of trader-specific informational events. This explains why volume is frequently used as a proxy for the mixing variable.

In applying the MDM to the market for corporate control, we interpret the common informational component, ϕ_i in Eq. (5) as the publicly announced bid price, and the average of the trader-specific informational component, $\overline{\varphi_i^j}$, as the market's assessment of the likelihood of the bid's success. The MDM predicts that dispersion in $\overline{\varphi_i^j}$ is required to induce speculative trading, and that as this dispersion increases, trading volume and stock volatility increases. For targets of takeovers that are ultimately successful, however, the MDM predicts that the dispersion of trader opinion will decline during the course of the bid, and with it trading volume and price volatility.[3]

Our application of the MDM to target stocks can be viewed as an exploration of the second moment implications of the target pricing model of Brown and Raymond (1986) and Samuelson and Rosenthal (1986). Their model[4] assumes that given a bid price, p_t^{b}, the price of a target stock on any day during the bid period, p_t, is determined by the market's assessment of the probability of success of the bid, π_t, and by the price to which it is expected to revert if the bid fails, p_t^{f}.

$$p_t = \pi_t p_t^{\mathrm{b}} + (1 - \pi_t) p_t^{\mathrm{f}}. \tag{7}$$

During the course of a takeover bid that is ultimately successful, traders in this model will revise upward their estimate of the bid's likelihood of success, π_t. As the conclusion of the bid approaches, π_t will therefore tend towards unity as traders increasingly agree on its outcome, the second term in Eq. (7) will tend to zero, and the target share price will converge to the bid price, p_t^{b}.[5] The similarity between this model and our application of the MDM to target stocks can be seen by noting that the bid price, p_t^{b} in Eq. (7), is our common informational component, ϕ_i in Eq. (5), and the likelihood of the bid's success, π_t in Eq. (7), is the average of our trader-specific informational component, $\overline{\varphi_i^j}$ in Eq. (5). Both models suggest that a change occurs in the price formation process when stocks become takeover targets. Given the bid price, the value of target stocks is determined largely by the likelihood of success of the bid. The extent to which price volatility changes depends on the dispersion of trader opinion as to the takeover's likelihood of success. Convergence of opinion is likely with targets of ultimately successful bids, and so a reduction in volatility is predicted in such cases. For targets of takeover bids that ultimately fail, the simplified pricing

[3] This prediction is supported by Hutson (2000) who reports that over three-quarters (155 out of 200) of the targets of cash bids actually cease trading before the conclusion of the bid.

[4] Brown and Raymond (1986) and Samuelson and Rosenthal (1986) applied their model to unrevised cash bids only. We allow the bid price to be time-varying, to encompass non-cash bids, and the possibility of bid price revisions.

[5] This model is an imperfect representation of the target pricing process. It appears to work well when applied to targets of takeover bids that are ultimately successful, but it tends to overestimate the likelihood of success for targets of failed bids (see Zissu, 1989; Hutson, 2000). This is probably because the likelihood of a subsequent bid is an important additional determinant of the price of stocks subject to takeover bids that fail (see inter alia Bradley, 1980; Bradley et al., 1983; Fabozzi et al., 1988).

models still holds, but the variable π_t in Eq. (7) does not converge to unity as for targets of successful bids,[6] and the variable fallback price, p_t^{f}, has a larger role in the price determination process. We therefore argue that for failed bids, there will be a reduction in price volatility, but this will not be as great as for targets of successful bids.

Another important factor affecting the extent to which the price volatility of target stocks changes post-announcement is the type of consideration offered by the bidder. If the offer is cash, one of the three variables in Eq. (7), p_t^{b}, becomes a constant. As the conclusion of the bid approaches and π_t tends to unity, the target share price will converge to the fixed bid price. This suggests that targets of ultimately successful cash bids should exhibit the lowest bid-period volatility. In pure share-exchange bids, p_t^{b} is a variable that is equal to the bidder's share price multiplied by the exchange ratio. Because the offer price varies with the bidder's share price, there will be a smaller reduction in the target's price volatility than in the case of cash bids.[7] For mixed bids, the reduction in the target's price volatility should lie between these two.

Four predictions flow from this discussion. *First*, if our application of the MDM to the market for corporate control is valid, volume should be a significantly positive determinant of the price volatility of target stocks as in similar models of equity, foreign exchange and futures markets. *Second*, the conditional price volatility of targets of successful bids should be significantly lower than their pre-bid volatility. *Third*, the conditional price volatility of targets of failed bids should decline by less than that of successfully targeted stocks. *Fourth*, the reduction in price volatility should be greatest for targets of cash bids, followed by, consecutively, mixed bids and share-exchange bids. Our predictions of reduced price volatility of target stocks imply that target betas should also decline post-announcement.[8] This implication is given empirical support by Bhagat et al. (1987), who found that the average target beta declined by 65% relative to the pre-announcement beta in their sample of cash takeover bids.

[6] Samuelson and Rosenthal (1986), Brown and Raymond (1986) and Barone-Adesi et al. (1994) found that π_t is significantly lower than for targets of successful bids.

[7] There are certain circumstances in which volatility could rise instead of fall; for example, in cases where the likelihood of success is high and the price volatility of the bidder is higher than that of the target.

[8] To see this, rewrite the expression for beta as follows, where m denotes the return on the market and a bar over a variable denotes its mean value.

$$\beta_i = \frac{\operatorname{cov}(\Delta p_t, \Delta m_t)}{\operatorname{var}(\Delta m_t)} = \frac{\dfrac{1}{N-1}\displaystyle\sum_{t=1}^{N}(p_t - \bar{p})(m_t - \bar{m})}{\dfrac{1}{N-1}\displaystyle\sum_{t=1}^{N}(m_t - \bar{m})^2}.$$

As the variance of the target stock declines, so does its covariance with the market. This reduces the numerator in the expression for beta.

3. Methodology and hypotheses to be tested

We specify a two-equation model for the mean and standard deviation of target stocks. In preliminary analysis using the generalised autoregressive conditional heteroscedastic (GARCH) model, we encountered convergence problems due to thin trading. In order to overcome this, we follow the procedure of Davidian and Carroll (1987) and Schwert (1989). The model is specified in Eqs. (8) and (9).

The return on the asset, Δp_t, is defined as the log difference between p_t and p_{t-1}; Δm_t denotes the return on the market, and LV_t denotes the log of trading volumes.

$$\Delta p_t = \alpha_0 + \sum_{i=1}^{5} \alpha_1^i \Delta p_{t-i} + \alpha_2 \Delta m_t \times \mathrm{DUMPRE}_t + \alpha_3 \Delta m_t \times \mathrm{DUMPOST}_t + \alpha_4 \mathrm{ANNOU}_t + \alpha_5 \mathrm{CRASH} + \varepsilon_t, \tag{8}$$

$$\sigma_t = \gamma_0 + \sum_{i=1}^{5} \gamma_1^i \sigma_{t-i} + \sum_{i=0}^{5} \gamma_2^i \mathrm{LV}_{t-i} + \gamma_3 \mathrm{DUMPOST}_t + u_t. \tag{9}$$

The mean Eq. (8) is a generally specified autoregressive model in which the target return is related to a constant, itself lagged up to five times (given that daily data is being used), the market return, and two dummy variables. The return on the market, Δm_t, is separated into pre-announcement and post-announcement components by means of two dummy variables, DUMPRE, which is set to unity before the takeover announcement and zero after, and DUMPOST, which is set to zero before the announcement and to unity after. This approach is preferable to calculating excess returns in advance of the econometric modelling, because it allows us to examine whether the role of the market in the target price formation process changes after the takeover announcement. If the estimated values of α_2 and α_3 are significantly different, it will lend support to our proposition that target stocks undergo a change in their price formation process when they are 'in play'. The dummy variable ANNOU is set to unity on the day of the announcement and to zero at all other times. It captures any spike in the return series that might occur on announcement of a takeover bid. The dummy variable CRASH is used in cases where the data period includes the 1987 stock market crash. It is set to unity on the day of the crash (19th October), and to zero elsewhere. This picks up any spikes in the returns series where a stock's price movement is significantly different from the market's movement on that day.

The dependent variable in the conditional variance Eq. (9) is obtained as the absolute value of the residuals from the mean Eq. (8), ($\sigma_t = |\varepsilon_t|$). It is related to a constant, itself lagged five times, and the current and five lags of the log of trading volumes. The dummy variable DUMPOST is included to examine whether there is a post-announcement change in the conditional price volatility of target stocks. If the estimated value of γ_3 is significantly negative, it will support our hypothesis that target stocks exhibit lower conditional price volatility when they are ‘in play’.

In order to appropriately account for the non-zero cross equation covariances which arise from the generated regressors problem (see, inter alia, Pagan, 1984, 1986; McAleer and McKenzie, 1991; Oxley and McAleer, 1993), Eqs. (8) and (9) are estimated jointly for each target stock using the generalised least squares (GLS) estimation procedure. This is done by estimating the mean Eq. (8), using the absolute value of the residuals as the dependent variable in Eq. (9), and sequentially restricting using the general-to-specific estimation strategy until the parsimonious version is obtained for each target stock in our sample. The GLS estimator is described by first stacking the system to be estimated in the following form with M equations and T observations,

$$\begin{bmatrix} y_1 \\ y_m \end{bmatrix} = \begin{bmatrix} X_1 \dots 0 \\ 0 \dots X_m \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_m \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_m \end{bmatrix}, \tag{10}$$

where $\boldsymbol{y}$ is an $MT \times 1$ vector of dependent variables, $\mathbf{X}$ is an $MT \times \left(\sum_{i=1}^{M} K_i\right)$ matrix of explanatory variables, $\boldsymbol{\beta}$ is a $\left(\sum_{i=1}^{M} K_i\right) \times MT$ matrix of coefficients and $\boldsymbol{\varepsilon}$ is an $MT \times 1$ vector of errors. In the models analysed here, Eq. (10) contains two equations (i.e., $M = 2$) with a variable number of observations (i.e., T contains 250 pre-announcement observations and considerably less after the announcement depending on the length of the bid period). This system incorporates the possibility of cross-equation correlation among the error terms which yields the following covariance matrix of errors,

$$E(\boldsymbol{\varepsilon}\boldsymbol{\varepsilon}') = \Omega = \begin{bmatrix} \sigma_{11}\mathbf{I} \dots \sigma_{1G}\mathbf{I} \\ \sigma_{G1}\mathbf{I} \dots \sigma_{GG}\mathbf{I} \end{bmatrix},$$

where $\mathbf{I}$ is the identity matrix, $G = MT$, and Ω is positive semidefinite. Writing the system in matrix form as in Eq. (11), we can describe the GLS estimator as given by Eq. (12).

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}, \tag{11}$$

$$\hat{\boldsymbol{\beta}} = (\mathbf{X}'\Omega^{-1}\mathbf{X})^{-1}\mathbf{X}'\Omega^{-1}\mathbf{y}. \tag{12}$$

The gain in efficiency of this GLS estimator over OLS estimation depends on a number of factors including the extent of relation across the equations in the system and the extent to which the $\mathbf{X}$ variables differ across equations. In the current context of estimating the conditional volatilities of target stocks, the potential for efficiency gain by estimating the system by GLS is considerable.

In empirically estimating our models, we test the following four hypotheses which are couched in terms of the parameter coefficients in Eq. (9). The superscripts ‘S’ and ‘F’ denote the targets of successful and unsuccessful takeovers respectively, while superscripts ‘C’, ‘M’ and ‘SE’ denote the targets of cash, mixed and share-exchange bids, respectively.

Hypothesis 1 (The price volatility–volume relation).

H_0^1: $\gamma_2 = 0$;
H_1^1: $\gamma_2 > 0$, which implies that volumes are positively related to price volatility.

Hypothesis 2 (Reduction in price volatility for targets of successful takeover bids).

H_0^2: $\gamma_3^S = 0$;
H_1^2: $\gamma_3^S < 0$ for targets of successful takeovers, which implies that the post-announcement conditional price volatility of target stocks declines relative to their pre-announcement levels.

Hypothesis 3 (Relative reduction in price volatility for targets of successful and failed takeover bids).

H_0^3: $\gamma_3^S = \gamma_3^F$;
H_1^3: $\gamma_3^S < \gamma_3^F$, which implies that the post-announcement reduction in conditional price volatility for targets of successful takeovers should exceed that of targets of failed takeovers.

Hypothesis 4 (Relative reduction in price volatility for targets of cash, share-exchange and mixed bids).

H_0^4: $\gamma_3^C = \gamma_3^M = \gamma_3^{SE}$;
H_1^4: $\gamma_3^C < \gamma_3^M < \gamma_3^{SE}$; which implies that the post-announcement reduction in conditional price volatility should be greatest for cash bids, exceeding that for mixed bids, with share-exchange bids exhibiting the smallest reduction.

The alternative of Hypothesis 1, H_1^1, posits a generalised form of the commonly found positive relation between price volatility and trading volume, which has been observed in the equity, foreign exchange and futures markets. It is of interest to examine whether this relation is found to hold in stocks subject to takeover bids. If so, it will contribute further evidence on the price volatility–volume relation in a market which has not hitherto been examined, and it will corroborate the MDM interpretation of the evidence provided here in favour of the subsequent hypotheses. If the null of Hypothesis 2, H_0^2, is rejected, the expectation that the conditional price volatility of stocks subject to successful takeover bids will decline during the post-announcement period will be confirmed. The alternative of Hypothesis 3, H_1^3, states that the reduction in conditional price volatility of targets of successful bids should exceed that for targets of failed bids. Finally, the alternative of Hypothesis 4, H_1^4, states that the reduction in the post-announcement conditional price volatility of targets of successful takeover bids should be greatest for cash bids, lowest for share-exchange bids, with mixed bids in between.

4. Data and preliminary results

The data set for this study consists of 112 companies listed on the Australian Stock Exchange, for which a full takeover bid was launched during the period from January 1985 to July 1993. Daily closing prices and volumes (number of shares traded per day) were obtained from the Australian Stock Exchanges' Statex service. The takeover information is drawn from the Corporate Adviser takeover database which provides the announcement date, the conclusion date and the outcome of the bid. Success is defined as either (a) the bidder meeting its minimum acceptance conditions,[9] or (b) the bidder declaring the bid unconditional and receiving acceptances from at least 50% of shareholders. In estimating our models, the pre-announcement period begins 250 days before the takeover announcement and ends at the close of business the day before the announcement. The post-announcement period begins at close of business on the day of the announcement, and runs until the formal conclusion of the bid. Many takeover targets in Australia are small and thinly traded. Our sample has therefore been compiled with liquidity as the most important criterion for inclusion. Listed target companies were sorted by average daily trading volume in the year preceding the bid. Taking the top 150 targets, we removed from the sample those that were not listed for the full prior year, and those for which trading was suspended at any time during that year or in the bid period. The final sample comprises 112 target stocks: 89 are targets of successful bids and the remaining 23 are targets of unsuccessful bids. It includes 68 targets of cash bids, 16 share-exchange bids and 28 mixed bids. Table 1 is a frequency table showing the number of cases of different consideration by outcome.

4.1. Summary statistics

Table 2 provides summary statistics for the full sample of target returns, divided into the pre-announcement and post-announcement periods. In calculating

[9] The most common minimum acceptance condition in Australia is 90% of voting shares from 75% of shareholders.

Table 1
Frequency table of outcome by consideration

	Success	Failure	Total
Cash	54	14	68
Mixed	21	7	28
Share-exchange	14	2	16
Total	89	23	112

these statistics, the pre-announcement period is defined to exclude the contaminating effects of the so-called ‘runup’ period (of 20 days), during which there is an observed tendency for target stock prices to rise prior to the public announcement of the bid. The post-announcement period excludes the day of the announcement

Table 2
Summary statistics for target returns
The pre-bid period runs from 250 to 20 days prior to the takeover announcement. The post-bid period starts 1 day after the takeover announcement and runs until the conclusion of the bid. These figures are cross-sectional averages of the statistics calculated for each target company in time-series. The column headed *Percent decline in standard deviation (p-value)* reports the results for the test that pre- and post-announcement unconditional standard deviations are equal against the alternative that the pre-announcement standard deviation exceeds the post-announcement standard deviation, using a one-tailed *t*-test with unequal variances.

	Sample size	Mean	Standard deviation	Skewness	Kurtosis	Percent decline in standard deviation (*p*-value)
Pre-bid period						
Total	112	0.000	0.035	−0.76	15.71	
By outcome						
Successes	89	0.000	0.037	−0.65	16.21	
Failures	23	−0.001	0.030	−1.19	13.82	
By consideration						
Cash	68	−0.001	0.033	−1.11	17.59	
Mixed	28	0.001	0.037	−0.24	15.27	
Share-exchange	16	0.000	0.046	−0.14	8.03	
Post-bid period						
Total	112	0.001	0.023	0.90	12.30	34 (0.00)
By outcome						
Successes	89	0.001	0.022	0.87	11.86	41 (0.00)
Failures	23	0.000	0.027	1.04	13.96	10 (0.30)
By consideration						
Cash	68	0.001	0.018	0.73	11.79	46 (0.00)
Mixed	28	0.001	0.028	1.68	16.16	24 (0.08)
Share-exchange	16	−0.001	0.040	0.24	7.37	15 (0.11)

in order to eliminate the one-off hike in price volatility and trading volumes associated with the announcement itself. In each case, the results are further divided by outcome of the bid (successes and failures) and by consideration (cash, mixed, and share-exchange bids). In common with related research, the returns display both skewness and kurtosis, with greater evidence of both during the pre-announcement period than during the post-announcement period. This is consistent with the possibility of a change in the post-announcement price formation process for target stocks.

The summary statistic of most relevance to this paper is the standard deviation of target returns. These results are best discussed in relation to the hypotheses presented at the end of Section 3. Although the hypotheses are couched in terms of the conditional volatilities obtained from estimating Eqs. (8) and (9) for each target stock, it is informative to see whether the unconditional volatilities behave similarly to their conditional counterparts. The average unconditional standard deviation for the full sample declines by a highly significant 34%, from 0.035 pre-bid to 0.023 post-bid. For successfully targeted stocks, the decline is even greater at 41%, from a pre-bid average of 0.037 to 0.022 post-bid. This is consistent with the alternative of Hypothesis 2. For targets of failed bids, the reduction in volatility is only 10%, which is not statistically significant ($p = 0.30$). Since this reduction is considerably less than for the targets of successful bids and is not statistically significant, this finding is consistent with the alternative of Hypothesis 3. Finally, the reduction in target price volatility from the pre-bid to the post-bid period is significant for cash bids at 46%, marginally significant for mixed bids at 24% ($p = 0.08$) and is insignificant at 15% for share-exchange bids ($p = 0.11$). The relative magnitudes of risk reduction when the sample is delineated by consideration is consistent with the alternative of Hypothesis 4.

These results are qualitatively consistent with Bhagat et al. (1987), who reported that the unconditional standard deviation of target stock returns declined by 16%, from an average of 0.025 pre-bid to 0.021 post-bid. The reduction in risk reported here is considerably greater. This may be explained by the fact that our sample comprises targets of full takeover bids, whereas over two-thirds of Bhagat et al.'s (1987) sample comprised partial bids.

4.2. Betas for target stocks

It is interesting to briefly examine the extent to which the effect of the market changes when stocks become takeover targets. Table 3 presents our estimated mean betas for the full sample, using a standard one-factor market model and measuring Δm_t by the return on the *All Ordinaries* stock market index. As in Table 2, the results are delineated by outcome of the bid (successes and failures) and by consideration (cash, mixed and share-exchange).

Comparing the betas pre- and post-announcement reveals that they tend to decline in a manner similar, but not identical to, the unconditional standard

Table 3
Estimated betas for target stocks
The pre-bid period runs from 250 to 20 days prior to the takeover announcement. The post-bid period starts 1 day after the takeover announcement and runs until the conclusion of the bid. These figures are cross-sectional averages of the statistics calculated for each target company in time-series. The column headed *Percent decline (p-value)* reports the results for the test that pre- and post-announcement betas are equal against the alternative that the pre-announcement beta exceeds the post-announcement beta, using a one-tailed t-test with unequal variances.

	Average beta		Percent decline (p-value)	Average length of bid period (days)
	Pre-bid	Post-bid		
Total	0.75	0.32	57 (0.00)	78
By outcome				
Successes	0.76	0.34	56 (0.00)	80
Failures	0.71	0.26	63 (0.00)	72
By consideration				
Cash	0.67	0.20	70 (0.00)	77
Mixed	0.87	0.38	56 (0.00)	67
Share-exchange	0.88	0.72	18 (0.28)	102

deviations. For the total sample, the average beta declines from 0.75 before the announcement to 0.32 afterwards. This decline of 57% is significant at the 1% level, and exceeds the 35% decline in unconditional standard deviations reported in Table 2. It is consistent with the findings of Bhagat et al. (1987), whose average beta declined by 65%. For cash, mixed and share-exchange bids, the betas decline by 70%, 56% and 17%, respectively. Although the reductions in the cash and mixed bid subsamples are significant at the 1% level, the betas for share-exchange bids are not. This is intuitive insofar as the variable value of the bidder's stock in share-exchange bids would be transferred to the target stock, to an extent that depends on the market's perceived likelihood of the bid's success.[10]

When the sample is delineated by outcome, the decline in beta is very similar and highly significant: 55% for successes and 63% for failures (compared to declines of 41% and 10%, respectively, for the unconditional standard deviations reported in Table 2). The post-announcement betas for the two groups are not significantly different ($p = 0.29$). Although the reduction in unconditional standard deviation for successes versus failures is very different, both of these groups depart from their relation to the market to a similar extent. This provides further evidence of a change in the price formation process for target stocks when they are 'in play'.

[10] For example, if the success of the takeover bid was certain, the target stock would be perfectly correlated with the bidder's stock and have an identical beta.

5. Econometric results

The model described in Eqs. (8) and (9) has been estimated using the procedure described in the previous section for each of the 112 target stocks in our sample. The pre-bid period begins 250 days before the takeover announcement and ends at the close of business the day before the announcement. The post-bid period begins at the close of business on the day of the announcement and runs until the formal conclusion of the bid. The first step in the econometric analysis was to examine the order of integration of the data. Using the augmented Dickey–Fuller test, the existence of a unit root was easily rejected during both the pre-bid and post-bid periods in all cases.[11] The stationarity of the data is clearly visible in Figs. 1 and 2, which present the conditional means and the conditional volatilities, respectively, for all stocks in the sample. These are pooled across the whole sample, and then by outcome (successes and failures) and by consideration (cash, mixed and share-exchange).

While we do not present detailed results for each of the 112 estimated models here, it is worth noting that the models perform quite well, exhibiting substantial dynamic behaviour with up to five lags of both the dependent variable and the log of volume in each model. The R^2 statistics indicate that they explain between 1% and 34% of the variation in the conditional standard deviations over the pre- and post-bid periods. Tables 4 and 5 present summaries of the important findings from the modelling process. Table 4 focuses on the role played by the market coefficients in the mean equations, and Table 5 summarises the results regarding the effect of the takeover announcement in the conditional standard deviation equations.

5.1. The mean equations

The return on the market, Δm_t, in the mean Eq. (8) is separated into its pre- and post-bid components using the dummy variables DUMPRE and DUMPOST. If the estimated coefficients on these variables are significantly different (if $\alpha_2 \neq \alpha_3$), it will support our proposition that target stocks undergo a change in their price formation process after the announcement of the takeover bid. Columns 1 and 3 of Table 4 report the average values of the market coefficients before (α_2) and after (α_3) the announcement of the takeover bid. Columns 2 and 4 report the proportion of each group for which the market variable is statistically significant at the 10% level or better. The last column reports the percent change in the average market coefficient after the announcement, and the p-value for the test that pre-

[11] The results of the stationarity tests are available on request from the authors, as are the full results from the econometric modelling.

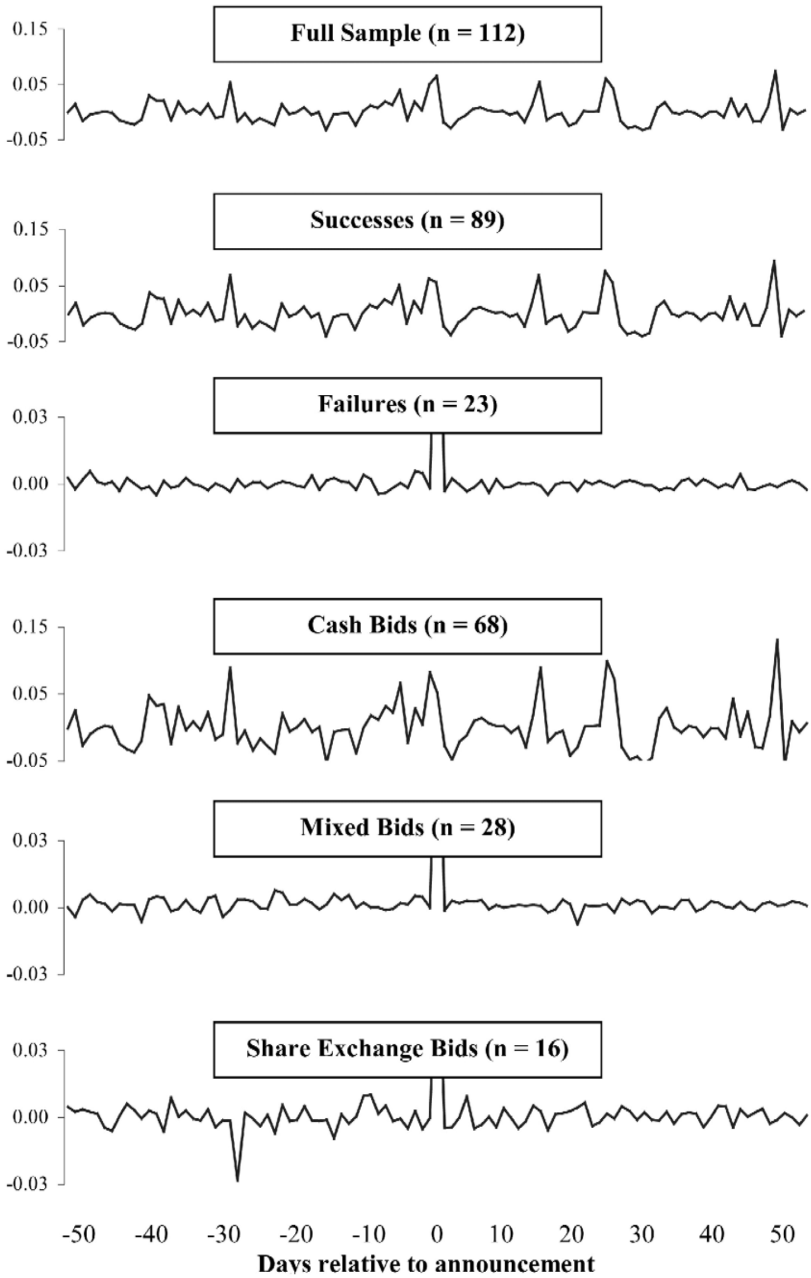

Fig. 1. Conditional mean of pooled target stocks. This figure depicts the conditional means of the pooled samples of takeover targets from 50 days prior to the public announcement of the bid until 50 days after the announcement.

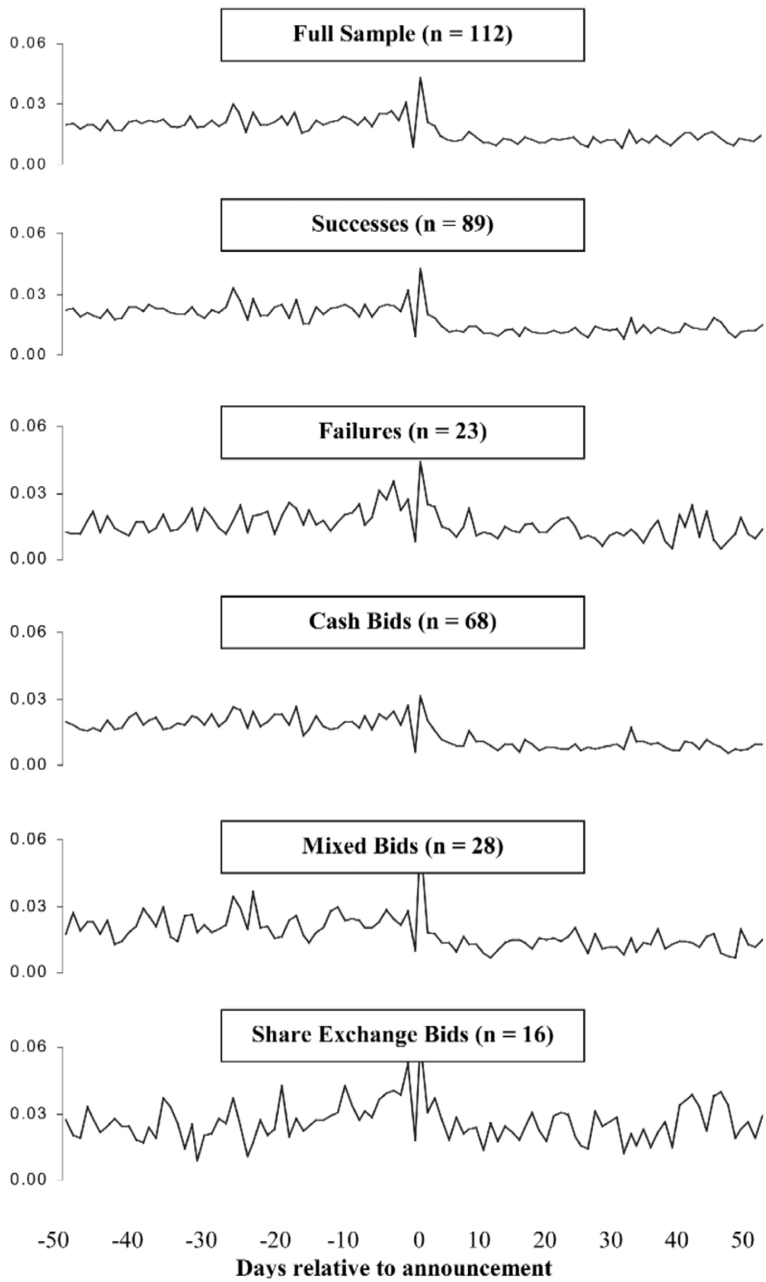

Fig. 2. Conditional volatility of pooled target stocks. This figure depicts the conditional volatilities of the pooled samples of takeover targets from 50 days prior to the public announcement of the bid until 50 days after the announcement.

Table 4
Market coefficients in the target mean equations
This table summarises the results of the market coefficients (α_2 and α_3) in the mean Eq. (8) for 112 target stocks, delineated by outcome and by method of payment. The columns headed *Percent significant* reports the percentage of the sample where a significant value for α_2 or α_3 was obtained. The last column reports the percent reduction in market effect after the announcement, and the *p*-values for the test that pre- and post-announcement market effects are equal against the alternative that the pre-announcement market effect exceeds the post-announcement market effect, using a one-tailed *t*-test with unequal variances.

	Pre-bid		Post-bid		Percent reduction (p-value)
	Average value α_2	Percent significant	Average value α_3	Percent significant	
Total	0.755	86	0.289	19	62 (0.00)
By outcome					
Successes	0.764	85	0.309	18	60 (0.00)
Failures	0.719	91	0.211	22	71 (0.00)
By consideration					
Cash	0.649	84	0.180	9	72 (0.00)
Mixed	0.907	96	0.333	32	63 (0.00)
Share-exchange	0.941	75	0.673	38	28 (0.13)

and post-announcement market effects are equal against the alternative that the pre-announcement market effect exceeds the post-announcement market effect, using a one-tailed *t*-test with unequal variances. The figures are first presented for the whole sample, followed by the sample delineated by outcome and by method of payment.

Looking firstly at the total sample, it is clear that after a takeover announcement, there is a reduction in both the average value of the market coefficient and the number of cases in which the return on the market is found to be significant. The average value of the pre-bid market coefficients (α_2) is 0.755, and it is significant at the 10% level, or better in 86% of cases (96/112). The average value of the market coefficients after the announcement (α_3) is 0.289, and it is significant at the 10% level, or better in only 19% (21/112) of cases. This represents a highly significant decline of 62% in the effect of the market on the pricing of target stocks after the takeover announcement.

For targets of successful bids, the average value for α_2 is 0.764 (with 85% being significant) and the average value for α_3 is 0.309 (with 18% significant). This decline of 60% in the effect of the market after the takeover announcement is statistically significant at the 1% level. It is clear that delineating the sample by outcome does not substantially alter the results, as the findings for the effect of the market on targets of failed bids is similar. There is a reduction in the average value of the market coefficient of 71%, and the proportion of significant coefficients declines from 91% to 22%. When the sample is delineated by consideration, however, the results are very different. The effect of the market on the targets of

Table 5
The effects of takeover announcements in the target volatility equations
This table reports summary results for the bid dummy coefficient, γ_3, in Eq. (9). This dummy is set at zero for the pre-announcement period, and unity for the post-announcement period. Average normalised value is γ_3 for each target divided by its mean volatility, averaged over the group. The standard errors for the average normalised returns are reported in brackets. The column headed *Percentage of γ_3's negative* reports the percentage of the sample where negative values for γ_3 were obtained.

	Average value (γ_3)	Average normalised value (γ_3)	Percentage of γ_3's negative
Total	−0.006	−0.331 (0.34)	63
By outcome			
Successes	−0.007	−0.374 (0.34)	69
Failures	−0.003	−0.165 (0.29)	39
By consideration			
Cash	−0.007	−0.411 (0.34)	71
Successes	−0.008	−0.480 (0.31)	80
Failures	−0.003	−0.145 (0.35)	36
Mixed	−0.006	−0.307 (0.27)	61
Successes	−0.007	−0.337 (0.29)	62
Failures	−0.002	−0.210 (0.19)	57
Share-exchange	−0.002	−0.036 (0.29)	31
Successes	−0.001	−0.023 (0.31)	36
Failures	−0.003	−0.124 (0.03)	0

cash and mixed bids is broadly similar, with the average value of α_3 being 72% and 63% smaller than α_2, respectively. Both of these reductions are statistically significant at the 1% level. For share-exchange bids, however, the average value of α_3 at 0.673 is not significantly smaller than the average value of α_2 at 0.941. The reduction in the effect of the market on target stocks after a takeover announcement is therefore greatest for cash bids, least (and insignificant) for share-exchange bids, and in between for mixed bids.

These results are consistent with the findings for pre- and post-announcement betas reported in Table 3. The evidence strongly suggests that the price formation process changes when target stocks are 'in play'. The extent to which this occurs does not vary with the bid's outcome, but it does vary with the method of payment offered by the bidder. A significant market effect remains during the bid period for most targets of pure share-exchange bids. This is probably because the bid price, which is an important determinant of the target's price, is related to the bidding firm's stock price in share-exchange bids. In order to cast more light on this issue, we proceed to examine the results from the volatility equations.

5.2. The conditional volatility equations

The alternative of Hypothesis 1, H_1^1, specifies that $\gamma_2 > 0$ in Eq. (9), implying that trading volume is positively signed in the volatility equations. We find that volume is most likely to affect volatility contemporaneously, and that the relation does not depend on either the outcome of the bid or the method of payment. In 83 of the 112 cases, γ_2^0 is significant at the 10% level or better, and all are positive. Of the 90 models in which statistically significant volume terms appear at any lag, 82 (91%) net out to be positive.[12] These findings are consistent with other studies of the price volatility–volume relation, and lend support to our application of the MDM to target stocks.

Our primary interest in the volatility equations, however, concerns whether the conditional price volatility of target stocks declines when they are 'in play'. This question is addressed by examining the behaviour of the coefficient γ_3 in Eq. (9) with reference to Hypotheses 2, 3 and 4. Table 5 summarises the results. It gives the mean value for γ_3 and the proportion of cases in which γ_3 is significantly negative. These figures are presented for the total sample, and for the sample delineated by outcome and consideration. Table 5 also includes mean values for 'normalised' γ_3's, which have been calculated for each target stock by dividing γ_3 by the absolute value of the mean of the dependent variable (MDV). This is necessary because the values for γ_3 are not strictly comparable to the extent that the magnitudes of the estimated conditional volatilities differ across the sample. The table includes the results for both the unadjusted and the normalised values for γ_3, with standard errors for the latter reported in brackets. In the following discussion, we focus on the normalised values of γ_3.

The alternative of Hypothesis 2, H_1^2, stipulates that $\gamma_3 < 0$ in Eq. (9) for targets of successful takeovers. The second row of Table 5 shows that the mean normalised value of γ_3 for successful takeovers is -0.374, and 69% (61/89) of the cases are significantly negative at the 10% level or better. Although not shown in the table, it is negative but insignificant in another 15 cases. In total, therefore, over 85% of the targets of successful bids exhibit a reduction in price volatility post-announcement.

It is interesting to compare these results with those for targets of failed bids. The alternative of Hypothesis 3, H_1^3, posits that the post-announcement reduction in price volatility for targets of successful takeovers should be greater than for failed bids, that is, $\gamma_3^S < \gamma_3^F$. The second row of Table 5 shows that the average normalised value of γ_3 for failed bids, at -0.165, is less than half that of successes. In addition, only 9 of the 23 cases (39%) are significantly negative at the 10% level or better. This confirms the alternative of Hypothesis 3, H_1^3. When delineating the sample by outcome and consideration, it can be seen that H_1^3 holds most strongly for targets of cash bids (for which $\gamma_3^F = -0.145$ is less than one-third the size of $\gamma_3^S = -0.480$), followed by mixed bids (with $\gamma_3^F = -0.210$ and $\gamma_3^S = -0.337$). H_0^3 cannot be rejected, however, for the share-exchange subsample.

[12] As mentioned in footnote 10, detailed results are available from the authors on request.

Turning lastly to Hypothesis 4, the alternative, H_1^4, states that $\gamma_3^{C} < \gamma_3^{M} < \gamma_3^{SE}$, implying that the post-announcement reduction in price volatility should be greatest for cash bids, exceeding that for mixed bids, with share-exchange bids exhibiting the smallest reduction. H_1^4 is upheld by the ordering of all three summary metrics appearing in Table 5. For the targets of cash bids, 71% are significantly negative; for mixed bids, the proportion is 61%, and for share-exchange bids, it is 31%. The average normalised γ_3's are, respectively -0.411, -0.307 and -0.036. For the share-exchange bids, the average normalised γ_3 is 9% the size of the average coefficient for the cash bids, and 12% the size of the mixed bids' average normalised value. The mixed bids' average normalised γ_3 is 75% the size of the normalised average for the cash bids.

These findings are consistent with the predictions discussed in Sections 2 and 3, which follow from our application of the MDM to the case of target stocks. When a stock becomes a takeover target, there is a shift in the pricing regime to one where the most important determinant, given a certain bid price, is the likelihood of success of the bid. The MDM implies that trading volume and price volatility are positively related to the divergence of investor opinion regarding stock value. With target stocks, we see a reduction in volume and volatility after the announcement of the takeover that is consistent with the convergence of investor opinion regarding value. The result is most dramatic for targets of ultimately successful bids, as the probability of success converges to 1 at the end of the bid period, and diversity of investor opinion collapses. For targets of successful share-exchange bids, however, the reduction in volatility is not as dramatic because the bid price varies with the bidder's share price.

There are, however, some exceptions to this strong finding of a reduction in the post-announcement price volatility of targets of successful cash bids. There may, for example, be continuing uncertainty as to the outcome of the bid if it is opposed by target management, or if there is a competing bid. In these cases, the continuing uncertainty will be reflected in a wider divergence of investor opinion about the outcome of the bid process than would otherwise be the case. This will in turn imply a greater dispersion in φ_i^{j} in Eq. (5) and continued price volatility induced by ongoing speculative trading. A closer look at the cases in which a significantly negative value for γ_3 is not found leads to the conclusion that this is most likely to be the case. Of the 11 successful cash bids where γ_3 is not significantly negative, three involved competing bids, and in five of the remainder, management vehemently opposed the bid. This is consistent with Smith et al. (1997), who found that targets of takeover bids that are expected to be contested by other bidders, and those that are opposed by target management, experience higher price volatility in the hours following the takeover announcement. Finally, it is worth noting that the MDM can also explain our observed smaller reduction in the conditional price volatility of targets of failed bids by a lower reduction in the dispersion of φ_i^{j} throughout the bid period than would occur in successful bids.

6. Summary and conclusions

The price volatility of stocks subject to takeover bids has received little academic attention. The literature is dominated by studies examining the level of prices around takeover announcements, which have consistently found that target stocks are subject to substantial revaluation. We have found that this revaluation is accompanied by a reduction in price volatility after the takeover announcement. Our explanation for the observed reduction in post-announcement price volatility suggests a change in the price formation process for target stocks which has not hitherto been made explicit. Given a particular bid price (or premium), the target's share price is determined largely by the market's assessment of the likelihood of success of the takeover bid. By applying the MDM to target stocks, we argue that 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. Our claim that the pricing process for target stocks departs from normal share pricing is supported by our finding that the market plays a significantly lesser role—in many case, no significant role at all—when targets are 'in play'.

In future research on this issue, an analysis of volatility transfer between target and bidder would be of considerable interest, as would the differential effects of cash versus share-exchange bids on the bidding company's stock. It would also be interesting to examine whether the option-implied volatilities of target stocks can assist in predicting the outcome of takeover bids. In the meantime, however, this study has implications for related research on two fronts. *First*, event studies that examine the gains to target shareholders assume unchanged risk after the takeover announcement. Our results show that this assumption is not valid, and that target shareholders tend to earn even greater risk-adjusted abnormal returns than has previously been estimated. Furthermore, our results show that shareholders of companies subject to share-exchange bids face a different level of risk from those subject to cash bids, which is different again from those subject to mixed bids. Future research on value creation in corporate takeovers should include not only the effect of time-varying risk on target excess returns, but also the differential effects due to differences in bid consideration. *Second*, our results have implications for appropriate regulation of the market for corporate control. The regulation of acquisitions in many countries imposes excessive cost burdens on bidding firms, which may inhibit the efficient working of the market. These regulations are often justified on the grounds of 'protecting' target shareholders. It is well recognised that target shareholders almost always earn abnormal returns, and our results show that this occurs alongside a strong tendency for their risk to decline. The resulting risk-adjusted abnormal returns make target shareholders the major 'winners' in corporate takeovers. Regulatory reform should recognise this and focus more on improving the efficient operation of the market for corporate control.

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