Consistent Estimation of Cross-Sectional Models in Event Studies

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Event studies often include cross-sectional regressions of announcement effects on exogenous variables. If the event is voluntary and investors are rational, then standard OLS and GLS estimators are inconsistent. Consistent ML estimators are constructed for a cross-sectional model of horizonial mergers relating announcement effects to exogenous characteristics of firms and industries. The OLS and ML estimates differ dramatically for bidders but not for targets. The evidence suggests that managers of bidders, but not targets, have valuable private information about the potential synergies from proposed mergers.

Many recent event studies include cross-sectional regressions of announcement effects on exogenous economic variables. Often, the estimated parameters are used to test hypotheses about investors' reactions to prespecified corporate announcements. For example, the *Journal of Financial Economics* (Vol. 15, 1986) contains several articles on the response of

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prices to announced debt and equity issues.[1] In these articles, abnormal stock returns over two days surrounding 'announced recapitalizations are regressed cross-sectionally on such exogenous variables as transaction costs and firm-specific risks, Similar cross-sectional regressions appear in articles on dividends and stock repurchases, the market for corporate control, as well as issues in industrial organization and the economics of deregulation.[2] If the explanatory variables are suggested by economic theory, then the common assumption has been that the OLS and GLS estimates of the cross-sectional parameters can be used to test theoretical predictions.

Unfortunately, the standard OLS and GLS estimators are inconsistent. With voluntary corporate events, such as those cited above, economically motivated managers can control the type, timing, or magnitude of public announcements. Rational managers voluntarily initiate an event only if it provides some personal or corporate benefit. Because abnormal returns from announcements can occur only if corporate insiders possess valuable private information not reflected in market prices prior to the event, outside investors rationally use both the announcement of a voluntary event and their knowledge of insiders' incentives to infer private information. Specifically, outsiders infer that insiders believe the event to have a positive net present value. This inference truncates the residual term that measures the value of inside information. If this truncation is ignored in cross-sectional regressions, then estimators of cross-sectional coefficients are inconsistent.

Although econometric issues in estimating abnormal returns have received considerable attention, the problem of truncated residuals in cross-sectional regressions has largely been ignored in finance? Recent exceptions are Acharya (1988, 1989) and Lanen and Thompson (1988). Acharya (1988) is the first application to event studies in finance of consistent estimators from the literature on limited dependent variables.' In his articles, Acharya focuses on consistent estimators of time-series parameters from the sequential signaling equilibrium of Harris and Raviv (1985). In Lanen and Thompson (1988)

[1] The articles are Asquith and Mullins (1986), Eckbo (1986), Masulis and Korwar (1986), and Mikkelson and Partch (1986).

[2] Examples include Vermaelen (1984) on stock repurchases, and Asquith, Bruner, and Mullins (1983), Eckbo (1985), and Smith, Bradley, and Jarrell (1986) on corporate control and industrial organization.

[3] Articles on econometric issues in event studies include partially anticipated events in Malatesta and Thompson (1985); contemporaneously correlated returns in Schipper and Thompson (1983), Thompson (1985), ind Sefcik and Thompson (1986); and the relative power of simple versus sophisticated statistical procedures for detecting abnormal returns In Brown and Warner (1980, 1985) and Malatesta (1986).

[4] Examples of this literature are Hausman and Wise (1977) and Maddala (1983).

plausible conditions are identified under which abnormal returns during the event period are not monotonic in information that is public prior to the event, even if the firm's cash flows are monotonic in that information. As a result, standard techniques for testing cross-sectional models about corporate cash flows using data from capital markets can yield incorrect inferences.

In this article, we also use results from the literature on limited dependent variables to derive consistent estimators in event studies. However, we focus on the coefficients of cross-sectional regressions for an event that satisfies the maintained hypotheses in models of limited dependent variables. These cross-sectional estimators measure the magnitude of abnormal stock returns around the announcement of a voluntary economic event in the presence of truncation bias. The estimators are then applied to a model of horizontal mergers. The application has been selected for three reasons. First, mergers are plausibly both discrete and nonrepetitive events, and corporate insiders can reasonably be assumed to maximize their stock's true value, conditional on their private information, rather than its market value, as determined by public information.[5] All three characteristics are critical to models with limited dependent variables. Second, the literature on industrial organization provides testable predictions about the source of synergy from horizontal. mergers. These predictions motivate the exogenous variables included in the cross-sectional regressions. Third, as in Eckbo (1985), the possibility of antitrust intervention adds an interesting, tractable complexity that mandates the nonlinear procedures advocated here. Specifically, the acquirer's proposal, the regulator's reaction, and the court's ruling can depend on distinct public and private information.

The article is organized as follows. In Section 1, an econometric method appropriate for cross-sectional studies of partially revealing, voluntary economic events is illustrated with a simple example. The method is applied to a model of horizontal mergers in Section 2, and cross-sectional parameters ate estimated in Section 3. Finally, the results are summarized in Section 4.

1. Truncated Residuals and Inconsistent Estimators

The problems produced by insiders' incentives and their effect on outsiders' inferences can be illustrated by the following simplification of the subsequent model of mergers. The managers of bidding firm

[5] In Harris and Raviv (1985), managers maximize a function of market values. An in other signaling models, these market values depend on public Information, including the event in question. Because insiders recognize the reaction of the market before they initiate their event, the signaling problem differs from the standard problem in models with limited dependent variables.

j have private information about the potential synergy from a possible merger. Using this information, they assess at y, the return on their firm's stock from its share of the synergy. That is, if v_j^+ and v_j^- are the managers' private evaluations of their firm's stock, with and without its share of synergy from the proposed merger, respectively, then the acquirer's return is $y_j \equiv \ln(v_j^+/v_j^-)$. Assume that the acquirer's assessment y_j depends linearly on a vector of publicly observable characteristics x_j and a single statistic η_j summarizing the inside information of firm j: $y_j = x_j\gamma + \eta_j$, with the vector of constants γ. Each acquiring firm's private or proprietary information η_j is distributed normally with mean 0 and variance ω^2, independently across all acquiring firms $j = 1, \ldots, J$.

In most event studies, cross-sectional parameters are estimated in two steps. First, for each firm the abnormal returns are estimated as residuals from a calibrating model, commonly the market model. Second, the parameters γ are estimated from a cross-sectional regression with the independent variables x_j. This two-step procedure can be conveniently summarized by a single time-series and cross-sectional regression:

$$r_{jt} = \alpha_j + \beta_j r_{mt} + d_{jt}x_j\gamma + \epsilon_{jt}, \tag{1}$$

for all firms $= 1, \ldots, J$ and times $t = -T_1, \ldots, 0, \ldots, T_2$. In (1) r_{jt} and r_{mt} are the continuously compounded rates of return on the stock of firm j and the market portfolio of stocks over period t; d_{jt} is a dummy variable equal to 1 during the event period and 0 otherwise; and x_j is a K-dimensional vector of explanatory variables suggested by theory. The residual ϵ_{jt} is assumed to satisfy

$$E(\epsilon_{jt}) = 0, \qquad E(\epsilon_{jt}^2) = \sigma^2 + d_{jt}\delta^2, \qquad E(\epsilon_{jt}, \epsilon_{j't'}) = 0,$$

for all firms $j \neq j'$ and all times $t \neq t'$.

For voluntary events this standard analysis can be inconsistent with rational expectations by participants in the capital market. To see this, suppose that the managers of the potential acquirer decide to merge

[6] Equation (1) differs slightly from the standard, two-step procedure. In (1) the parameters can be estimated from data covering the entire sample period, rather than Just the nonevent period as in the standard procedure. This increases slightly the efficiency of the estimators. Second, the dummy variable d_{jt} can be correlated with the mum on the market r_{mt}, unlike the two-step procedure In which d_{jt} and r_{mt} must be uncorrelated for the estimated coefficients to be unbiased Third, the residual variance during the event period $\sigma^2 + \delta^2$ an exceed the residual variance during the nonevent period σ^2. The incremental variance δ^2 is positive if there is additional residual variance during the the event period or if independent variables are omitted from the cross-sectional regression in the second step of the two-step procedure. The pooled equation (1) an be modified to cover complications that ate familiar from previous event studies. For example, if the economic event is partially anticipated by investors in the capital market, then the coefficients must be reinterprected, as in Malatesta and Thompson (1985). Also, to reflect tumors and the random arrival of news, the dummy in (1) can be redefined as a stochastic variable with a positive support over some sequence of periods preceding the event, as in Ball and Torous (1988).

if and only if they assess their firm's share of the synergy as nonnegative. Thus, they announce a merger if and only if their firm's return satisfies $0 \leq y_j = x_j\gamma + \eta_j$. Outside investors recognize the managers' incentives even though they cannot observe their inside information η_j. If the announced merger completely surprises outsiders, then each investor computes the acquirer's expected return from the announcement as $E(y_j \mid \eta_j \geq -x_j\gamma)$ Assume that outsiders regard their uncertainty about the insiders' assessment y_j as unsystematic risk. In this case, competition in the capital market generates during the announcement period the abnormal return

$$F(x_j) \equiv E(y_j \mid \eta_j \geq -x_j\gamma)$$

$$= x_j\gamma + E(\eta_j \mid \eta_j \geq -x_j\gamma) = x_j\gamma + \omega\frac{n(z_j)}{N(z_j)}, \qquad (2)$$

where n and N represent, respectively, the normal density and distribution functions with the standardized variate $z_j \equiv x_j\gamma/\omega$. In (2) the ratio $(z_j)/N(z_j)$ is the expectation of a standardized normal variate that is truncate below at $-z_j$. The coefficient ω in (2) reflects the standardization of z_j:

$$E(\eta_j \mid \eta_j \geq -x_j\gamma) = \omega E(\eta_j/\omega \mid \eta_j/\omega \geq -z_j).$$

This abnormal return $F(x_j)$ replaces the linear specification x_j in (1):

$$r_{jt} = \alpha_j + \beta_j r_{mt} + d_{jt}F(x_j) + \zeta_{jt}. \qquad (3)$$

The residual ζ_{jt} in (3) has the same properties as the residual ϵ_{jt} in (1):

$$E(\zeta_{jt}) = 0, \qquad E(\zeta_{jt}^2) = \sigma^2 + d_{jt}\delta^2, \qquad E(\zeta_{jt}, \zeta_{j't'}) = 0,$$

for all firms $j \neq j'$ and all times $t \neq t'$.

If the event is voluntary and investors are rational, then the correct, cross-sectional model is (3). In this case the residual ϵ_{jt} does not have the properties specified below (1). Instead, the residual in (1) includes the last term in (2):

$$\epsilon_{jt} = \zeta_{jt} + \omega\frac{n(z_j)}{N(z_j)}.$$

[7] With a standardized normal variate z, its density n satisfies $n'(z) = -zn(z)$. If z is truncated below at θ, then its conditional expectation is

$$E(z \mid z \geq \theta) = \frac{1}{1 - N(\theta)}\int_{\theta}^{\infty} zn(z)\,dz = -\frac{1}{N(-\theta)}\int_{\theta}^{\infty} n'(z)\,dz = \frac{n(-\theta)}{N(-\theta)}.$$

See Maddala (1983).

As a result, the residual ϵ_{jt} is both positive on average and correlated with the independent variables x_j. In particular, a small change in the ith independent variable x_{ij} affects the residual ϵ_{jt} as follows:

$$\frac{\partial \epsilon_{jt}}{\partial x_{ij}} = -\gamma_i \frac{n(z_j)}{N(z_j)}\left[z_j + \frac{n(z_j)}{N(z_j)}\right].$$

Thus, the deviation of the truncated conditional mean of the dependent variable y_j from its unconditional mean is a function of the independent variables x_j. Consequently, the OLS and GLS estimators of the coefficients in (1) are inconsistent. The direction of this asymptotic bias can be determined only in special cases. For example, if the regression coefficient γ in (1) is a scalar and the public variable x_j is joint normally distributed with the synergistic value y_j then the least-squares estimator $\hat{\gamma}$ of γ is biased toward zero.

Thus far, outside investors have been assumed not to anticipate the merger. In fact, the event may be partially anticipated. To illustrate, suppose that the outside investors learn that the managers of firm j have identified a possible takeover target. Specifically, outsiders recognize that insiders have received private information about the proposed target, but do not know its value η_j. Conditional on the rumor, investors estimate the probability of a takeover at $\Pr(\eta_j \geq -x_j\gamma)$. That is, outsiders recognize that insiders may have received favorable private information, $\eta_j \geq -x_j\gamma$, and thus decide to merge.[8] Again, assume that outsiders regard their uncertainty about the insider's information η_j as unsystematic risk. After the rumor, but before an announcement of a takeover, outsiders expect an immediate return on the acquirer's stock equal to the expected return conditional on a merger times the probability of a merger. In this second case, competition among investors in the capital market generates around the date of the rumor the abnormal return

$$E(y_j \mid x_j) = E(y_j \mid \eta_j \geq -x_j\gamma)\Pr(\eta_j \geq -x_j\gamma) = F(x_j)N(z_j), \quad (4)$$

again with $z_j \equiv x_j\gamma/\omega$. The abnormal return around the date of the announcement is then given by the difference

$$G(x_j) \equiv E(y_j \mid \eta_j \geq -x_j\gamma) - E(y_j \mid x_j) = F(x_j)[1 - N(z_j)]. \quad (5)$$

The conditional expectation $G(x_j)$ replaces $F(x_j)$ in (3).

[8] With this simple specification, the rumor raises from 0 to 1 the probability that firm j has a potential target. More generally, a model with partial anticipation can be constructed, much as in Malatesta and Thompson (1985), in which the arrival of a rumor raises an outsider's perception of the probability of a potential target, but does not increase it from 0 to 1.

2. An Econometric Model of Horizontal Mergers

2.1 Antitrust regulation and announcement effects

Consider a firm that has identified a potential target in the same industry. As in the introductory example of Section 1, the firm's managers have both public and private information with which to evaluate the synergy from the proposed merger. Using this information, they announce a merger if and only if they assess the return on their firm's stock from the proposed merger to be nonnegative: $0 \leq y_{1j} \equiv x_j\gamma_1 + \eta_{1j}$. This specification of the firm's return matches the notation from the previous section with one modification: henceforth, the subscript 1 indicates the firm as opposed to the regulator or the court. Similarly, the statistic summarizing the acquirer's private information η_{1j} is assumed to be normally distributed with mean 0 and constant variance ω_1^2. In other words, the variables y_j, γ, η_j, and ω^2 from Section 1 are relabeled henceforth as y_{1j}, γ_1, η_{1j}, and ω_1^2.

Once a merger proposal becomes public, the regulatory authorities must either challenge the merger in court or permit it to proceed. In general, regulators act conditionally on both the public information x_j and their private information. This private information is summarized by the statistic η_{2j} that is normally distributed with the mean 0 and variance ω_2^2. If the proposed merger meets specific legal criteria that establish sufficient prima facie evidence of monopolistic intent, then the regulators challenge the merger. To model this, let γ_2 represent the weights attached by regulators to the public information x_j, and assume that a challenge occurs if $y_{2j} \equiv x_j\gamma_2 + \eta_{2j}$ exceeds a critical value, taken without loss of generality to be zero. Thus, a court challenge occurs if and only if $y_{2j} \geq 0$. In other words, the regulator focuses on statistic y_{2j} and ignores the inside information implicit in the firm's announcement, $y_{1j} \geq 0$. This simple specification with y_{2j} distinct from y_{1j} is motivated mainly by the observed divergence between the public interests of regulators and the private interests of firms. For example, governmental regulators may be concerned with the deadweight monopolistic costs created by the merger, while the acquiring firm is interested in its total monopolistic rents.

A legal challenge by the regulator is adjudicated in a court. The court has access to both public information x_j, weighted by the legal criteria γ_3, and its private information, summarized by the statistic η_{3j}. The latter variable is normally distributed with mean 0 and variance ω_3^2. The court then computes the statistic $y_{3j} \equiv x_j\gamma_3 + \eta_{3j}$ and blocks the merger whenever its estimate of the monopolistic rents created by the merger y_{3j} exceeds a critical value, again taken without loss of generality to be zero. Thus, the court blocks the proposed merger if and only if $y_{3j} \geq 0$. In general, the court need not use the same

legal criteria as the regulator in assessing the monopolistic rents from the mergers. Also, the court has public interests that diverge from the private interest of acquiring firms. Accordingly, the court is assumed to focus on the statistic y_{3j} and to ignore the inside information that is implicit in both the firm's proposal of a merger, $y_{1j} \geq 0$, and the regulator's decision to challenge the merger, $y_{2j} \geq 0$.

By assumption, the acquirer, regulator, and court have independent private information. Conditional on the public information x_j, the merger is challenged by the regulator with probability $p_{2j} = N(x_j\gamma_2/\omega_2)$, and independently blocked by the court with probability $p_{3j} = N(x_j\gamma_3/\omega_3)$. Thus, a proposed merger produces one of three possible outcomes: no challenge with probability $1 - p_{2j}$, an unsuccessful challenge with probability $p_{2j}(1 - p_{3j})$ and a successful challenge with probability $p_{2j}p_{3j}$. After a proposed merger, the acquirer's managers privately assess the abnormal return to their stock from a synergistic merger at y_{1j}, conditional on either no challenge or an unsuccessful challenge. However, if the merger is blocked by a successful challenge, then the acquirer's net gain is 0.

To value the expected synergy from the horizontal merger, the acquirer's management must forecast both the reaction of antitrust regulators as well as the legal resolution of a possible antitrust suit. Specifically, the acquirer's unconditional or expected net gain from a merger equals the sum of the three conditional gains multiplied by their associated probabilities. Assume that the acquirer's legal costs equal at most a negligible fraction of its total equity value before the acquisition. Using both their public and private information, the acquirer's managers then assess the rate of return on their firm's stock from the proposed merger as[9]

$$y^*_{1j} \equiv [(1 - p_{2j}) + p_{2j}(1 - p_{3j})]y_{1j} = (1 - p_{2j}p_{3j})y_{1j}.$$

Given this assessment, the acquirer's managers then propose a merger if and only if $y^*_{1j} \geq 0$, or, equivalently, $y_{1j} \geq 0$. In short, the managers maximize their firm's true or intrinsic value, rather than their personal utility, as in an agency model, or a weighted average of market and true values, as in many signaling models.

Abnormal returns around the announced merger depend critically on the market's prior anticipation of the announcement. Accordingly, assume first that the announced merger completely surprises outside

[9] Alternatively, the acquiring firm could incur a legal cost from a challenge. If the legal cost is a constant percentage c of the acquirer's premerger equity value, whether or not the challenge Is successful. and the proposed merger is not dropped after-the announcement of a regulatory challenge, then $y^*_{1j} = (1 - p_{2j}p_{3j})y_{1j}$. We tried this specification and estimated c as an additional parameter. The estimate was not significantly positive.

investors. Also, assume that outsiders regard their uncertainty about the insiders' assessment of their synergies from the proposed merger as unsystematic risk. Again, outsiders recognize insiders' incentives, but do not observe their private information η_{1j}. In this case, competition in the capital market generates during the announcement period the abnormal return

$$F_j^*(x_j) \equiv E(y_{1j}^* \mid \eta_{1j} \geq -x_j\gamma_1) = (1 - p_{2j}p_{3j})\left[x_j\gamma_1 + \omega_1\frac{n(z_j)}{N(z_j)}\right], \tag{6}$$

again with $z_j \equiv x_j\gamma_1/\omega_1$. This corresponds to the announcement effect without prior anticipation (2) from the introductory example of Section 1. The simple specification (6) depends critically on the presumed independence of the private information η_{ij}, $i = 1, 2, 3$.

Alternatively, outside investors may anticipate an announcement. In this second case, any abnormal return around the announcement should reflect outsiders' prior information. Specifically, outsiders should expect after a rumor, but before an announcement, that the acquirer will earn the synergistic return that corresponds to (4): $E(y_{1j}^* \mid x_j) = F_j^*(x_j)N(z_j)$. Subtracting this expression from (6) yields the abnormal return at the announcement:

$$G_j^*(x_j) \equiv F_j^*(x_j)[1 - N(z_j)]. \tag{7}$$

This corresponds to the announcement effect with prior anticipation (5) from the introductory example. The abnorma1 returns, $F_j^*(x_j)$ or $G_j^*(x_j)$, replace $F_j(x_j)$ in the pooled model (3) and form the basis for the nonlinear cross-sectional regressions in Section 3.

2.2 Cross-sectional model

The cross-sectional model, used to explain the size of the abnormal returns from announcements of horizontal mergers, has the following form:

$$x_j\gamma_i \equiv \gamma_{0i} + \gamma_{1i}\mathrm{CR}_j + \gamma_{2i}\mathrm{NR}_j + \gamma_{3i}\mathrm{VR}_j + \gamma_{4i}\mathrm{PM}_j + \gamma_{5i}\mathrm{TI}_j, \tag{8}$$

for all events $i = 1, 2, 3$, and firms $j = 1, \ldots, J$. In (8) CR and NR are the premerger values of the four-firm concentration ratio and the number of nonmerging rival firms in the major four-digit SIC industry of the target. The value ratio VR is the natural log of the maximum of the book value of the bidder's assets and the market value of its equity (if listed) divided by the corresponding maximum for the

target.[10] The payment method PM is a dummy variable with the value 1 if the method of payment is cash and/or debt and 0 otherwise. Finally, the takeover index TI is a measure of previous acquisitions in the target's major two-digit SIC industry.

As specified in (8), the acquirer's abnormal return from the announced merger reflects the structure of its industry. In general, industrial structure affects corporate conduct and thereby the value of investment opportunities. In more concentrated industries, firms are strategically more interdependent and hence may be less inclined to compete.[11] Alternatively, mergers may occur if the resulting redeployment of assets reduces operating costs, perhaps by facilitating the introduction of new technology.[12] Also, if the resources needed to generate synergistic gains are specific to the industry, then the bargaining power of bidder and target firms may be affected by the number of rivals in the industry. In each case industrial structure affects the magnitude of abnormal returns from announcements of proposed mergers. To measure this effect, the cross-sectional model (8) includes both the four-firm concentration ratio CR and the number of rivals NR in the major industry of the target.

The third explanatory variable in (8) is a measure of the relative size of the bidder and target firms. The value ratio VR is included for three reasons. First, the relative size of the bidder and target may affect the relative bargaining power of the two firms. Second, it may affect the government's decision to challenge the proposed merger, and thereby the acquirer's abnormal return at the announcement date. Finally, the relative size affects the bidder's percentage return from the acquisition, with a given dollar gain producing a smaller percentage return for large bidders. This smaller percentage return may be more difficult to detect statistically.

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[10] The book value b and stock value s are poorer instruments for the firm's unobserved size or market value v than the maximum of the book and stock values max (b, s) if

$$\max[\mathrm{cov}(b, v), \mathrm{cov}(s, v)] < \mathrm{cov}[\max(b, s), v].$$

This inequality holds if

$$\mathrm{cov}(b, v \mid b < s) < \mathrm{cov}(s, v \mid b < s),$$
$$\mathrm{cov}(b, v \mid b > s) > \mathrm{cov}(s, v \mid b > s),$$

and

$$E(v \mid b < s) = E(v).$$

The first conditional covariance can hold if the firm has either significant growth opportunities or sufficiently dated, depredated investments whenever $b < s$, whereas the second can hold if the firm has sufficient debt outstanding whenever $b > s$.

[11] Although formal models of this process have been developed for industries In which all the firms are symmetric, they are not robust to asymmetries between firms and cannot be estimated directly without additional restrictive assumptions. See Schmalensee (1985).

[12] For example, see Brozen (1982).

The fourth explanatory variable is the method of payment. Recent empirical work has shown that the form of payment affects both the level and distribution of takeover gains. For example, targets typically realize significantly higher returns in public-tender offers of cash than in exchange offers of the bidder's shares. Also, over the two-day announcement period, bidding firms in U.S. mergers have nonnegative abnormal returns with offers of cash, but significantly negative abnormal returns with offers of stock.[13] Possible explanations for this empirical evidence include different corporate and personal taxes with offers of cash versus securities, agency costs, and informational asymmetries.[14] To date no empirical study has demonstrated conclusively which theory best explains the method of payment. Accordingly, our approach is agnostic. The payment method PM is introduced purely as a proxy for the publicly observable value of the synergy that could be induced by, say, taxes or agency costs. Because this variable is arguably endogenous, the subsequent estimate γ_4, should be interpreted as a measure of the effect of $\mathbf{PM}_j$ and all unobservable characteristics of firm j that are correlated with $\mathbf{PM}_j$.

Finally, firms may differ both across industries and over time in the potential synergies from mergers. To allow for this variation, an index of recent takeover activity in the industry is included as an explanatory variable. The takeover index is computed as $\mathbf{TI} \equiv \frac{1}{2}n_0 + \frac{1}{3}n_1 + \frac{1}{6}n_2$, where n_t is the total number of takeovers in the industry t years before the proposed merger. This index is a weighted measure of previous acquisitions in the industry, with greater weight given to more recent acquisitions. The index may be interpreted as the propensity of firms in the industry to acquire targets, as reflected by the recent history of acquisitions in the industry.

3. Empirical Results

3.1 Sample

With the exception of data on the payment method PM and the takeover index TI, the sample used in this study was compiled by Eckbo (1985). The sample covers 196 horizontal mergers between July 1963 and December 1981. It is restricted to announcements in the *Wall Street Journal* of proposed mergers that were subsequently approved by the shareholders of the bidder and target.[15] The bidder was listed on the New York or American stock exchanges (NYSE or ASE), and

[13] See Huang and Walking (1987), Eckbo and Langohr (1989). and Travlos (1987).

[14] Implications of taxes for mergers are discussed in Carleton et al. (1983). and Gilson, Scholes, and Wolfson (1988). The optimal method of payment under Asymmetric information is modeled in Hansen (1987), Fishman (1989), and Eckbo, Giammarino, and Heinkel (1990).

Table 1
Sample statistics for the Independent variables in cross-sectional regressions

Variable	Mean	Median	Minimum	Maximum
		Total sample (J = 196)		
CR	43.8	37.0	5.00	99.0
NR	10.5	15.2	1.00	55.0
VR	1.77	1.64	−3.53	5.86
TI	5.65	5.00	0.00	24.0
		Challenged mergers (J = 80)		
CR	58.6	59.0	5.00	99.0
NR	4.80	3.00	1.00	29.0
VR	1.44	1.79	−3.52	5.86
TI	6.23	5.00	0.00	24.0
		Unchallenged mergers (J = 116)		
CR	33.5	31.0	6.00	94.0
NR	14.5	6.00	1.00	55.0
VR	1.99	1.83	−1.78	5.82
TI	5.32	4.00	0.00	22.0

Variables are the concentration ratios CR, the number of rivals NR, the value ratio VR, and the takeover Index TI. The total sample of 196 mergers covers the period from 1968 to 1981. The concentration ration CR is measured as a percentage for the major four-digit SIC industry of the target. The number of rivals NR arc the number of nonmerging firms in the major four-digit SIC industry of the target that arc listed on the NYSE or the ASE. The value ratio VR k the natural log of the maximum of the book value of the bidder's assets and the market value of its equity (if listed) divided by the corresponding maximum for the target. The takeover Index TI, which is available up through 1978 only, is the number of takeovers In the target's major two-digit SIC industry during the two years before the acquisition and the current year until the acquisition. Additional detail about the sample appear in Section 3.1.

the target's major economic activity was mining or manufacturing. The value ratio VR is computed from the Compustat and CRSP tapes and *Moody's* manuals, whereas the takeover index TI is compiled from the Federal Trade Commission's *Report on Mergers and Acquisitions* for 1979. The takeover index is available only for 1973-1978, a period covering 166 of the 196 horizontal mergers. Of the total sample of 196 horizontal mergers, 80 were challenged by either the Federal Trade Commission or the Department Of Justice with violating Section 7 of the Clayton Act, the major antitrust restriction on mergers in the United States since 1950. In 59 of these 80 challenges, the government successfully either blocked the proposed merger, ordered a divestiture, or imposed other costly penalties on the merging firms. The outcomes of all cases are described in the appendix of Eckbo and Wier (1985).

[15] Only a small fraction of all proposed mergers are subsequently rejected by shareholders of the merging firms. Historically, this has been especially true for horizontal mergers, in which there is evidence that abnormal returns are on average positive to bidders. See Eckbo (1985). In our model, rejections occur only if managers or shareholders receive unfavorable information after the announcement. Because managers do not have this information at the announcement date, excluding proposals that shareholders subsequently rejected does not introduce a selection bias.

Summary statistics for our sample of proposed mergers appear in Table 1. The values of the four-firm concentration ratio CR and the number of industry rivals NR in the samples of challenged and unchallenged mergers are consistent with the enforcement rules of the antitrust authorities.[16] The mean (median) levels of the concentration ratio CR are 59 percent (59 percent) in the challenged sample and 34 percent (31 percent) in the unchallenged sample. The corresponding statistics for the number of rivals NR are 5 (3) and 15 (6), respectively. By contrast, both the value ratio of the bidder relative to the target VR and the takeover index TI are similar across the challenged and unchallenged mergers.

3.2 Estimation procedures

In our sample, all proposed mergers were announced at different dates, thereby effectively eliminating contemporaneous correlation of stock returns across events. In this case only the efficiency of the estimators is improved by pooling the time-series and cross-sectional data, as in (1) and (3).[17] Hence, to simplify the computation, the following two-step procedure is employed. First, OLS is used with daily data to estimate the parameters of the market model:

$$r_{jt} = \alpha_j + \beta_j r_{mt} + \mathrm{AR}_j d_{jt} + \epsilon_{jt}. \tag{9}$$

The variables in (9) are defined as in (1). Again, the dummy variable d_{jt} equals 1 during the event period and 0 otherwise. The parameter AR, is the average daily abnormal return over the event period. As in Eckbo (1985), the estimation period is days -200 to -4, and the event period is days -3 to +3, both measured relative to the announcement in the *Wall Street Journal* at day 0.[18] With this event period, the cumulative abnormal return is computed as $\mathrm{CAR}_j \equiv 7\mathrm{AR}_j$.

In the second step the OLS estimates of the cumulative abnormal returns are used as variables in the likelihood function from which all parameters of the model are estimated. This likelihood function is the product of the likelihood functions for each of the three events (merger proposal, government challenge, and court decision). Starting with events 2 and 3, recall that the regulators challenge a merger proposed by firm j if and only if $y_{2j} = x_j'\gamma_2 + \eta_{2j} \geq 0$. In turn, the court blocks the proposed merger if and only if $y_{3j} = x_j\gamma_3 + \eta_{3j} \geq 0$. Accordingly, define the dummy variables

[16] Values of concentration ratios and market shares that trigger a Section 7 challenge appear in the *Merger Guidelines* issued by the Department of Justice in 1968 and revised in 1982.

[17] In the pooled model (3) the coefficients α and β are estimated over the entire time period, not just the nonevent period. See note 6.

[18] Using the same event period permits a comparison with Eckbo (1985). As reported in an earlier version of this paper, alternative event and estimation periods do not appear to alter out results substantially.

$$y_{ij}^* \equiv \begin{cases} 0, & \text{for } y_{ij} < 0, \\ 1, & \text{for } y_{ij} \geq 0, \end{cases}$$

for events $i = 2, 3$, and firms $j = 1, \ldots, J$. In other words, if the regulator challenges the merger, then $y_{2j}^* = 1$; otherwise, $y_{2j}^* = 0$. Similarly, if the court concurs and blocks the merger, then $y_{3j}^* = 1$; otherwise, $y_{3j}^* = 0$. Therefore, for each event $i = 2, 3$, the likelihood function is

$$L_i = \prod_{\{j: y_{ij}^* = 0\}} N\left(\frac{x_j \gamma_i}{\omega_i}\right) \prod_{\{j: y_{ij}^* = 1\}} \left[1 - N\left(\frac{x_j \gamma_i}{\omega_i}\right)\right]. \tag{10}$$

Because only the ratios γ_i/ω_i are identified in this likelihood function, no generality is lost by setting $\omega_i = 1$. The remaining event is the announcement of a proposed merger, $i = 1$. If the announcement is unanticipated, the likelihood function is

$$L_1 = (2\pi\theta^2)^{-J/2} \exp\left\{-\sum_{j=1}^{J} \frac{[\widehat{\text{CAR}}_j - F_j^*(x_j)]^2}{2\theta^2}\right\}, \tag{11}$$

where $\theta^2 = \text{var}[\widehat{\text{CAR}}_j - F_j^*(x_j)]$ and F_j^* is from (6). With prior anticipation F_j^* is replaced by the abnormal return G_j^* from (7).

As a computational approximation we use (10) to calculate the ML estimates of the probabilities p_{ij}, $i = 2, 3$, and (11) to compute γ_1, the coefficients of central interest.[19] In the nonliner optimizations the estimated parameters from a cross-sectional OLS regression are used as initial values, and local optima are eliminated by experimenting with different starting values. The standard error from this OLS regression is also used as the initial value for the parameter ω_1.

3.3 Parameter estimates

The average, estimated cumulative abnormal return $\widehat{\text{CAR}}_j$ is reported in Table 2 for both the total sample of 196 mergers and the subsample of 80 mergers that were challenged. For bidders the average CAR is approximately 1 percent in both samples, but only barely significant with the respective z- values of 1.77 and 1.85. For targets, the corresponding values are both larger, at about 11 percent, and significant in both samples.

The estimated coefficients for the regulatory challenge and legal

19 This procedure is equivalent to imposing a separability condition on the general likelihood function $L = L_1 \cdot L_2 \cdot L_3$. The condition is that the $\partial L_i/\partial p_{ij}$ at the maximum of L ($i = 2, 3$ and $j = 1, \ldots, J$). In this ease, the ML estimates $\hat{p}_{ij}$ from L also maximize the likelihood functions (10). If this condition is violated, the resulting parameter estimates contain an approximation error. Given (11), it an be shown that this approximation error is of a smaller order of magnitude for the ML estimates of γ_1 than for the ML estimates of the probabilities p_{ij}.

Table 2
Estimates of announcement-induced abnormal stock returns

Horizontal mergers (1963–1981)	Sample size	Estimated average CAR (%) 7-day window (−3 through 3)
All mergers		
Bidders	160	0.64 (1.77)
Targets	104	11.20 (15.90)
Challenged mergers		
Bidders	67	1.01 (1.85)
Targets	43	11.50 (12.6)

Summary of regression results for the model: $r_{jt} = \alpha_j + \beta_j r_{mt} + AR_j d_{jt} + \epsilon_{jt}$ where r_{jt} and r_{mt} are the continuously compounded rates of return of firm j and the value-weighted market portfolio over day t, and the dummy variable d_{jt} is 1 if day t is within the prespecified event period and 0 otherwise. The event period is day -3 through 3 relative to the announcement at day 0 of the proposed merger in the *Wall Street Journal*. The abnormal return parameter AR_j is the average daily abnormal return over the 7-day event period, and the table reports the 7-day abnormal return, $CAR_j = 7AR_j$, averaged over the total sample of horizontal mergers, 1963-1981. The numbers in parentheses are z- values. For large sample sizes J, the statistic $z = (1/\sqrt{J})\Sigma_j(\hat{AR}_j/\hat{\sigma}_{AR_j})$ is approximately normally distributed, where $\hat{\sigma}_{AR_j}$ the standard error of the OLS estimate of the abnormal return parameter AR_j.

resolution appear in Table 3. The first row contains the ML estimates $\hat{\gamma}_2$ that determine the estimated probability of a challenge by the regulators $\hat{p}_{2j}$ for each firm $j = 1, \ldots, J$. The estimated coefficients of both the concentration ratio CR and the number of rivals NR are significantly different from zero.[20] The hypothesis that the cross-sectional variables have no explanatory power is tested using the x^2 statistic.[21] The x^2 statistic of 77.2 with 3 degrees of freedom is significant at the 1 percent level. The second row contains the ML estimates $\hat{\gamma}_3$ that determine the estimated probability of success conditional on a challenge $\hat{p}_{3j}$ for each firm j. The x^2 statistic of 1.52 suggests that the variables x_j do not explain the probability of a successful challenge. As a result, the probability& is estimated using the proportion of successful challenges in the sample: $\hat{p}_{3j} = 59/80$.

For the bidding firm the estimated cross-sectional coefficients appear in Table 4. The OLS estimates of γ_1 from the cross-sectional model (8) are reported in the first row. The x^2 statistic with 5 degrees of freedom is not significantly different from zero, suggesting that the

[20] The payment method PM and the takeover index TI were found to have a negligible effect on the estimated probability of a challenge $\hat{p}_{2j}$ and were dropped.

[21] This statistic equals minus twice the difference between the unrestricted log-likelihood and the restricted log-likelihood with all parameters but the constant equal to zero. The statistic has an asymptotic x^2 distribution with degrees of freedom equal to the number of restricted parameters. See Theil (1971. p. 396).

Table 4
Cross-sectional estimates for bidders

Explanatory variables[1]								
Constant	CR	NR	VR	PM	TI	$\hat{\omega}_1$	ln L	χ^2 statistic
Standard linear model $H(x_j) = x_j\gamma_1$								
1.99E−4	4.14E−4	1.51E−4	−2.12E−4	−6.01E−4	−1.51E−3		197.5	1.38
(0.01)	(0.49)	(0.38)	(−0.05)	(−0.04)	(−0.82)			(5 df)
Model with correction for truncation bias[2] $H(x_j) = x_j\gamma_1 + \omega_1\frac{n(z_j)}{N(z_j)}$								
−.1476	−8.32E−4	−3.11E−4	8.26E−3	7.82E−2	−4.64E−3	4.63E−2	205.6	17.6*
(−8.84)	(−2.18)	(−0.77)	(1.48)	(1.61)	(−1.81)	(6.12)		(6 df)
Model with correction for truncation bias and prior anticipation[2] $H(x_j) = \left[x_j\gamma_1 + \omega_1\frac{n(z_j)}{N(z_j)}\right][1 - N(z_j)]$								
.164	−4.54E−3	−2.78E−3	4.14E−2	.142	−9.72E−3	4.74E−2	208.8	24.0*
(3.18)	(−3.47)	(−0.96)	(2.34)	(1.87)	(−3.52)	(3.85)		(6 df)

ML estimates of the coefficients γ_1 and the standard deviation of managers' private information ω_1 in three cross-sectional models of the form

$$\mathrm{CAR}_j = (1 - p_{2j}p_{3j})H(x_j) + \epsilon_j, \qquad j = 1, \ldots, J,$$

where CAR, Is the abnormal stock return to bidder j relative to the merger proposal announcement, p_{2j} is the probability of a government challenge, p_{3j} is the probability that the challenge will be successful, and x_j is a vector of explanatory variables. The first model is the standard linear model estimated using OLS, which does not correct for truncation bias. The second model adjusts for truncation bias, whereas the third model also adjusts for the possibility of prior anticipation of the merger event. Total sample of 145 listed bidden, 1963-1978. The procedure for estimating CAR_j is given in Table 2. p_{2j} is computed as $N(x_j\hat{\gamma}_2)$ using the values from the first row of Table 3. p_{3j} is set equal to the sample proportion 59/80 since $\hat{\gamma}_3$ in Table 3 is insignificantly different from zero. For each firm, prior to the estimation, the dependent and independent variables are standardized by the standard error of the market model regression used to generate CAR, The nonlinear models are estimated using the likelihood function L_t in expression (11), using the OLS estimates of the coefficients as initial (starting) parameter values. The normal distribution is approximated to nine digits. The numbers in parentheses are t -values for the linear model and asymptotic t- values for the nonlinear model.

[1] The payment method PM is 1 if the payment is ash and/or debt and 0 otherwise. The remaining variables are defined In Table 1. The takeover Index TI is available only up through 1978-thus, the somewhat shorter sample period in this table.

[2] $z_j = x_j\gamma_1/\omega_1$.

* Significant at the 1% level.

lihood ratio test of Vuong (1989). Under the null hypothesis that both models fit the data equally well, Vuong shows that the difference in the maximum log-likelihood values of the models, appropriately standardized, has a standard normal distribution in large samples. The test is a comparison of two nonnested models, neither of which need be correct. For bidders, the test statistic has a value of 0.92. Thus, the null hypothesis of equal fit for the nonlinear models with and without rumors cannot be rejected.

As an informal check on the importance of truncation bias, the nonlinear model for bidders is applied to targets. For targets the estimated coefficients of the cross-sectional model (8) appear in Table 5. The first row of the table contains the OLS estimates, whereas the second row contains the ML estimates for the announcement effects without prior anticipation (6).[23] Also, the two sets of estimated coefficients have the same signs at similar levels of significance. The values of the log-likelihoods and x^2 statistics are nearly identical, and the latter are significant at the 5 percent level. Also, the estimated standard deviation of the residual representing inside information in the nonlinear model $\hat{\omega}_1$ is insignificantly different from zero. Apparently, the nonlinear model adjusted for truncation bias has no additional explanatory value for targets.

These results are consistent with the hypothesis that managers of bidders, but not targets, are privately informed about the potential synergies from proposed mergers. In particular, the results do not contradict the proposition that outside investors react rationally to self-motivated revelation of inside information through public announcements of proposed mergers by managers of bidding firms-with or without rumors. That is, when reacting to voluntary public announcements of proposed mergers, investors in the capital market appear to recognize that the managers of bidders, but not targets, have valuable private information. Relatively uninformed investors then use their knowledge of managers' incentives to infer some of the private information implicit in public announcements. In short, truncation bias helps to explain announcement effects for bidders, but not for targets.

The individual parameter estimates from the nonlinear models are interesting. The estimated coefficient of the four-firm concentration ratio CR is significantly negative for bidders and significantly positive for targets. The estimated coefficient of the number of rivals NR is insignificantly different from zero for bidders and significantly negative for targets. Collectively, these results are consistent with the

[23] Econometrically, it is difficult to predict targets in takeovers using publicly available information. See Palepu (1986). As a result, we do not present estimates of the partially anticipated announcement (7).

Table 5
Cross-sectional estimates for targets

Explanatory variables[1]								
Constant	CR	NR	VR	PM	TI	ω_1	ln L	χ^2 statistic
Standard linear model $H(x_j) = x_j\gamma_1$								
−6.40E−3	6.00E−3	−3.70E−3	2.20E−2	1.35	−2.30E−3		37.14	14.02*
(−0.07)	(2.08)	(−3.01)	(1.45)	(2.71)	(−0.37)			(5 df)
Model with correction for truncation bias[1] $H(x_j) = x_j\gamma_1 + \omega_1\frac{n(z_j)}{N(z_j)}$								
−6.20E−3	5.32E−3	−2.86E−3	2.09E−2	0.129	−1.86E−3	−3.16E−3	37.17	14.08*
(−0.84)	(3.98)	(−3.04)	(1.77)	(2.65)	(−0.27)	(−0.42)		(6 df)

ML estimates of the coefficients γ_1 and the standard deviation of managers' private information ω_1 in two cross-sectional models of the form

$$CAR_j = (1 - p_{2j}p_{3j})H(x_j) + \epsilon_j, \qquad j = 1, \ldots, J,$$

where CAR_j is the abnormal stock return to target j relative to the merger proposal announcement, p_{2j} is the probability of a government challenge, p_{3j} is the probability that the challenge will be successful, and x_j is a vector of explanatory variables. The first model is the standard linear model estimated using OLS, which does not correct for truncation bias; whereas the second model corrects for truncation bias. Total sample of 80 listed targets, 1963-1978. See Table 4 for definition of variables and details of the estimation procedure.

[1] $z_j = x_j\gamma_1/\omega_1$.

* Significant the 5% level.

hypothesis that the relative bargaining power of the target is higher in concentrated industries. For both bidders and targets, the estimated coefficients of the value ratio VR and the payment method PM are positive in the nonlinear models. The significantly positive effect of cash or debt versus equity in the model with prior anticipation is consistent with the empirical evidence of Travlos (1987), for bidders in mergers, and Huang and Walkling (1987) and Eckbo and Langohr (1986), for targets in tender offers. Finally, the coefficient of the takeover index TI is significantly negative for bidders and indistinguishably different from zero for targets. This is consistent with the hypothesis that investors are uninformed about the identities of the targets. Suprisingly, for the sample of bidders the coefficient of TI is affected by the adjustment for prior anticipation-the difference between the second and third rows in Table 4. Evidently, the takeover index TI does more than determine the market's prior probability of a takeover bid. One possible explanation is that, other things equal, rents to bidders are on average lower in industries with higher acquisition frequencies. Perhaps the resources required for mergers are partly specific to industries, rather than firms, resulting in lower returns to bidders in industries with previous takeovers.

4. Conclusions

Many recent event studies include OLS and GLS estimates of parameters in cross-sectional models. These estimates are used to explain the magnitude of abnormal stock returns around corporate announcements. In fact, abnormal returns around announcements require that managers have valuable private information prior to their public actions. Also, managers must have an incentive to initiate voluntary corporate events, such as proposed mergers. In this case, investors rationally use both announcement events and their knowledge of managers' incentives to infer inside information. Given this relationship in voluntary events between private information, insiders' incentives, and outsiders' inferences, standard OLS or GLS estimates of cross-sectional coefficients are asymptotically biased. In this article, the bias is avoided by using nonlinear estimators that are familiar from the literature on limited dependent variables. Specifically, ML estimators are applied to a model of horizontal mergers, which is consistent with the requirements of limited dependent variables.

Inferences from the OLS and ML estimators are shown to differ dramatically. For bidders, the standard OLS estimates of the cross-sectional parameters are generally insignificant, whereas the ML estimators of the nonlinear model are significant. For targets, the linear and nonlinear estimates are virtually identical. This result is consis-

tent with the hypothesis that managers of bidders, but not targets, have private information about potential synergies from proposed mergers. These estimates suggest that the gains to bidders from horizontal mergers decrease with the size of the bidder relative to the target, the concentration of firms in the industry, and the number of previous takeovers in the industry. The gains to targets increase with concentration and decrease with the number of rival firms in the industry. Finally, there is evidence that the gains of both the bidder and the target are higher with offers of cash versus stock. These empirical results regarding gains to bidder firms follow from the ML estimators, which correct for truncation bias, but not from the standard OLS estimators.

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