American Finance Association

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Source: *The Journal of Finance*, Vol. 43, No. 2 (Jun., 1988), pp. 413-429
Published by: Blackwell Publishing for the American Finance Association
Stable URL: http://www.jstor.org/stable/2328468
Accessed: 26/11/2009 07:36

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THE JOURNAL OF FINANCE • VOL. XLIII, NO. 2 • JUNE 1988

A Generalized Econometric Model and Tests of a Signalling Hypothesis with Two Discrete Signals

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ABSTRACT

To test the major prediction of a signalling hypothesis—that the market price is monotonic in the signal—the price response to the signal must be measured. Since a signal is an outcome of a rational decision rule of the signaller, the market can infer the true type of the signaller from the signal. This necessitates estimation of the price response to the signal, conditional on the rational decision rule. Thus, the empirical models (e.g., event studies in corporate finance) that estimate the market price responses to signals without conditioning on the rational decision rules are misspecified if viewed as tests of the prediction of a signalling hypothesis. This paper builds a generalized econometric model with two possible discrete signals, derives the rational decision rules, presents a simple estimator of the price response to a signal, and illustrates its use in testing a recently expounded hypothesis that firms signal their true value by forcing or not forcing an outstanding convertible bond.

SIGNIFICANT DEVELOPMENT HAS TAKEN place in the theory of signalling as well as its applications. Spence [31] was the first to develop the theory of signalling for the job market where a less-productive worker (lower type) finds it costly to mimic a more-productive worker (higher type) in acquiring more education. The job market, which does not observe the workers' true types, responds to this situation and offers a higher wage to a worker with more education than to the one with less education. Independently, Rothschild and Stiglitz [30] developed a similar model for the insurance market. Riley [28] builds on these concepts to give general conditions for a signalling equilibrium. Many applications of the signalling paradigm have appeared in corporate finance. For example, managers are hypothesized to signal the true value of a firm through (a) capital structure (Ross [29]) or (b) dividends (Bhattacharya [4], John and Williams [20], and Miller and Rock [26]), or the true value of a project through equity holdings (Leland and Pyle [24]). Recently, Harris and Raviv [13] hypothesized that managers signal the true prospects of the firm by forcing or not forcing a conversion of an outstanding convertible bond. Despite the seriousness of the signalling hypotheses expounded in these important papers, very little has been done to test them.

What is testable in a signalling hypothesis? The major predictions of a signalling hypothesis are (I) the informationally consistent equilibrium price function is monotonic in the signal and (II) the signal is monotonic in the true

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type. For designing a test of (II), e.g., in case of job-market signalling, we must obtain data on the workers' types *before* they acquire education. Such data are, however, unobservable.[1] We may obtain data on the workers' types after they have acquired education. However, since the workers' types, so obtained, may have evolved directly due to education, a test of positive correlation between the workers' ex post type and their education would not be a powerful test of (II), i.e., of the hypothesis that a higher type worker chooses a higher education. Thus, a test of (II), as such, appears impossible.[2] Therefore, the major testable implication of a signalling hypothesis is (I). To test (I), we must estimate the market wage paid in response to the chosen level of education since the entire wage does not come from education alone. To do so, the market wage paid in response to education should be estimated conditional on the rational signalling (decision) rule that defines a worker's level of education.

I am not aware of a formal test of the job-market signalling hypothesis. There have been, however, attempts to estimate stock price responses to corporate events, e.g., to an increase in dividend payout. If a signalling equilibrium can be shown to exist in the stock market with the events as signals, then one wonders whether the standard event study should be viewed as a test of (I). Viewing it so is incorrect since the price responses in the standard event-study models are not estimated conditional on the signaller's (managers') decision rules that rationally define the signals.[3] Thus, as a procedure for testing implication (I), the standard model of corporate event study is misspecified.

This paper (a) builds a generalized econometric model with two possible discrete signals, (b) defines the rational signalling rules, and (c) presents a simple estimator of the price response to a signal. This model is useful to formulate and test not only the existing signalling hypotheses but also new ones in a time-series framework.[4] We illustrate its use in testing a recently expounded hypothesis that firms signal their true value by forcing or not forcing an outstanding convertible bond. We chose to test the convertible-bond call signalling hypothesis, originally

[1] Observability of the ex ante true type at once nullifies the informational asymmetry assumed in a signalling model.

[2] Ofer and Siegel [27] attempt to test the dividend signalling hypothesis by measuring the correlation of the earnings forecast error with the dividend change. To view theirs as a test of (II), one has to implicitly assume, in their model, that the one-period earnings forecast error (realized ex post) is a proxy for the true ex ante value of the firm's stock (more precisely, its surprise component). This assumption would not appear reasonable since the true type is perhaps "some" function of all future earnings. The (publicly known) correlation of the dividend change with the earnings forecast error, however, yields a price effect on the announcement of the dividend change. Thus, measuring the correlation is a direct test of dividend-announcement effect, i.e., of (I). For other interesting aspects of their test, see Ofer and Siegel [27].

[3] Detailed discussion of the standard model of event study, originally devised by Fama, Fisher, Jensen, and Roll [11], can be found in Brown and Warner [6, 7]. The estimator of stock price response, derived in the event study model of Acharya [3], accounts for decision rules of the manager. Those decision rules are, however, not derived as here from a model of signal equilibrium.

[4] To apply this model for estimating and testing models of informational equilibria for a signal with a continuum of possible values, the continuous signal will have to be discretized. For example, to test the job-market signalling model, we must define two possible levels of education, say, "high" and "low". For testing with the continuous signal as such, i.e., without such discretization, see Acharya [1].

suggested by Harris and Raviv, because it has two possible discrete signals ("call" and "no call" of an outstanding convertible bond), obviating the need to discretize a continuous signal in another hypothesis. The other interesting aspects of this hypothesis are discussed in the text later. We do the tests of implications of the convertible-bond call signalling hypothesis using the generalized econometric model proposed in this paper. Thus, although ours is a test of the implications of the Harris-Raviv signalling hypothesis of call policy, it is not an exact test of their model.

The rest of the paper is organized as follows. Section I describes a model of a signalling equilibrium with two discrete signals. Section II builds an econometric formulation of the signalling hypothesis and its tests. This section describes the decision rules, conditional prices, tests of the implication of a signalling equilibrium, and the estimation procedure. Section III tests the implications of the signalling hypothesis of convertible-debt call policy. Section IV concludes.

I. A Model of Signalling Equilibrium with Two Discrete Signals

In this section, we develop a simple model of informational equilibrium to test signalling paradigms in corporate finance. Extending this model to formulate other signalling hypotheses, e.g., the job-market signalling hypothesis, is trivial.

Consider that the manager of a firm must choose one of two possible actions (signals), $s = l$ (low) and $s = h$ (high), $h > l$, immediately after receiving private information at time τ ($t - 1 < \tau \leq t$). We assume that the manager's private information is a draw of nature denoted by $\omega \in \Omega$. To define an equilibrium for the binomial signals, h and l, we partition the space of the manager's private information into message $m = G$ (good) and $m = B$ (bad) such that $G \cup B = \Omega$ and $G \cap B = \{\emptyset\}$. Let $p(m)$ be the investors' prior (at $t - 1$) probability belief that the manager's message is m ($m = G, B$); let $p(s \mid m)$ be the probability that the manager issues signal s ($s = h, l$), given message m ($m = G, B$); and let $q(m \mid s)$ be the investors' posterior probability belief [with which they infer from the signal s ($s = h, l$)] that the manager's private message is m ($m = G, B$). In order to choose a strategy, $p(s \mid m)$, over $\{h, l\}$, the manager is assumed to maximize his or her wage in the period $(t - 1, t]$. Let the manager's wage be $W(s, \omega)$ if he or she issues signal s and his or her private information is ω. We assume that this wage function is an additive concave increasing function of the stock prices at signal time, τ, and t:

$$W(s, \omega) = w[P(s)] + w[\tilde{P}(s, \omega)], \quad (s = h, l), \tag{1}$$

where $w[\cdot]$ is a concave function, increasing in its argument, $P(s)$ is the stock price, conditional on signal s, at time τ, and $\tilde{P}(s, \omega)$ is the stock price at t, observed conditional on signal s.[5]

Let the firm's true value per share, given the manager's private information ω and signal s, be $v(s, \omega)$. The nature of this true value per share $v(s, \omega)$, with

[5] Such a wage function is commonly assumed in dynamic signalling models. (See, e.g., Miller and Rock [26], p. 1042, for a discussion of this type of a function, and Harris and Raviv [13], footnote 10, p. 1267).

respect to the manager's private information and signal, is crucial for the existence of a signalling equilibrium. For example, in the dividend signalling model, interpreted in our framework, we have (a) $v(l, \omega) - v(h, \omega) \geq 0$, $\forall \omega \in \Omega$, and (b) $v(l, g) - v(h, g) < v(l, b) - v(h, b)$, $\forall g \in G$ and $\forall b \in B$, where h denotes an "increase in dividend payout" and l denotes "no change in dividend payout." (See, e.g., Bhattacharya [4] for a discussion of this cost.) The condition (a) means that increasing the signal (from l to h) is costly, and (b) means that such a cost increases if the quality of message worsens (from G to B). Given this structure of the true value per share, we show the existence of a signalling equilibrium in our generalized model. It will be clear later that the test of implications of a signalling hypothesis is a test of existence of this crucial structure of the true value per share with respect to the signal and the manager's private information. To build the model in a time-series framework, we assume that the realized true value per share at t is $v(s, \omega)$ plus a noise η where, given ω and s, $\eta \sim N(0, \sigma^2)$. We also make a commonly made assumption that the investors price the stock by conditional expectation of the true value per share, given all their information. Then, the stock price observed conditional on s at time t, $\tilde{P}(s, \omega)$, is given by

$$\tilde{P}(s, \omega) = v(s, \omega) + \eta, \tag{2}$$

and the market price per share, conditional on issuance of signal s ($s = h, l$) at τ, $P(s)$, is given by

$$P(s) = \textstyle\sum_{m=G,B} q(m \mid s)\mathrm{E}[v(s, \omega) \mid m], \quad (s = h, l), \tag{3}$$

where $\mathrm{E}[\cdot \mid \cdot]$ is the expectation operator, conditional on information of investors immediately after the signal-announcement time τ. We then define an informational equilibrium using the concepts of sequential equilibrium that follow Kreps and Wilson [21] and are related to Harris and Townsend [14]. By using the concepts of sequential equilibrium, we not only define an informational equilibrium for discrete signals, similar to the equilibrium for a continuum of signal values defined by Riley [28], but also ensure that the probability beliefs of the investors, given the strategies of the manager, are consistent with Bayes' rule.

Definition of a Signalling Equilibrium: The equilibrium consists of (a) the investors' probability beliefs and (b) the manager's strategy such that (a) and (b) are together consistent with Bayes' rule:

$$q(m \mid s) = p(m)p(s \mid m)/[p(s \mid G)p(G) + p(s \mid B)p(B)], \quad (m = G, B). \tag{4}$$

(a) *Investors' Beliefs*: The investors believe with probability 1 that the manager issues signal h (l) if the manager's private message is G (B); that is,

$$q(G \mid h) = 1 = q(B \mid l). \tag{5}$$

(b) *Manager's Strategy*: The manager issues signal h (l) if and only if his or her information is G (B); that is,

$$p(h \mid G) = 1 = p(l \mid B). \tag{6}$$

THEOREM: *There exist* (a) *a nondegenerate prior probability* $p(G)$ $(0 < p(G) < 1)$ and (b) *a wage function* $w(\cdot)$ *such that* (i) *the investors' posterior probabilities* (5) *and the manager's strategy* (6) *are consistent with Bayes' rule* (4), (ii) *the manager's strategies* (6) *are optimal with respect to* (1), *and* (iii) $P(h) > P(l)$.

Proof: See the Appendix.

We next give an econometric characterization of the equilibrium implications and define the tests.

II. Econometric Formulation of the Signalling Hypothesis and Tests

The manager's expected incentive (extra wage) of issuing signal h over that of issuing l, given the private information ω, is

$$y(\omega) \equiv \mathrm{E}^M[W(h, \omega)] - \mathrm{E}^M[W(l, \omega)], \tag{7}$$

where $\mathrm{E}^M[\cdot]$ is the mathematical expectation given ω. To the econometrician, $y(\omega)$ in (7) is a latent random variable in the signalling paradigm. For simplicity and tractability, we assume that y is a normal random variable generated by the sigma-algebra over the manager's latent information space Ω. Let $t = u + \xi$, where u is the outsiders' prior (at $t - 1$) expectation of y. Then it follows that ξ is a normal random variable with zero mean, given the outsiders' prior information at $t - 1$.

A. Decision Rules

The informational equilibrium, in the simplest terms, yields a partition of the manager's information space Ω—messages G and B:

$$G \equiv \{\omega \mid y(\omega) \geq 0\} \quad \text{and} \quad B \equiv \{\omega \mid y(\omega) < 0\}. \tag{8}$$

Clearly, (8) is sufficient for the manager to issue signal h (l) whenever his or her private information $\omega \in G$ ($\omega \in B$). Since the investors interpret these signals correctly, observations of signals h or l reveals whether $y \geq 0$ or $y < 0$. Using $y = \xi + u$,

$$h \quad \text{occurs if and only if} \quad \xi \geq -u, \tag{9}$$

and

$$l \quad \text{occurs if and only if} \quad \xi < -u.$$

For convenience that will be clear later, we divide both sides of the inequalities (9) by the standard deviation of ξ such that the resulting ξ has unit variance. The rational decision rules (9) imply existence of a stock price function $P(s)$ such that

$$P(h) > P(l), \tag{10}$$

which is the implication (I) of the signalling hypothesis, discussed in the introduction. If the prices, $P(s)$, $s = h, l$, can be estimated conditional on the signals, i.e., on the market's expectations of the manger's decision rules (9), then the implication (10) can be easily tested. Rejection of (10) clearly implies a rejection of (9).

The standard model of event study, originally devised by Fama, Fisher, Jensen, and Roll [11], measures stock price response to an event, e.g., the convertible-bond call announcement, merger of corporations, corporate earnings announcements, stock splits, and government regulatory policy changes. Some of these events have been modeled as credible signals that the corporate manager uses to convey the true prospect of the firm to the market. Examples of such signalling theories include the convertible-bond call signal and increase in dividend payout. The standard event-study model, which measures the stock price response to such a signal (treated as an event) *without* conditioning on the signalling rules (9), cannot be construed as a test of the signalling paradigm.

B. Conditional Prices

Testing of the implication (10) can be equivalently achieved by a test of $[P(h) - P']/P' > [P(l) - P']/P'$, where P' is the stock price at $t - 1$. From (2) and (3), $[P(s) - P']/P' = \mathrm{E}[(\tilde{P}(s, \omega) - P')/P' \mid s] \equiv \mathrm{E}[R_s \mid s]$, where R_s is the rate of return (henceforth just "return") to the stock of the firm, observed conditional on the signal s over time period t. Hence, a test of (10) is a test of $\mathrm{E}[R_h \mid h] > \mathrm{E}[R_l \mid l]$. In doing this test, we recognize that marketwide movements cause a component of the stock return so that

$$R_s = \mu + \varepsilon_s, \tag{11}$$

where μ, the "normal return", is determined by marketwide movements in stock returns and is thus unrelated to the signal s, and ε_s, the "abnormal return", is (possibly) related to the signal.[6] We assume that ε_s is a stationary random variable with $\mathrm{E}(\varepsilon_s) = 0$, $s = h, l$. Our test reduces to a test of $\mathrm{E}[\varepsilon_h \mid h] > \mathrm{E}[\varepsilon_l \mid l]$.

Let R denote the return and ε denote the abnormal return to the stock in a random sample, picked without any selection rule over the issuance of signals h or l. In other words,

$$R = I_h R_h + I_l R_l \tag{12}$$

and

$$\varepsilon = I_h \varepsilon_h + I_l \varepsilon_l, \tag{13}$$

where $I_h = 1$ if and only if the firm chooses the signal h, and $I_h = 0$ otherwise, and where $I_l = 1 - I_h$. To preclude arbitrage opportunities in the stock market, we assume that[7]

$$\mathrm{E}(\varepsilon) = 0. \tag{14}$$

[6] Note that μ can be more specifically defined to be a linear function of the return on a market index or of the marketwide factors. Also, the coefficients (e.g., the market 'beta') in such a definition can be dependent on the signal.

[7] If $\mathrm{E}(\varepsilon) \neq 0$, then an arbitrageur can form an investment strategy to obtain more than the expected rate of return, μ.

Since, by the projection theorem, we can write $\varepsilon_s = \mathrm{E}[\varepsilon_s \mid s] + \nu_s$, where $\mathrm{E}(\nu_s \mid s) = 0$, we have, from the definition (13) of ε, $\varepsilon = \sum_{s=h,l} \mathrm{E}[\varepsilon_s \mid s]I_s + \nu$, where $\nu \equiv \sum_{s=h,l} \nu_s I_s$. Then, the stock-return model becomes

$$R = \mu + \textstyle\sum_s \mathrm{E}[\varepsilon_s \mid s]I_s + \nu. \tag{15}$$

For simplicity in estimation, we assume that the stock return is stationary, conditional on marketwide factors (that determine μ) and the signal. This assumption implies that ν is stationary over time.[8] Also for estimation, we need to derive explicit expressions for $\mathrm{E}[\varepsilon_s \mid s]$ in (15). Since ε_s and ξ are stationary random variables, the projection theorem guarantees that (noting that ξ has unit variance) $\varepsilon_s = \mathrm{cov}(\varepsilon_s, \xi)\xi + \zeta$, where $\mathrm{E}(\xi \mid \zeta) = 0$. Then letting $\pi_s = \mathrm{cov}(\varepsilon_s, \xi)$, $\mathrm{E}[\varepsilon_h \mid h] = \pi_h \mathrm{E}[\xi \mid \xi > -u] = \pi_h \phi(-u)/[1- \Phi(-u)] = \pi_h \phi(u)/\Phi(u)$, using the symmetry of the normal distribution of ξ. Similarly, $\mathrm{E}[\varepsilon_l \mid l] = -\pi_l \phi(-u)/\Phi(-u) = -\pi_l \phi(u)/[1 - \Phi(u)]$. Notice that, to guarantee (14), i.e., $0 = \mathrm{E}(\varepsilon) = \sum_{s=h,l} \mathrm{E}(\varepsilon_s \mid s)\mathrm{pr}(s) = 0$, we have (using the above expressions) $\pi_h = \pi_l \equiv \pi$. Thus, defining

$$d_h \equiv \phi(u)/\Phi(u) \quad \text{and} \quad d_l \equiv -\phi(u)/[1 - \Phi(u)], \tag{16}$$

we have

$$[P(s) - P']/P' = \mathrm{E}[\varepsilon_s \mid s] = \pi d_s, \quad (s = h, l). \tag{17}$$

Plugging the formulas (17) for $\mathrm{E}[\varepsilon_s \mid s]$ in (15):

$$R = \mu + \pi[d_h I_h] + \pi[d_l I_l] + \nu. \tag{18}$$

C. *Tests of the Signalling Hypothesis*

The testable implication (10), equivalent to $[P(h) - P']/P' > [P(l) - P']/P'$, thus reduces to a test of [using (17)] $\pi d_h > \pi d_l$ in model (18). Since it is clear from (16) that $d_h > 0$ and $d_l < 0$, we just need to test whether $\pi > 0$ in model (18).

D. *Estimation*

To estimate π in model (18), we need to characterize d_h and d_l, which are functions of u, i.e., of the investors' expectations of the manager's differential incentive y. For a simple chacterization of u_{it} (for firm i at time $t - 1$), we assume that the investors' expectations about y_{it} are homogenous and linear in their information. We consider a vector of variables z_{it} in the investors' prior (at $t - 1$) information set that are relevant to the signal. (Note that we avoid suffixes, $t - 1$, for brevity.) Then

$$u_{it} = \mathrm{E}(y_{it} \mid z_{it}) = \theta' z_{it}, \tag{19}$$

where θ is a conforming vector of coefficients.

Using (19), we can estimate π in (18) by full-information maximum-likelihood estimation. (See, e.g., Heckman [15] or Lee [23].) Simpler consistent estimation

[8] The assumption is similar in spirit to the one employed by other researchers. (See, e.g., Gibbons [12].)

of these quantities in two stages is, however, possible. Considering a sample of firms ($i = 1, \cdots, N$) over a period ($t = 1, \cdots, T$), we estimate, in the first stage, the prior probability of signal h, $\Phi(u_{it})$, by maximizing the following likelihood function:

$$L = \prod_{\{I_{hit}=1\}} \Phi(\theta' z_{it}) \prod_{\{I_{lit}=1\}} [1 - \Phi(\theta' z_{it})],$$

where $I_{hit} = 1$ if and only if h occurs for firm i at time t and $I_{hit} = 0$ otherwise; $I_{lit} = 1 - I_{hit}$. Using $u_{it} = \theta' z_{it}$, we estimate d_{hit} and d_{lit}, defined in (16). In the second stage, we estimate π using the maximum-likelihood estimates of d_{hit} and d_{lit} in (18) by OLS or by GLS. Thus, in the second stage, we run the following regression:

$$R_{it} = \mu_{it} + \pi[I_{hit}\hat{d}_{hit}] + \pi[I_{lit}\hat{d}_{lit}] + v_{it}, \tag{20}$$

where $v_{it} = \pi[I_{hit}(d_{hit} - \hat{d}_{hit})] + \pi[I_{lit}(d_{lit} - \hat{d}_{lit})] + \nu_{it}$. The two-stage method, presented here for our model with panel data,[9] is a variant of the two-stage method proposed for the cross-sectional models by Heckman [15] or Lee [22]. The Heckman-Lee two-stage method will make two groups: one with the observations, irrespective of their times of occurrence, for all $I_{hit} = 1$ and the other for all $I_{lit} = 1$. Their method will then estimate two separate regresions, one for each group. It cannot incorporate any possible cross-sectional covariance of v_{it} in (20) since the same firm i may not remain in the same group over the entire sample period. Importance of the cross-sectional covariance of the error in the stock return, v_{it}, is discussed by Gibbons [12]. Also, the Heckman-Lee method of estimating one such model (20) for each group cannot guarantee the specification $E(\varepsilon_{it}) = 0$ in (14).[10]

Asymptotic consistency and normality of the estimator of π in the model (20) follows since $\hat{d}_{hit}$ and $\hat{d}_{lit}$ are maximum-likelihood estimates of d_{hit} and d_{lit} and Slutsky's theorem applies.[11] It is easy to see that the estimator of the variance matrices of the errors in (20), under the seemingly-unrelated-regressions framework (GLS), are the ones estimable by any package that does GLS.[12] For simplicity, however, the second-stage models (20) can be estimated under OLS.

III. Test of the Convertible-Bond Call Signalling Hypothesis

Recent literature in corporate finance reports two important theoretical predictions about the convertible-bond call behavior under a perfect market. The same literature, however, empirically rejects those predictions, giving rise to two interesting puzzles. The first puzzle is related to the perfect-market prediction of Brennan and Schwartz [5] and of Ingersoll [18] that it is optimal for the firm to call the convertible bond as soon as is feasible. Ingersoll [19], however, finds that firms actually call a convertible when the conversion value far exceeds the

[9] It is the same as that proposed in Acharya [2] and used in Acharya [3].

[10] See Acharya [2].

[11] Proofs of consistency of estimators of coefficients in the second-stage regression (20) will be similar to those in any two-stage estimation procedure. (See, e.g., Heckman [17].)

[12] Acharya [2] formally derives this result by following Lee [22] and Dhrymes [10].

call price and that the market imperfections such as transactions costs, existence of a notice period, and corporate income taxes do not explain this call behavior.[13] The second puzzle is as follows: since calling the convertible bond transfers the conversion-option value from the convertible holders to the stockholders, the investors should respond to the transfer of the conversion-option value by bidding up the share price. Mikkelson [25], however, documents that there is a significant decline in the stock price around the call-announcement date.[14] Harris and Raviv explain these puzzles in a model where the manager knows more than the market. According to Harris and Raviv, the corporate managers call an outstanding convertible when they expect to give to the convertible holders less by forcing a conversion than by not forcing. This, everything else equal, will occur when the managers' private information indicates a sufficiently bad prospect of the firm because then a forced conversion will make the convertible holders share the bad prospect rather than exercise their option (not to convert) to have a higher straight-bond value. If the managers are known to follow this strategy consistently, then the rational investors will interpret the call action accordingly and bid down (up) the stock price whenever a call announcement (postponement) occurs. A test of the untested implications of the convertible-bond call signalling hypothesis is very important toward resolving the puzzles.

A. *Testable Implications*

The Harris-Raviv convertible-debt call hypothesis, in light of the above discussion, implies

(i) a negative expected abnormal stock return on a convertible-bond call announcement and
(ii) a positive expected abnormal stock return on a convertible-bond call postponement.

A third implication of the Harris-Raviv hypothesis follows from the condition that will guarantee credibility of the convertible-bond call signal. For the signal to be credible, the manager must call the bond as soon as the bad information is received. Harris and Raviv show that this can be ensured if the following is true:

(iii) the expected abnormal stock return on call announcement is more negative the longer the delay in calling, reckoned from the first feasible date.

[13] The median firm in Ingersoll's [19] sample waits until conversion value exceeds the call price by as much as 43.9 percent. The violation of the theoretical prediction is further corroborated by Constantinides and Grundy's [9] sample of 756 firms in which conversion value exceeds call price by more than fifty percent for twenty-three percent of the convertibles, more than eighty percent for twelve percent of the convertibles, and more than 175 percent for almost three percent of the convertibles.

[14] Note that Mikkelson [25] estimates the call-announcement effect but not the call-postponement effect. In his study, the average stock return during the two-day call-announcement period is −1.065 percent per day against +0.054 percent per day during the fifty-day control period beginning eleven days after call announcement. This measure of the call-announcement effect, however, is not estimated conditional on rational decision rules of the manager that structurally define the call-announcement/postponement signals in the Harris-Raviv hypothesis.

Mikkelson estimates the call-announcement effect but not the call-postponement effect. Also, Mikkelson's procedure does not estimate the stock price effect conditional on the rational decision rules of the manager. Thus, Mikkelson's testing procedure, viewed as a test of the implications of the Harris-Raviv signalling hypothesis, is misspecified.[15] Here we do tests of (i), (ii), and (iii) by estimating price responses to the signals, conditional on the rational decision rules of the manager.

B. Empirical Formulation of the Tests

To test (i), (ii), and (iii), we first build a model to specify μ in (20). We do so by assuming that the following market model generates the return to a stock:

$$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it}, \quad \forall i, \tag{21}$$

where R_{mt} is the return to the market portfolio,[16] $\beta_i = \mathrm{cov}(R_{it}, R_{mt})/\mathrm{var}(R_{mt})$, and α_i is the intercept. We further assume that the Sharpe-Lintner version of the capital asset pricing model holds cross-sectionally over any time period:

$$\mathrm{E}(R_{it}) = R_{ft} + \beta_i[\mathrm{E}(R_{mt}) - R_{ft}], \tag{22}$$

where R_{ft} is the risk-free rate. Taking the expected value of R_{it} in (21) and using (22) to eliminate α_i yields

$$R_{it} - R_{ft} = \beta_i(R_{mt} - R_{ft}) + \varepsilon_{it}.$$

For the empirical work, we treat μ_{it} in (20) as the normal return equal to $\beta_i(R_{mt} - R_{ft})$ and R_{it} in (20) as the excess return (over the risk-free rate) on the stock. In the first stage, we estimate d_{hit} and d_{lit}, and, in the second stage, we use the maximum-likelihood estimates $\hat{d}_{hit}$ and $\hat{d}_{lit}$ to estimate the following model:

$$R_{it} - R_{ft} = \beta_i(R_{mt} - R_{ft}) + \pi\hat{d}_{hit}I_{hit} + \pi\hat{d}_{lit}I_{lit} + \pi_g I_{git} + v_{it}, \tag{23}$$

where $I_{hit} = 1$ if calling is feasible at the beginning of t but firm i does not call in t, $I_{hit} = 0$ otherwise; $I_{lit} = 1$ if firm i calls in time period t, $I_{lit} = 0$ otherwise; $I_{git} = 1$ if calling is infeasible at the beginning of t and firm i takes no action in t or it does not have convertibles in t, $I_{git} = 0$ otherwise.[17]

Using results in Section II, Subsection C, we simply need to test whether $\pi > 0$ in (23) to infer whether (i) or (ii) are true. If, however, (iii) is also true, the expected abnormal return, conditional on call announcement, must decrease with call delay, i.e. (suppressing subscripts i and t), $\partial\mathrm{E}(\varepsilon \mid \mathrm{call})/\partial z_j < 0$, where z_j is the call delay reckoned from the first feasible date. For testing this, note that $\mathrm{E}[\varepsilon \mid \mathrm{call}] = \pi d_l$ and, from (16), that $\partial\mathrm{E}[\varepsilon \mid \mathrm{call}]/\partial z_j = \pi\partial d_l/\partial z_j = \pi(\partial d_l/\partial u)(\partial u/\partial z_j)$, where $u \equiv \theta' z$ and $\partial u/\partial z_j = \theta_j$. It can also be shown that $\phi(u)/[1 - \Phi(u)]$ is a monotonically increasing function of u, implying that $\partial d_l/\partial u$

[15] To illustrate the event-study methodology, Acharya [3] estimates the price effects, conditional on managerial decision rules that are statistically equivalent to (9) here. That paper, however, does not test the crucial condition (iii) of the signalling hypothesis.

[16] An equally weighted portfolio index (NYSE and AMEX combined) is used as a proxy for R_{mt}.

[17] Note that the firms that called before the end of the sample period can be retained in the sample over the entire sample period by conveniently defining the indicator I_{git}. The model (23) is indeed similar to the model (20) if $\pi_g = 0$. Our subsequent empirical results indicate that π_g is statistically insignificant.

< 0 since $d_l = -\phi(u)/[1 - \Phi(u)]$. Then a test of implication (iii) is a test of $\pi > 0$ *and* $\theta_j > 0$ if implications (i) and (ii) are also true. Thus, a test of the signalling hypothesis, i.e., of (i), (ii), and (iii), is a joint test of $\pi > 0$ and $\theta_j > 0$.

C. Outsiders' Prior Information

To estimate d_{hit} and d_{lit}, which are functions of $u_{it} = \theta' z_{it}$, we need to specify convertible call policy-related variables, z_{it}, in the market's prior information set. The variables, z_{it}, should be chosen so that u_{it} reflects the market's prior expectation of the manager's information relevant to his or her decision, i.e., to the call or no-call action. In other words, these variables should constitute the market's source of information about the manager's wealth (incentive) resulting from calling over that of not calling the convertible bond. We first specify the variables and then discuss their relevance to the market's expectation of the manager's information.

z_{1it} = coupon on a convertible bond (per \$100 of its face value) minus the dividend payable if a conversion takes place at the beginning of t
= $100(C - D/C_p)$, where C is monthly coupon rate (dollars per dollar of face value of the convertible bond), D is monthly dividend per share, and C_p is the conversion-price (dollars of face value of the convertible bond per share), all at the beginning of t;

z_{2it} = convertible-bond floor, which is the maximum of the conversion value and the underlying bond value[18]
= $\max(B_v, V)/D_p$, where B_v is the underlying bond value of the convertible, V is the conversion value, and D_p is the market price of the convertible at the beginning of t. To normalize the bond floor $\max(B_v, V)$ over the cross-section, we divided it by D_p;

z_{3it} = standard deviation of the rate of return to the stock;

z_{4it} = a measure of the capitalized value of coupon liability
= $\delta C/R_f$, where δ is the amount of convertible outstanding and R_f is the risk-free rate;

z_{5it} = delay in calling the convertible bond, as reckoned from the first feasible date.

Everything else equal, the higher the net periodic payment, z_{1it}, the greater the cost (to the current stockholders) of keeping the convertible bond uncalled. Such a cost implies a reduction in the manager's incentive of not calling over the incentive of calling the convertible bond. We should therefore expect an increase in the probability of calling the convertible bond when z_{1it} is higher. The convertible-bond floor, z_{2it}, is a protection that the convertible bondholders enjoy at cost to the current shareholders. The higher this floor, the lower the managerial incentive, and, hence, the manages should be expected to minimize it. We should thus expect the probability of call to increase with the convertible-bond floor. Conversion-option value to a convertible bondholder increases with the standard deviation of the underlying stock return, z_{3it}. The higher the value of this option, the less the value due to the convertible bond resulting to the current sharehold-

[18] The underlying bond value is alternatively termed as investment value and is equal to the value of a bond equivalent to the convertible in all but the conversion and call provisions.

ers, the less the manager's incentive, and the more likely it is that the managers call such a convertible. Thus, as z_{3it} increases, the probability of call should increase. Similarly, the higher the liability (of keeping the convertible bond uncalled), z_{4it}, to the current shareholders, the greater should be the chances that managers call the convertible. Also, from the discussion in Section III, Subsection *B*, the coefficient of call delay in the probability of call postponement, $\Phi(\theta' z_{it})$, must be positive if the Harris-Raviv signalling hypothesis is true. Thus, the variables z_{it} should be important determinants of the probability of convertible-bond call.

D. The Data

Monthly data[19] on call prices, conversion prices, and market prices of the convertible bonds, and the amount of convertible bonds outstanding were obtained from Moody's Bond Record. Issue dates, maturity dates, call-announcement dates, coupon rates, and coupon-payment dates were drawn from Moody's Bond Survey and reconciled with the Moody's Industrial Manual and Moody's Bond Record. Call-announcement dates have also been reconciled with the corporate news reported in the *Wall Street Journal Index*. Interest rates used were the monthly T-bill returns obtained from Ibbotson and Sinquefield. Stock prices, rates of return, number of shares outstanding, and dividend yields were obtained from CRSP tapes.[20]

E. Results

Table I gives the estimates of θ and the standard errors obtained in the estimation of the probability of call postponement, $\Phi(\theta' z_{it})$. The p-value of almost zero indicates that the coefficient vector $(\theta_1, \cdots, \theta_5)$ is highly significantly different from zero. Signs of the coefficients reveal very interesting direction of change in the probability of call with the variables z_1 through z_5. The probability of call postponement decreases, i.e., the probability of call increases, with all the variables z_1 through z_4, quite as expected. A positive sign of the coefficient of call delay, θ_5 in Table I, in the probability of call postponement, $\Phi(\theta' z_{it})$, is, as discussed in Section III, Subsection *B*, consistent with the testable implication (iii).

Note that the correlation matrix of $z_1, \cdots, z_5$, given in Table I, shows that the call delay and the coupon in excess of dividend are negatively correlated, indicating that the more the net periodic payment the shorter the delay in calling. This is expected. However, the statistical insignificance of the coefficient θ_5 should be interpreted carefully because of the high collinearity in these two variables. We therefore estimate the probability of call postponement without

[19] Data on the variables z_1 through z_4 are not available on a daily basis.

[20] Stocks with missing values for returns over 1980 through 1984 have been excluded. Firms with multiple convertibles during 1980 through 1984 have also been excluded. Firms that have issued a convertible bond after calling the outstanding one were, however, included in the analysis. Finally, the sample includes forty-seven stocks with fifty-two convertibles and thirty-six calls over the sample period of sixty months. The effective length of sampling period is, however, fifty-nine months beginning February 1980 because we use one-period lagged observations in some cases. This reduces the number of calls in the sample to thirty-five because one call occurred in January 1980.

Table I

Probability of Call Postponement (Using All Variables) $= \Phi(\theta' z_{it})$[a]

Coefficient (Variable)	Estimate	Standard Error	t-Statistic
θ_0 (Constant)	3.607	0.794	4.540
θ_1 (Coupon − Dividend)	−1.639	0.454	−3.613
θ_2 (Bond Floor)	−1.669	0.543	−3.074
θ_3 (Standard Deviation)	−7.381	4.334	−1.703
θ_4 (Amount of Liability)	−0.062	0.051	−1.203
θ_5 (Call Delay)	0.003	0.003	0.909

Correlation Matrix of the Variables

$\text{cor}(z_1, z_2) = 0.052$
$\text{cor}(z_1, z_3) = 0.217$, $\text{cor}(z_2, z_3) = -0.263$
$\text{cor}(z_1, z_4) = 0.523$, $\text{cor}(z_2, z_4) = 0.024$, $\text{cor}(z_3, z_4) = 0.236$.
$\text{cor}(z_1, z_5) = -0.673$, $\text{cor}(z_2, z_5) = 0.138$, $\text{cor}(z_3, z_5) = -0.323$, $\text{cor}(z_4, z_5) = -0.422$.

[a] Log likelihood, $l = -111.529$. Log likelihood with only the constant (θ_0), $l_0 = -148.155$. Likelihood ratio statistic (five degrees of freedom) $= -2(l_0 - l) = 73.252$. p-Value $= 0.000$, $R^2 = 1 - l/l_0 = 00.247$. Number of observations $= 905$. The likelihood-ratio (LR) test statistic tests the significance of the deviation of the coefficient vector (excluding the intercept) from zero in the probit model stated above. The larger the value of the LR test statistic (i.e., the smaller the p-value), the stronger is the evidence that the coefficient vector is different from zero. The R^2 measure is suggested by Chow [8].

the first variable, coupon in excess of dividend, and report the results in Table II. These results show that the call delay has a positive and a statistically significant coefficient.

For estimating π in (23), we construct two random samples of thirty stocks each. These samples have some firms (six in sample I and seven in sample II) that did not have any outstanding convertible bond during the sample period and some firms (five in sample I and seven in sample II) that did not call during that period. The results of the second-stage multivariate regression (23) are given in Table III. We have reported the estimates of π for two cases: (a) when all variables $z_1, \cdots, z_5$ have been included in the estimation of probability of call postponement, as in Table I, and (b) when the first variable, coupon minus dividend, has been excluded from the probability estimation, as in Table II. The estimates for case (a) are reported outside the brackets whereas those for case (b) are reported within the brackets in Table III. The coefficient π is significantly positive in both samples in either case. This empirical result is consistent with testable implications (i) and (ii). Since the estimated $\theta_5 > 0$ and $\pi > 0$, we also fail to reject (iii). Note that a positive π implies that the call-announcement effect πd_{lit} is negative and the call-postponement effect πd_{hit} is positive. The means of these estimates are given in Table III.

IV. Conclusion

The econometric model presented in this paper is very useful for testing a signalling hypothesis. The empirical tests done by using the model are interesting. The significant coefficients (with correct signs) in the estimated probability of

Table II

Probability of Call Postponement (Variable z_1 Excluded) $= \Phi(\theta' z_{it})$[a]

Coefficient (Variable)	Estimate	Standard Error	t-Statistic
θ_0 (Constant)	4.322	0.739	5.846
θ_2 (Bond Floor)	−1.582	0.491	−3.221
θ_3 (Standard Deviation)	−10.689	4.233	−2.525
θ_4 (Amount of Liability)	−0.116	0.050	−2.341
θ_5 (Call Delay)	0.010	0.003	2.978

[a] Log likelihood, $l = -118.425$. Log likelihood with only the constant (θ_0), $l_0 = -148.155$. Likelihood ratio statistic (five degrees of freedom) $= -2(l_0 - l) = 59.460$. p-Value = 0.000, $R^2 = 1 - l/l_0 =$ 00.201. Number of observations = 905. The likelihood-ratio (LR) test statistic tests the significance of the deviation of the coefficient vector (excluding the intercept) from zero in the probit model stated above. The larger the value of the LR test statistic (i.e., the smaller the p-value), the stronger is the evidence that the coefficient vector is different from zero. The R^2 measure is suggested by Chow [8].

Table III

Estimates of π and π_g in the model (23)[a]

$$R_{it} - R_{ft} = \beta_i(R_{mt} - R_{ft}) + \pi\hat{d}_{hit}I_{hit} + \pi\hat{d}_{lit}I_{lit} + \pi_g I_{git} + v_{it}$$

	Coefficient	Sample I		Sample II	
Estimate	π	0.01525	[0.01839]	0.01056	[0.01215]
Standard Error		0.00646	[0.00667]	0.00653	[0.00677]
Estimate	π_g	0.00132	[0.00130]	0.00135	[0.00140]
Standard Error		0.00170	[0.00170]	0.00171	[0.00171]
Estimated Mean of					
πd_{it} (Call Announcement Effect)		−0.02690	[−0.0316]	−0.01900	[−0.02030]
πD_{it} (Call Postponement Effect)		0.00120	[0.00130]	0.00070	[0.00080]

[a] The results outside the brackets correspond to all variables, $z_1, \cdots, z_5$, included in the estimation of the probability of call postponement, i.e., to $\theta_0, \cdots, \theta_5$ in Table I. The results in the brackets correspond to the probability estimated without the first variable, coupon minus dividend, i.e., to θ_0, $\theta_2, \cdots, \theta_5$ reported in Table II.

call postponement imply that this probability is nondegenerate (neither zero nor one). This implies that the call-announcement (postponement) signals of the managers are partially anticipated. Such a result is inconsistent with the predictions of theories under a perfect capital market since these predictions imply a fully anticipated call policy of a firm. This nondegenerate probability of call postponement is, however, consistent with an information-based theory of call policy. So we tested and failed to reject the major implications of a recently hypothesized signalling hypothesis of convertible bond call policy.

Appendix: Proof of Theorem

(i) Choose $p(G)$ such that $0 < p(G) < 1$. It is easy to check that the posterior probabilities (5) and the manager's strategy (6) are consistent with Bayes' rule (4).

(ii) For the manager's strategies (6) to constitute an equilibrium, given the investors' posterior probabilities beliefs (5), the manager must issue signal h (l) if and only if his or her message is G (B). Since the manager finds it optimal to issue h if and only if $y(\omega) \geq 0$, those realizations of ω for which $y(\omega) \geq 0$ must define G. Thus,

$$G = \{\omega \mid y(\omega) \geq 0\}. \tag{A1}$$

Similarly,

$$B = \{\omega \mid y(\omega) < 0\}. \tag{A2}$$

Given these definitions of G and B, strategies (6) and beliefs (5), the equilibrium prices, conditional on issuance of the signal s, are given by, using (3),

$$P(h) = \mathrm{E}[v(h, \omega) \mid G] \quad \text{and} \quad P(l) = \mathrm{E}[v(l, \omega) \mid B]. \tag{A3}$$

Having characterized G and B and then $P(h)$ and $P(l)$, it remains to be shown that there exist values of exogenous realizations of ω and of other parameters such that the subspaces $\{\omega \mid y(\omega) \geq 0\}$ and $\{\omega \mid y(\omega) < 0\}$ are well defined. Choose the function $w(\cdot)$ as

$$w(X) = -\exp(-X). \tag{A4}$$

The function in (A4) indicates that the manager's utility function belongs to the class of constant absolute risk aversion. Choose $G = \{g\}$, $g \in \Omega$ and $B = \{b\}$, $b \in \Omega$ such that $0 < p(G) < 1$ and

$$v(h, g) > v(l, b), \tag{A5}$$

$$v(h, g) = v(l, g), \tag{A6}$$

and

$$v(h, b) < v(l, b). \tag{A7}$$

The manager's incentive of issuing signal h, given his or her private message, is

$$y(\omega) = w[P(h)] + \mathrm{E}^m[w(v(h, \omega) + \eta)] - w[P(l)] - \mathrm{E}^m[w(v(l, \omega) + \eta)]. \tag{A8}$$

Using (A3) through (A7) in (A8), $y(g) \geq 0$ if and only if

$$\exp[-v(l, b)] - \exp[-v(h, g)] + \exp(\sigma^2/2)[\exp(-v(l, g)) - \exp(-v(h, g))] \geq 0, \tag{A9}$$

which holds, given the chosen values (A6). Similarly, $y(b) < 0$ if and only if

$$\exp[-v(l, b)] - \exp[-v(h, g)] + \exp(\sigma^2/2)[\exp(-v(l, b)) - \exp(-v(h, b))] < 0. \tag{A10}$$

With $v(h, b)$ sufficiently less than $v(l, b)$ in (A10), $y(b) < 0$ holds.

(iii) Then, using (A3) and (A5), $P(h) = v(h, g) > v(l, b) = P(l)$. Q. E. D.

REFERENCES

1. S. Acharya. "A Generalized Model of Stock Price Reaction to Corporate Policy Announcement: Why Are Convertibles Called 'Late'?" Unpublished Ph.D. dissertation, Northwestern University, 1986.
2. ———. "Estimation of Intertemporal Models with Selectivity." Unpublished mimeo, New York University, Graduate School of Business Administration, March 1987.
3. ———. "Insiders' Decision of Corporate Events: A Simple Measure of Expected Abnormal Return." Unpublished mimeo, New York University Graduate School of Business Administration, August 1987.
4. S. Bhattacharya. "Imperfect Information, Dividend Policy and 'Bird in Hand Fallacy'." *Bell Journal of Economics and Management Science* 10 (Spring 1979), 259–70.
5. M. J. Brennan and E. S. Schwartz. "Convertible Bonds: Valuation and Optimal Strategies for Call and Conversion." *Journal of Finance* 32 (December 1977), 1699–1715.
6. S. J. Brown and J. B. Warner. "Measuring Security Price Performance." *Journal of Financial Economics* 8 (September 1980), 205–58.
7. ———. "Using Daily Stock Returns, The Case of Event Studies." *Journal of Financial Economics* 14 (March 1985), 3–31.
8. G. C. Chow. *Econometrics.* New York: McGraw Hill Book Co., 1983, 262.
9. G. M. Constantinides and B. Grundy. "Call and Conversion of Convertible Bonds: Theory and Evidence." University of Chicago Graduate School of Business working paper, 1985.
10. P. J. Dhrymes. *Econometrics, Statistical Foundations and Applications.* New York: Springer-Verlag, 1970, 166.
11. E. F. Fama, L. Fisher, M. Jensen, and R. Roll. "The Adjustment of Stock Prices to New Information." *International Economic Review* 10 (February 1969), 1–21.
12. M. R. Gibbons. "Multivariate Tests of Financial Models—A New Approach." *Journal of Financial Economics* 10 (March 1982), 3–27.
13. M. Harris and A. Raviv. "A Sequential Signalling Model of Convertible Debt Call Policy." *Journal of Finance* 40 (December 1985), 1263–82.
14. M. Harris and R. M. Townsend. "Resource Allocation under Asymmetric Information." *Econometrica* 49 (January 1981), 33–64.
15. J. Heckman. "Shadow Prices, Market Wages and Labor Supply." *Econometrica* 42 (July 1974), 679–94.
16. ———. "The Common Structure of Statistical Models of Truncation, Sample Selection and Limited Dependent Variables and a Simple Estimator for Such Models." *Annals of Economic and Social Measurement* 5 (1976), 475–92.
17. ———. "Statistical Models for Analysis of Discrete Data." In C. Manski and D. McFadden (eds.), *Structural Analysis of Discrete Data with Applications.* Cambridge: M.I.T. Press, 1981.
18. J. Ingersoll. "A Contingent Claims Valuation of Convertible Securities." *Journal of Financial Economics* 4 (May 1977), 289–322.
19. ———. "An Examination of Corporate Call Policies on Convertible Securities." *Journal of Finance* 32 (May 1977), 463–78.
20. K. John and J. Williams. "Dividends, Dilution, and Taxes: A Signalling Equilibrium." *Journal of Finance* 40 (September 1985), 1053–70.
21. D. M. Kreps and R. Wilson. "Sequential Equilibria." *Econometrica* 50 (July 1982), 863–94.
22. L. F. Lee. "Identification and Estimation in Binary Choice Models with Limited (Censored) Dependent Variables." *Econometrica* 47 (July 1979), 977–96.
23. ———. "Generalized Econometric Models with Selectivity." *Econometrica* 51 (March 1983), 507–12.
24. H. Leland and D. H. Pyle. "Informational Asymmetrics, Financial Structure and Financial Intermediation." *Journal of Finance* 32 (May 1977).
25. W. H. Mikkelson. "Convertible Calls and Security Returns." *Journal of Financial Economics* 9 (September 1981), 237–64.
26. M. H. Miller and Kevin Rock. "Dividend Policy under Asymmetric Information." *Journal of Finance* 40 (September 1985), 1031–51.

R. Ofer and D. Siegel. "Tests of Rational Signalling Models Using Expectational Data: An Application to Dividend Signalling." J. L. Kellogg Graduate School of Management, Northwestern University working paper, 1986.

J. Riley. "Informational Equilibrium." *Econometrica* 47 (March 1979), 331–59.

S. A. Ross. "The Determination of Financial Structure: The Incentive Signalling Approach." *Bell Journal of Economics* 8 (Spring 1977).

M. Rothschild and J. Stiglitz. "Equilibrium in Competitive Insurance Markets: An Essay in the Economics of Imperfect Information." *Quarterly Journal of Economics* 90 (November 1976), 629–50.

1. A. M. Spence. "Competitive and Optimal Responses to Signals: Analysis of Efficiency and Distribution." *Journal of Economic Theory* (March 1974).