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Information Content of Insider Trading Around Corporate Announcements: The Case of Capital Expenditures

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ABSTRACT

There is gathering evidence of insider trading around corporate announcements of dividends, capital expenditures, equity issues and repurchases, and other capital structure changes. Although signaling models have been used to explain the price reaction of these announcements, a usual assumption made in these models is that insiders cannot trade to gain from such announcements. An innovative feature of this paper is to model trading by corporate insiders (subject to disclosure regulation) as one of the signals. Detailed testable predictions are described for the interaction of corporate announcements and concurrent insider trading. In particular, such interaction is shown to depend crucially on whether the firm is a growth firm, a mature firm, or a declining firm. Empirical proxies for firm technology are developed based on measures of growth and Tobin's q ratio. In the underlying "efficient" signaling equilibrium, investment announcements and net insider trading convey private information of insiders to the market at *least cost*. The paper also addresses issues of deriving intertemporal announcement effects from the equilibrium (cross-sectional) pricing functional. Other announcement effects relate the intensity of the market response to insider trading, variance of firm cash flows, risk aversion of the insiders, and characteristics of firm technology (growth, mature, or declining).

REACTION OF SECURITY PRICES to corporate announcements of dividends, capital expenditures, equity issues and repurchases, and other changes in capital structure has been widely documented.[1] Since the documented evidence suggests that these announcements convey to the market some private information possessed

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[1] Dividend announcement effects appear in Pettit (1972), Charest (1978), Aharony and Swary (1980), Asquith and Mullins (1983), and other papers too numerous to site. Announcement effects of financial restructuring (including security issues or repurchases) are summarized in Jensen and Smith (1985, Tables 2 and 3) and Smith (1986, Tables 1 and 3). Some preliminary evidence on announcements of capital expenditures appears in McConnell and Muscarella (1985), Mishra (1985), and Doukas, Rahman, and Switzer (1986).

by corporate insiders, signaling models have been used to explain the price reaction.[2] However, most signaling models have specified an objective for the corporate insiders which implicitly assumed that insiders cannot trade. The viability of the signaling equilibrium requires an assumption which precludes the insiders from trading after emitting an exaggerated signal. In many models this is assumed explicitly (e.g., k, the fraction of shareholders selling out, is exogenously specified in Miller and Rock (1985) or Vishwanathan (1987)). In other models it is forced through the exogenous parameters of the managerial wage function (see, e.g., Ross (1977) or Harris and Raviv (1985)) or implicitly assumed (see, e.g., John and Williams (1985) or Bhattacharya (1979)). The above restriction is far from innocuous for two reasons. First, there is mounting evidence of significant insider trading around corporate announcements (see, e.g., John and Lang (1988), Karpoff and Lee (1987), Choi (1986), Copeland and Lee (1988), and Hirschey and Zaima (1989)). Second, if the net trading of corporate insiders is influenced by the private information they have, understanding insider trading and its information content is important to studying corporate announcements.

This motivates the novel perspective of this paper. We model "net insider trading" as a signal used by corporate insiders *jointly* with the signaling activity (e.g., dividends, security issues or repurchases, capital structure changes) which is the subject of the corporate announcement. In an environment where corporate insiders have information superior to the market about the future prospects of the firm, the trading activity of corporate insiders would be one of the most direct signals available to them to communicate their private information to the market. Indeed, disclosures about insider trading are actively tracked by investment services for "buy" and "sell" signals. By modeling the corporate announcement and the concurrent strategic insider trading as "joint signals," we study the interaction of the two signals. Here, we examine an equilibrium where insiders may trade strategically in their own interest, adhering to the disclosure requirements. Such trading by insiders depends on their private information, and it interacts with the information content of the concurrent corporate announcement. In other words, the insiders and the market consider the interaction of insider trading activity and the market beliefs used in pricing the firm's securities. Insiders realize that their trades affect their welfare not only directly through the gains from trade but indirectly by affecting the credibility of their signaling activity and therefore its cost effectiveness.

In modeling the extent of insider trading as a signal, we run counter to the spirit of the market microstructure models with informed traders. There, the informed traders (including corporate insiders) execute "private" trades to profit

[2] John and Williams (1985), Miller and Rock (1985), Ambarish, John, and Williams (1987), John and Nachman (1986), and Ofer and Thakor (1987) contain references to extensive evidence on dividends and some explanations based on signaling models. Ambarish, John, and Williams (1987), Miller and Rock (1985), and Myers and Majluf (1984) provide signaling explanations of equity issue announcement effects. See Ross (1977) and John (1987) for signaling explanations of documented evidence on leverage changing transaction announcements summarized in Jensen and Smith (1985) and Jensen (1986). See Mishra (1985), Trueman (1986), and Ambarish, John, and Williams (1987) for signaling explanations of the security price reactions of capital expenditure announcements. Choi (1986), Leland and Pyle (1977), Ofer and Thakor (1987), and Vermaelen (1984) suggest explanations for the announcement effect of stock repurchases based on signaling models.

at the expense of the "noise traders" and market makers. Although this literature (e.g., Glosten and Milgrom (1985), Kyle (1985), and Admati and Pfleiderer (1988)) has produced important insights, we need a different perspective to study trading by corporate insiders around corporate announcements. Prior to any major corporate announcements, corporate insiders are often privy to "material facts," critical private information which affects the value of claims they can potentially trade. At this time these insiders are under the spotlight for potential violations of insider trading laws. In the United States, Section 16(b) of the Securities and Exchange Act of 1934 says that insiders must disclose material facts which are known to them by virtue of their position but are not known to persons with whom they deal and which, if known, would affect their investment judgment.[3] Failure to disclose constitutes a violation of anti-fraud provisions. If, on the other hand, disclosure prior to affecting a purchase or a sale is improper or unrealistic under the circumstances, the insider must forego the transaction. Given the spirit of these laws, insider trading *concurrent* with other corporate announcements is characterized as "effectively" observable.[4] This is intended to be a "reduced form" representation of our belief that there is enough information in the market about the extent of insider trading (e.g., through the market makers and from the SEC reporting requirements), so that the market can interpret the informational content of the corporate announcement conditional on the extent of insider trading which precedes it.

Even though the framework of this paper applies to any major corporate announcement and concurrent insider trading activity, details of the equilibrium and empirical implications derived will depend on the specific corporate announcement in question. In this paper we focus on corporate announcements of capital expenditure (levels of current investment). In the "efficient" signaling equilibrium of this paper, corporate insiders use their own net trading and announced changes in capital expenditures to convey their private information to the market at least cost.

In this paper, we also address some issues of efficiency of the signals used. A common practice in financial signaling models has been to pick somewhat arbitrarily an observable activity of the firm (chosen by corporate insiders) and show that this activity has the appropriate cost structure required for the existence of an information equilibrium, say, as in Spence (1973) or Riley (1979). The issue of efficiency of the chosen signal vis à vis other available mechanisms to convey credible private information to the market has not been addressed.[5] In this model, multiple mechanisms exist for conveying information to the market. Private information of the type which is conveyed relatively costlessly (say, current earnings information) is communicated through audited earnings reports and other audited statements. However, other types of private information (say,

[3] The "abstain or disclose" doctrine exists in one form or the other in 28 of the 38 biggest stock markets of the world (see de Caires (1987)).

[4] Since there is no public announcement of (even large) insider trades, there is an interesting empirical issue of whether the "announcement effect" would be observed on the day of transaction or on the day of reporting. The insider trading data base published by the SEC (Official Summary of Securities Transactions and Holdings) contains *both* dates.

[5] Ambarish, John, and Williams (1987) and Milgrom and Roberts (1986) are exceptions.

the success probability of the R & D effort or the quality of the investment opportunities available) are more difficult to convey. Here insiders have two signals available: the investment levels announced and the level of insider holdings in the firm. Since both signals individually satisfy the Spence-Riley cost structure, either of them could have been used exclusively to convey the private information at some cost. In other words, insiders could have used either deviating from full-information optimal investments or suboptimal diversification in their own holdings in the firm to convey their entire private information to the market. Therefore, if a particular mechanism (or a mix of the two signals) is selected in the "efficient" signaling equilibrium, it is because the selected signal (or mix of signals) conveys the private information most effectively (at minimum cost).

In this model, the firms' insiders can signal simultaneously with investment announcements and levels of insider holdings. Because outside investors can infer all private information from either signal exclusively, corporate insiders *need* not signal with either of the two mechanisms. Nevertheless, as shown here, many firms with valuable inside information will use *both* signals, investments and insider holdings, in the efficient signaling equilibrium. However, the nature of the mix of signals efficiently chosen can depend on the class of firms signaling. In particular, how the private information attribute influences the productivity of new investment determines whether firms will choose to underinvest (compared to full-information levels) or overinvest in the efficient signaling equilibrium. For ease of reference, we will categorize firms into three successive classes based on the relationship of the marginal productivity of new investments and the private information attribute: for *growth* firms, this relationship is increasing; for *declining* firms, it is decreasing; for *mature* firms, no relationship exists. In the efficient signaling equilibrium, in all three classes of firms, insiders hold underdiversified positions in their own holdings in the firm. However, only growth firms and declining firms deviate from their full-information optimal levels of investment; mature firms invest at full-information optimal levels, growth firms overinvest, and declining firms underinvest. More interestingly, the announcement effect of investment increases is shown to be positive for the stocks and bonds of growth firms, whereas it is negative for the securities of declining firms and neutral for mature firms.

The model yields detailed empirical implications for the announcement effect of changes in investment and changes in insider holdings for prices of stocks and bonds. The derived announcement effects relate the intensity of the price response to measures of insider trading, variance of earnings, and the characteristics of the technology of the firm (growing, mature, or declining). Empirical proxies for firm technology can be constructed from measures of growth and Tobin's q ratios. Currently available data on capital expenditure announcements, insider holdings, and insider trading can be used to test these predictions. Some such empirical work is pursued in a companion paper, John and Mishra (1990), in progress.

The paper is organized as follows. In the model presented in Section I, insiders choose their own holdings, investment, and issue of stock to maximize their welfare as a function of their private information. Firms sell no bonds, pay no

taxes, and incur no interaction costs. Outsiders observe all components of firms' sources and uses of funds but not their complete production technologies. Instead, this latter information can be communicated credibly to outsiders only through a firm's investment decisions and insider's holding of stock. In this context, both signaling equilibria and the efficient signaling equilibrium are defined.

Next, the efficient signaling equilibrium is characterized in Section II. First, the signaling problem is transformed into an equivalent nonmimicry problem. In this equivalent problem, insiders in more valuable firms choose their holdings and investment to maximize their welfare subject to a nonmimicry constraint. This constraint stipulates that insiders in less valuable firms have no incentive to mimic the shareholding and investment of the more valuable firms even to obtain in the market their higher stock prices. The nonmimicry problem and its solution are characterized in Appendix A. Empirical implications are discussed in Section III. Conclusions and theoretical extensions are sketched in Section IV.

I. The Basic Model

The design of the following model attempts to capture the essential aspects in a simple, tractable framework. In our single period model, $t = 0$ denotes the initial date and $t = 1$ denotes the final date. At $t = 0$, the firm has current cash C, which includes the cash from operations as well as any external financing done at firm level by selling riskless claims.[6] The firm has access to a technology (or an investment opportunity set) denoted as $f(I, \theta)$. The technology represents a set of assets such that an investment of amount I made at $t = 0$ results in a random cash flow $f(I, \theta) + \tilde{u}$ at $t = 1$ for a firm of quality θ (specified in detail below), where $\tilde{u}$ is a normally distributed random variable with mean zero and variance σ^2. Consider a corporate insider (an entrepreneur) who determines, at $t = 0$, a fraction α of the firm to hold, selling the residual fraction $(1 - \alpha)$ to outsiders in the market. He or she also decides and announces an investment level I, where the residual amount $C - I$ is paid out as dividends.

Information about the firm's future cash inflow is *asymmetric*. To specify this asymmetry as simply as possible, represent by θ, with $\theta \in \Theta$, the value of a single state variable affecting the firm's future profitability. For example, θ may measure its insiders' forecasted return on either assets in place or, alternatively, opportunities to invest. The firm's identity, θ, is private information; it is known to the corporate insiders but not observed directly by outsiders. In particular, insiders observe the private attribute θ before picking both their holdings α and the investment level I, whereas outsiders must attempt to infer θ from the observable actions of insiders. By contrast, the prior probability $\pi(\theta)$ of possessing the private attribute θ is common knowledge. Moreover, the distribution of $\tilde{u}$

[6] The outside claims the firm can issue for external financing are restricted to be riskless debt and equity. This assumption is made primarily for tractability of the model. For convenience, we include the riskless claims in C and treat separately the outside equity sold. Such an assumption is common to papers in this area; see Miller and Rock (1985), John and Williams (1985), and Ambarish, John, and Williams (1987).

is also common knowledge. Except for θ, all other parameters of the subsequent problem are common knowledge. For example, the current cash C is fully revealed to outsiders through costless corporate audits. Similarly, corporate audits will verify that I is the level of investment actually undertaken.

The entrepreneur-insider is risk averse and has a negative exponential utility function with coefficient of absolute risk aversion h, $h \geq 0$. He or she invests the portion of his or her wealth not tied up in the firm in a riskless asset (assumed to have a zero rate of return). We will also assume that risk-neutral valuation is appropriate for the economy.[7]

After one period, at $t = 1$, the cash flows are realized and distributed pro-rata to the shareholders. As indicated earlier, $f(I, \theta)$ denotes the present value of this future cash inflow, as calculated by insiders, conditional on their corporate investment I and private information θ. By convention, we take higher θ to represent more favorable private information. In other words, for all feasible I, i.e., $I \geq 0$ and all $\theta \in \Theta$, we have $f(I, \theta_2) > f(I, \theta_1)$ when $\theta_2 > \theta_1$. Also the function $f(\cdot, \theta)$ is positive, continuously differentiable, strictly increasing, and strictly concave in investment, with the corner conditions $f'(0, \theta) = \infty$ for all $\theta \in \Theta$.

Conditional on his or her private information θ, the corporate insider will maximize his or her expected utility of the end-of-period wealth $\tilde{W}$. This is a function of the market price paid for the fraction of the firm sold. This market price, however, can only depend on what is common knowledge and on the observable actions of the insiders. In other words, the pricing function used by the market will be a function of I and α (and parameterized by all common knowledge). Let $P(I, \alpha)$ be the cum-dividend price assigned by the market for the entire firm value. The existence of such a market pricing function $P(\cdot, \cdot)$ will be proved and its properties characterized.

The optimization of the corporate insider can be specified as follows: choose the insider holding α and the investment level I to maximize expected utility, conditional on the pricing function P. This optimization is *equivalent* to[8]

$$\max_{\alpha, I \geq 0} E(\tilde{W}) - \frac{h}{2} \operatorname{var}(\tilde{W}), \tag{1}$$

where

$$\tilde{W} = \alpha[C - I + f(I, \theta) + \tilde{u}] + (1 - \alpha)P.$$

(1) can be written as

$$\max_{\alpha, I \geq 0} \alpha[C - I + f(I, \theta)] + (1 - \alpha)P - \frac{h}{2} \sigma^2 \alpha^2. \tag{2}$$

[7] The assumption of a risk-neutral valuation for the economy is not a restrictive one. It is similar in its implications to the assumption that all investors are possibly risk averse but that an additional investment, the market portfolio, is available. As shown in Leland and Pyle (1977), where such is the setting, none of our conclusions about α would change.

[8] For large enough h and σ^2, it can be shown that any solution to (1) automatically satisfies $\alpha \leq 1$. For expositional ease, we will not carry this constraint along. Arguing in the spirit of Leland and Pyle (1977), where suboptimal diversification provides the signaling costs of α, clearly, any value of α close to its value in a well diversified portfolio would satisfy the constraint $\alpha \leq 1$.

Note that the maximand in the above optimization is a function of the private information θ, the observable (signaling) activities, α and I, and the market pricing function $P(\alpha, I)$. Denote the insider's maximand in (2) as $U(\theta, \alpha, I, P)$, and rewrite (2) as

$$\max_{\alpha, I \geq 0} U(\theta, \alpha, I, P). \tag{3}$$

Let $\{\alpha(\theta), I(\theta)\}$ denote the solution to (3).

To characterize the equilibria, we will need to refer to the *true value* of the firm, i.e., the value which the market would have assigned to the entire firm (cum-dividend) had it been informed of the value of θ. Use $V(\theta, \alpha, I)$ to denote this true value function for a firm using activity levels α and I. Given risk-neutral pricing by the market,

$$V(\theta, \alpha, I) = C - I + f(I, \theta). \tag{4}$$

Now we are ready to define a signaling equilibrium and an *efficient* signaling equilibrium (with multiple signals) in this context. Given a perfectly competitive capital market, both insiders and outsiders regard the pricing function P as fixed by market forces. Conditional on the pricing function P, corporate cash C, and information θ, insiders then select their optimal holdings $\alpha(\theta)$ and the firm's optimal investments $I(\theta)$ to satisfy the incentive-compatibility condition (3). In turn, outsiders buy new shares (and trade outstanding shares), believing correctly that the stock's total market price, measured cum-dividend, equals its concurrent true value:

$$P[\alpha(\theta), I(\theta)] = V[\theta, \alpha(\theta), I(\theta)]. \tag{5}$$

Equation (5) is called the competitive-rationality condition. As in Riley (1979), a signaling equilibrium $\{\alpha(\theta), I(\theta), P[\alpha(\theta), I(\theta)]\}$ must satisfy both the incentive-compatibility condition (3) and the competitive-rationality condition (5).

Many signaling equilibria may exist. Specifically, with a single private attribute θ, many combinations of the two corporate controls, α and I, may satisfy both (3) and (5). Accordingly, among all such combinations, a Pareto-efficient solution is selected. This equilibrium, called "the efficient" signaling equilibrium, solves the following problem:

$$\max_{P \geq 0} \int_{\theta} U\{\alpha(\theta), I(\theta), P[\alpha(\theta), I(\theta)]; \theta\}\, d\pi(\theta), \tag{6}$$

subject to (3) and (5). In other words, among all feasible signaling equilibria, defined by (3) and (5), the pricing function P must minimize ex ante signaling costs. If π is strictly positive for θ, then the scheduled P which satisfies (6) is the Pareto-optimal schedule. A signaling equilibrium $\{\alpha(\theta), I(\theta), P[\alpha(\theta), I(\theta)]\}$ which satisfies (3), (5), and (6) will be called the *efficient* signaling equilibrium.

Here, in the efficient signaling equilibrium, both insider holdings and investment announcements are strategically used to convey the single-dimensional private information θ at minimal signaling costs. For a fixed investment, the single signal of insider holdings can credibly convey all private information (as

shown in Leland and Pyle (1977)). Similarly, for a fixed α, investment announcements have been shown to be able to signal private information. (See John and Kalay (1985), Mishra (1985), John (1987), John and Nachman (1990), and Trueman (1986).) However, using both signals strategically achieves signaling most efficiently. Moreover, the strategic interaction of insider trading and investment announcements with concurrent stock price responses provides a rich menu of empirically testable implications.

II. Efficient Signaling Equilibrium and Announcement Effects

In this section, we characterize the efficient signaling equilibrium and its properties. These include the optimal insider holdings and investment announcements in equilibrium as well as the market pricing function and its properties. These properties and the implied announcement effects will be shown to be crucially dependent on the investment opportunities available to the firm. To formalize such a dependence in our signaling equilibrium, we will subdivide investment opportunity sets into three classes based on how the marginal product of current investment I varies with θ, the private information attribute. For ease of reference, we will call these three classes of firms growth firms, mature firms, and declining firms.

Definition 1: A family of firms, $\theta \in \Theta$, will be called *growth* firms if $\frac{\partial^2 f}{\partial I \partial \theta} > 0$ for all θ and all $I \geq 0$. A family of firms, $\theta \in \Theta$, will be called *mature* firms if $\frac{\partial^2 f}{\partial I \partial \theta} = 0$ for all θ and all $I \geq 0$. A family of firms, $\theta \in \Theta$, will be called *declining* firms if $\frac{\partial^2 f}{\partial I \partial \theta} < 0$ for all θ and all $I \geq 0$.

The marginal product of current investment is increasing in θ among growth firms for all $I \geq 0$, whereas among mature firms it is constant and among declining firms it is decreasing. Similarly, the Pareto-optimal investment I^o $\left(\text{such that } \frac{\partial f(I^o, \theta)}{\partial I} = 1\right)$ is increasing in θ among growth firms, constant in θ among mature firms, and decreasing in θ among declining firms.

Now we proceed to characterize the efficient signaling equilibrium for the different classes of firms. To accomplish this, we follow the methodology in Ambarish, John, and Williams (1987). We do not provide the details here. The important steps in the analysis are given in Appendix A.

PROPOSITION 1: *In the efficient signaling equilibrium, for all but the poorest firms, insider holdings are higher than those for optimal diversification. Among growth firms, all but the poorest firms overinvest. Among declining firms, all but the poorest firms underinvest. Among mature firms, investment is at full-information optimal levels. Insider holdings, in equilibrium, are monotonically increasing in θ for all three categories of firms. Equilibrium levels of investment are increasing in θ among declining firms, decreasing in θ among growth firms, and constant in θ among mature firms.*

Proof: See Appendix A.

The efficient signaling equilibrium characterized above for each of the three categories of firms specifies a *corresponding* pricing function $P(\alpha, I)$ used by the market to interpret the information content of insider trading and investment changes. The announcement effects for stock price which are implied by these pricing functions are derived in Proposition 2.

Two observations are noteworthy about this efficient signaling equilibrium, particularly in contrast to earlier investment-signaling models such as John and Kalay (1985), Mishra (1985), and Trueman (1986). There, the higher quality firms overinvest more than their poor quality competitors. In our equilibrium, such a result obtains only in the case of growth firms. In other words, a higher investment is taken by the uninformed market to be a signal of higher quality, conditional on the common knowledge information available in the market that the firms in question are growth firms. For the remaining firms (mature or declining classes), the same signal of higher investments may connote either no differences in quality or poorer quality. The main observation here is that the investment signals have to be interpreted by the market conditional on the class of technologies of the signaling firms.

A second novel feature of our equilibrium is that we allow insiders to change their holdings strategically as a function of their private information. In most earlier signaling models, insider (manager) is exogenously given a fraction of the firm, say α_0, and cannot revise that position based on his or her private information. For example, see Miller and Rock (1985), where the insider holdings are fixed exogenously at $(1 - k)$, or Ross (1977) or Harris and Raviv (1985), where the managerial compensation functions have a similar effect. In our model, we allow the insider to obtain his or her private information and then optimally pick his or her holding $\alpha^*(\theta)$ conditional on his or her private information.[9]

Now we will examine some properties of the pricing function $P(\alpha, I)$ which arise in the efficient signaling equilibrium. The cross-sectional relationships of P to insider holdings and to investment announcements are easily calculated. The announcement effects implied by these relationships provide important empirically testable hypotheses.

PROPOSITION 2: *The announcement effect of an increase in insider holding is positive for all classes of firms. The announcement effect of an increase in investment is positive for growth firms, neutral for mature firms, and negative for declining firms.*

[9] The following interpretation of our equilibrium will be useful for relating it to data on insider trading. Prior to receiving his or her private information, the manager is holding a fraction, say α_0, in his or her firm; he or she obtains private information at $t = 0$ and then announces an investment level $I^*(\theta)$ and *revises* his or her holding in the firm to $\alpha^*(\theta)$, both conditional on his or her private information. $\{I^*(\theta), \alpha^*(\theta)\}$ are of course the efficient equilibrium signaling choices. The insider is a net buyer if $\alpha^*(\theta) > \alpha_0$ and a net seller if $\alpha^* < \alpha_0$. In either case the revision transaction $\alpha^*(\theta) - \alpha_0$ happens at the *signaled* price $P(I^*, \alpha^*)$. In other words, our insider trades from α_0 to $\alpha^*(\theta)$ based on his or her private information, fully realizing that the market price depends on the announced investment and his or her trading. Further elaboration in the empirical setting of the paper is given in Section III.

Proof: From among the many pricing functions which can support the equilibrium, choose a differentiable function P. Next, compute the necessary conditions from the original optimization of the insiders in (2), given the pricing function P. Rearrange the results to obtain $\frac{\partial P}{\partial \alpha}$ and $\frac{\partial P}{\partial I}$, evaluated at $\alpha^*(\theta)$ and $I^*(\theta)$, as follows:

$$\frac{\partial P}{\partial \alpha} = \frac{\alpha}{1-\alpha} h\sigma^2, \tag{7}$$

$$\frac{\partial P}{\partial I} = \frac{-\alpha}{1-\alpha}(1 - f_2'). \tag{8}$$

Here f_2' denoted $\frac{df_2(I_2^*)}{dI}$ in Appendix A, where the equilibrium is explicitly solved for the case of $\Theta = \{\theta_1, \theta_1\}$, $\theta_2 > \theta_1$, and f_1 and f_2 are the technologies of firm 1 (of type θ_1) and firm 2 (of type θ_2). For $0 < \alpha < 1$, $\frac{\partial P}{\partial \alpha} > 0$ for all classes of firms. The announcement effect of an investment increase depends on the sign of $\frac{\partial P}{\partial I}$ in (8): sign $\frac{\partial P}{\partial I} = -\text{sign}(1 - f_2')$. Now, the different announcement effects for different technology classes follow from Definition 1 and the equilibrium investment strategies. See also equations (A18) and (A19) of Appendix A. Q.E.D.

The multiplicity of the announcement effect of investments (capital expenditures) based on the class of firm technologies is an important testable result of our model. The details of these and other empirical implications of equations (7) and (8) are developed in the next section.

III. Empirical Implications

The efficient signaling equilibrium of Proposition 1 and the announcement effects derived in Proposition 2 have several empirical implications. Some implications are familiar from previous, more restrictive models; others are new. The implications relate the announcement effect of capital expenditures to the insider trading activity and the firm technologies. Deriving intertemporal announcement effects from the cross-sectional pricing function P is an important step in obtaining testable empirical implications.

A. Intertemporal Announcement Effects

The comparative statics (7) and (8) characterize the optimal pricing function P evaluated at the optimal shareholding α_2^* and the optimal capital expenditures I_2^* of firm 2. If these properties are to hold for all possible values of θ_1 and θ_2, then the resulting pricing function P can be used to derive intertemporal announcement effects. To clarify these announcement effects, let us focus on the announcement date s (which corresponds to $t = 0$ in our theoretical model).

Given that the signaling equilibrium will obtain, which is common knowledge, just *prior* to the announcement (observation) of the signal levels, $\alpha^*(\theta)$ and $I^*(\theta)$, the market knows the following: the class of firms (growth, mature, or declining) involved in signaling, the distribution of θ, $\bar{\theta}$ its mean value, functions $\alpha^*(\cdot)$ and $I^*(\cdot)$ of θ, and the pricing function $P(\alpha, I)$ with its value $\bar{P} = E_\theta[P(\alpha(\theta), I(\theta)]$. Let $\bar{\alpha}, \bar{I}$ be such that $\bar{P} = P(\bar{\alpha}, \bar{I})$. Prior to announcement, the price is $\bar{P}$. At the time of announcement, insiders reveal their choices of $\alpha^*(\theta)$ and $I^*(\theta)$. Now the pricing function $P(\alpha, I)$ and the values of $\frac{\partial P}{\partial \alpha}$ and $\frac{\partial P}{\partial I}$ in equations (7) and (8) tell the market how to price the stock conditional on the announced investments and concurrent revision of insider holdings to $\alpha^*(\theta)$. In particular, if $\alpha^*(\theta) > \bar{\alpha}$, then $P > \bar{P}$, and, if $\alpha^*(\theta) < \bar{\alpha}$, then $P < \bar{P}$. In other words, a higher (lower) final insider holding, implied by net insider buying (selling), elicits a higher (lower) price than $\bar{P}$. Now the interpretations of investment announcements are more complicated. Here the common knowledge information about the firm class (growth, mature, and declining) is used as specified by $\frac{\partial P}{\partial I}$ in (8). For example, for growth firms, $I^*(\theta) > \bar{I}$ implies $P > \bar{P}$, whereas, for mature firms, $I^*(\theta) > \bar{I}$ implies $P = \bar{P}$, and, for declining firms, $I^*(\theta) > \bar{I}$ implies $P < \bar{P}$, and so on. It is these implications which provide the announcement effects.

Although, in the theoretical model, both signals are "announced" to the market simultaneously, in empirical work it will be useful to consider the scenario where the signals are released sequentially. For example, take the scenario where the market knows the extent and direction of insider trading first and then the investment announcement. In other words, the signals are sent sequentially (first insider trading, then investment change) rather than simultaneously as implied by the discussion above. The announcement effects for this case also follow from the model. Based on their private information θ, the insiders *choose* the optimal values for *both* signals $\alpha^*(\theta)$ and $I^*(\theta)$ at date $(s-1)$ (*prior* to the investment announcement day). First, the change in insider holdings from $\bar{\alpha}$ to $\alpha^*(\theta)$ is observed. The new price, which is conditioned only on the insider trading, is $P(\alpha^*(\theta), \bar{I}) \equiv \bar{P}(\bar{I})$ (which is different from $\bar{P}$). If $\alpha^*(\theta) > \bar{\alpha}$, then $\bar{P}(\bar{I}) > \bar{P}$ (i.e., the price goes up), and, if $\alpha^*(\theta) < \bar{\alpha}$, then $\bar{P}(\bar{I}) < \bar{P}$. On investment announcement day, say on day s, $I^*(\theta)$ is also revealed to the market, and the price changes from $\bar{P}(\bar{I})$ to $P(\alpha^*(\theta), I^*(\theta))$, which incorporates the additional information conveyed by the investment signal, $I^*(\theta)$. Again, the common knowledge about the firm class (growth, mature, and declining) is used by the market in determining whether the price response should be positive, zero, or negative for an increase in investment, $I^*(\theta) > \bar{I}$.

Two general comments are in order. First, the above announcement effects apply to insider holdings and investments jointly as well as individually, each with the other held constant. We will analyze these three categories separately in detail. Second, these announcement effects apply not only to the stocks of the firm but to other securities of the firm, in particular, bonds. Even though only stocks were modeled explicitly, it should be clear from the nature of the response

of the market pricing function $P(\alpha, D)$ that all outstanding claims of outsiders can be included. In other words, $\alpha^*(\theta)$ and $I^*(\theta)$ reveal to the market the private information θ of the firm which leads to a revaluation in the market of the entire value of the firm. All securities whose payoff function is monotonic in the value of the firm should move in the same direction in response to the revelation of θ.

B. *Joint Effects*

The efficient signaling equilibrium in Proposition I implies that insiders in firms with better than (worse than) average θ would signal that to the market by increasing (decreasing) the insider shareholdings and by announcing higher than expected investment levels in growth (declining) industries. This in turn implies that the following patterns should occur together.

Declining Firms	$I \downarrow$	$P \uparrow$	$\alpha \uparrow$
	$I \uparrow$	$P \downarrow$	$\alpha \downarrow$
Growth Firms	$I \uparrow$	$P \uparrow$	$\alpha \uparrow$
	$I \downarrow$	$P \downarrow$	$\alpha \downarrow$

In other words, in growing industries higher-than-expected investment announcements should be accompanied by a positive stock price response and net buying by insiders. Similarly, lower-than-expected investment announcements should elicit a negative stock price response and net selling by insiders. On the other hand, in declining industries, higher-than-expected investment announcements should be concurrent with some net selling by insiders, and lower-than-expected investment announcements should occur along with net buying on the part of corporate insiders.

Data on capital expenditure announcements in various categories are available.[10] Similarly, insider holdings and insider trading data are also available.[11] It is possible to test the occurrence of the predicted patterns two ways. 1) Stratify the sample into two classes based on the price response to investment announcement ($P \uparrow I \uparrow$ and $P \downarrow I \downarrow$ in one class and $P \uparrow I \downarrow$ and $P \downarrow I \uparrow$ in the other). In the first category, α should have the same direction of change as I, whereas, in the second category, α should change in direction opposite to that of I. 2) Develop and use a well-defined measure of "growth" firms and "declining" firms

[10] Data on investment announcements made by individual firms can be obtained by searching the Predicasts PTS F & S Indexes through Dialog Information Retrieval Service.

[11] Details of insider trading are available from the *Official Summary of Security Transactions and Holdings* published by the SEC. Section 16(a) of the Securities and Exchange Act of 1934 requires corporate officers, directors, and holders of more than 10 percent of any type of security to report transctions in their holdings to the SEC within 10 days of the end of the month in which the transaction takes place. The *Official Summary* contains these reports. It is published monthly on the basis of reports that are filed in the previous month and that usually are made with respect to trades in the month before. Along with the number of shares traded, the *Official Summary* gives the class of shares traded, the date of the trade, the name of the trader and his or her relationship to the corporation, the nature of the ownership of the securities ("direct" or "indirect"—through a trust, family member, or other intermediary), the trader's month-end holdings, and descriptive footnotes indicating the character of the transaction.

to stratify the sample. (For example, Rozeff (1982) uses two measures of growth developed by the Value Line Investment Survey. The average Tobin's q ratio of the firm can also be used as the basis of this stratification.) Now test whether the predicted patterns are obtained for each subsample.

As mentioned earlier, we expect similar price response for stocks and bonds from the efficient signaling equilibrium. Studying the bond price response might enable us to differentiate our model from the implications of agency-theoretic arguments which may predict opposite price responses for stocks and bonds.

Now we examine the implications of (7) and (8) which characterize the announcement effects which apply to insider trading and investments individually with the other held constant.

C. *Insider Trading*

Equation (7) and the discussion above detail the price response to insider trading activity or to the other changes in insider holdings of common stock, with capital expenditures held constant. Insider buying or selling, as well as stock repurchases, equity issues, conversion to equity of convertible bonds, etc., leads to changes in insider holdings. Equation (7) predicts that transactions which increase insider holdings (insider buying and stock repurchases) should elicit a positive price response and that this price response should be more intense the larger the parameters α, h, and σ^2. In the SEC data set, we *do* have the date of each insider trading; it will be interesting to see whether it is possible to detect any "announcement" effect of individual insider trades. We expect to encounter two difficulties here. First, there is no immediate public announcement of the trades even though market makers and analysts may gain such information with a short time lag. Second, there are a number of trades spread over a period of time caused by the same impending information event (i.e., announcement of capital expenditures), such that the effect of any given trade is likely to be diffused. For these reasons, we do not expect to find a strong announcement effect. It would also be interesting to see whether there are any announcement effects on the days of *reporting* of major insider transactions.

Vermaelen (1981, 1984) and Choi (1986) document some preliminary evidence consistent with $\dfrac{\partial P}{\partial \alpha}$ being positively related to α. In fact, Vermaelen (1984) finds the relationship between $\dfrac{\partial P}{\partial \alpha}$ and α (after controlling for the tender premium and the fraction repurchased) to be positive and significant. However, more work needs to be done examining the detailed implications of (7), in particular the positive relationship of $\dfrac{\partial P}{\partial \alpha}$ to α, h, and σ^2.

Equity issues, bond conversions (which lead to declining insider holdings), and insider selling provide other settings for examining the detailed relationship in (7). Equation (7) also predicts that the negative stock price response to the above transactions should be more intense for firms with large insider holdings (α) and large earnings variability (σ^2). Stock price responses consistent with the direction

implied in (7) have been documented in detail in studies of equity issues and stock repurchases (e.g., Asquith and Mullins (1983), Masulis and Korwar (1986), Choi (1986), Dann (1981), and Vermaelen (1981, 1984)). However, the details of (7) provide further testable implications.

D. Investment Announcements

Equation (8) details the response of the market price of the firm's securities (stocks and bonds) to unexpected changes in investment. Depending on the class of firms (growth or declining), we get different predictions for the price response. Moreover, the intensity of response should be increasing in α, the insider holdings (within a given class). Empirical testing of these many implications of (8) would again involve stratifying growth firms and declining firms based on the measures of technology discussed earlier.

Some preliminary evidence consistent with (8) already exists. (See Mishra (1985), McConnell and Muscarella (1985), and Doukas, Rahman, and Switzer (1986).) Mishra's results for an unstratified sample are mixed, which would be consistent with a sample of mature firms. McConnell and Muscarella (1985) find positive stock price response in their sample in general. However, in the context of a declining industry (oil industry in the late 1970's), they find that announcements of increases in exploration and development expenditures in the period 1975–1981 were associated with systematic *decreases* in stock prices. On announcement of increases in R & D expenditure, Doukas, Rahman, and Switzer (1986) find that the response has also varied with classes of firms. In their total sample of 65 firms, 24 had significantly positive effects and 12 had significantly negative effects. The authors conclude that the market structure of the firms and their technology explain the differential response.

The above studies are preliminary, and much more empirical work needs to be done to sort out the detailed announcement effects derived in (7) and (8) by investigating stock and bond price reponses to investment announcements and concurrent insider trading.

IV. Conclusion

In this paper, we argue that trading by corporate insiders (subject to disclosure regulation) should be viewed as a plausible mechanism for conveying their private information to the market. Our theory and evidence suggest that viewing insider trading as a signaling activity jointly with other corporate signals may be a useful perspective to understand insider trading around corporate announcements and the attendant price effects.

In this paper we examine an information equilibrium where the better informed corporate insiders use the level of their own trading strategically along with the corporate announcements in dealing with a less informed market. The framework used is that of an efficient signaling equilibrium with multiple signals (i.e., both the extent of insider trading and the announced changes in corporate capital expenditures are signals). More specifically, corporate insiders have superior information about a single attribute which parameterizes the NPV of their

investment opportunity set. Insiders can convey changes in this information to outsiders through many combinations of revisions in insider holdings and announced investments. Given a single private attribute and two independent signals, the efficient mix of the two signals must then minimize the dissipative cost of signaling.

Our equilibrium yields several testable implications for the announcement effects of investments and changes in insider holdings. One of the novel features of our model is that it implies that the proper interpretation of the investment signal should be conditioned on concurrent insider trading. In other words, whether investment increases signal "good news" or "bad news" will depend on the other signal—the extent of insider trading. For firms with net insider selling, the stock price response should be negative, for others positive.

In equilibrium, firms signal with both revisions in insider holdings and investment. When investment is fixed, unexpected increases in insider holding elicit an increase in stock and bond prices. However, when insider holdings are fixed, the announcement effect of investment is negative for declining firms and positive for growth firms. Detailed announcement effects also characterize how the intensity of the price response varies with insider holdings, variance of cash flows, entrepreneurial risk aversion, and the class of firm technology (growth or declining). By designing an empirical proxy for firm technology based on Tobin's q ratio and growth measures, the rich harvest of empirical implications of our model can be tested directly using available data on insider holding (and insider trading) and capital expenditure announcements.

Appendix A

In this appendix we provide a proof of Proposition 1 by characterizing the efficient signaling equilibrium and the investment and insider trading strategies for the three different classes of firms. The analysis is similar to Ambarish, John, and Williams (1987).

A. A Solution

First, we will construct the equilibrium for the restricted case of two types of firms and extrapolate. Let $\Theta = \{\theta_1, \theta_1\}$, $\theta_2 > \theta_1$. As before, θ_j, $j = 1, 2$, is the value of the private information attribute. Also, denote $f(I, \theta_j) = f_j(I)$. Recall that, for all feasible investments $I \geq 0$, we have that the function f_j is continuously differentiable, strictly increasing, and strictly concave, with corner conditions $f_j'(0) = \infty$. Given $\theta_2 > \theta_1$, we also have $f_2(I) > f_1(I)$, for all $I \geq 0$. Moreover, by Definition 1, a class of growth firms is characterized by

$$f_2'(I) > f_1'(I) \quad \text{for all} \quad I \geq 0, \tag{A1}$$

a class of mature firms by

$$f_2'(I) = f_1'(I) \quad \text{for all} \quad I \geq 0, \tag{A2}$$

and a class of declining firms by

$$f_2'(I) < f_1'(I) \quad \text{for all} \quad I \geq 0, \tag{A3}$$

Define $U^j(\alpha, I, P) = U(\theta_j, \alpha, I, P)$ and $V^j(\alpha, I) = V(\theta_j, \alpha, I)$, where U and V functions were defined in equations (3) and (4), respectively. Now the efficient signaling equilibrium is defined as follows: conditional on the pricing function P, all common knowledge (including whether (A1), (A2), or (A3) holds), and private information θ_j, insiders select their optimal holdings α_j and investment I_j to maximize their objective U_j.

$$(\alpha_j, I_j) \text{ solves } \max_{\alpha, I \geq 0} U^j[\alpha, I, P(\alpha, I)]. \tag{A4}$$

In turn, outsiders price the firm (and its securities) based on the optimal holdings and investment announcements (α_j and I_j) selected by the insiders.

In the equilibrium, the price so imputed turns out to be the true value of the firm in (4):

$$P(\alpha_j, I_j) = V^j(\alpha_j, I_j). \tag{A5}$$

In short, a signaling equilibrium $\{\alpha_j, I_j, P(\alpha_j, I_j)\}$ satisfies the incentive-compatibility condition (A4) and the competitive-rationality condition (A5). The efficient signaling equilibrium $\{\alpha_j, I_j, P(\alpha_j, I_j)\}$ satisfies the *additional* condition:

$$\max_{P \geq 0} \sum_{j=1}^{2} \pi_j U^j[\alpha_j, I_j, P(\alpha_j, I_j)]. \tag{A6}$$

Among all feasible signaling equilibria defined by (A4) and (A5), the efficient signaling equilibrium minimizes the total costs (or welfare costs) of signaling (compared to that in a full-informational setting).

To characterize the efficient signaling equilibrium, we will proceed by transforming the problem in (A4), (A5), and (A6) into an equivalent nonmimicry problem. In the nonmimicry problem, insiders in more valuable firms choose their holdings and investment levels to maximize their true (full-information) welfare subject to a nonmimicry constraint. This constraint stipulates that the welfare attained by the insiders in the less valuable firm by implementing full-information-optimal shareholding and investment policies exceeds their welfare attained by mimicking the policies of the more valuable firm even to receive their higher stock price. Thus, insiders in the more valuable firms 2 must select a vector of signals which induce insiders in the less valuable firms 1 not to mimic the more valuable firms by matching their signals even to obtain their (firm 2's) higher price in the market. By contrast, insiders in the more valuable firms have no incentive to mimic the less valuable firms. Consequently, the weighted average of welfares in (A6) attains its maximum value when insiders in each type of firm select the signals which maximize their true welfare subject to the nonmimicry constraint on each firm 2.

B. The Nonmimicry Problem

To formalize this nonmimicry problem, focus first on the problem facing the insiders in the more valuable firms. Since $\theta_2 > \theta_1$ and $V^2 > V^1$, if the outside investors are to pay the higher, correct price for firm 2, then they must be able to distinguish between the two firms. For this to be possible, insiders in firm 2 must select their shareholding α_2 and investment I_2 such that insiders in the less

valuable firm 1 have no incentive to mimic. Thus, insiders in firm 2 must pick the vector of signals α_2 and I_2 satisfying the nonmimicry constraint:

$$U^1[\alpha_2, I_2, V^2(\alpha_2, I_2)] \leq U^1[\alpha_1^*, I_1^*, V^1[\alpha_1^*, I_1^*)], \tag{A7}$$

where α_1^*, I_1^* are the *distinct* optimal choices for firm 1 (to be specified below). If insiders in firm 1 were to mimic firm 2, matching both its shareholdings α_2 and investments I_2, and thereby collect from the market a price equal to the higher value $V^2(\alpha_2, I_2)$ appropriate for firm 2, then the value of their objective would be that on the left-hand side of (A7). Instead, if insiders in firm 1 do not mimic firm 2 but choose their own distinct optimal α_1^* and I_1^* (and stand identified as the less valuable firm), then their welfare will be that on the right-hand side of (A7) (α_1^* and I_1^* are specified in more detail below). Whenever (A7) holds, insiders in firm 1 have no incentive to mimic firm 2.

Given that the nonmimicry condition (A7) holds, outside investors can identify correctly each firm and pay for it the appropriate price as in (4). In this case insiders in each firm j choose their shareholdings α_j^* and investment I_j^* which maximize their true welfare $U^j[\alpha, I, V^j(\alpha, I)]$. For the more valuable firms, $j = 2$, such maximization is constrained by inequality (A7). For the less valuable firms, $j = 1$, there is no nonmimicry constraint.

More specifically, α_2 and I_2 solve

$$\max_{\alpha, I \geq 0} U^2[\alpha, I, V^2(\alpha, I)], \tag{A8}$$

subject to the constraint in (A7), and α_1 and I_1 solve

$$\max_{\alpha, I \geq 0} U^1[\alpha, I, V^1(\alpha, I)]. \tag{A9}$$

Rewriting the above programs using (2) and (4), we have, for firm 2,

$$\max_{\alpha, I \geq 0} C - I + f_2(I) - \frac{h\sigma^2}{2}\alpha^2 \quad \text{s.t.} \quad \text{constraint (A7)} \tag{A10}$$

and, for firm 1,

$$\max_{\alpha, I \geq 0} C - I + f_1(I) - \frac{h\sigma^2}{2}\alpha^2. \tag{A11}$$

Under symmetric information, the market can observe each firm's private attribute and pay a price equal to the appropriate true value. Anticipating this, insiders in firm j would choose their shareholdings and investment to maximize $U^j[\alpha, I, V^j(\alpha, I)]$ unconstrained. Denote by α_j^o and I_j^o the resulting symmetric-information solution for firm j. The insiders diversify optimally under symmetric information: $\alpha_j^o = 0$, $j = 1, 2$. Also the optimal investment I_j^o is picked where I_j^o uniquely satisfies the familiar first-order condition:

$$1 = f_j'(I_j^o). \tag{A12}$$

That is, the insiders in firm j invest in all projects with nonnegative NPVs. Here, a remark is in order about $\alpha_j^o = 0$, $j = 1, 2$. The proper interpretation for $\alpha_j^o = 0$ is that, under symmetric information, insiders do not hold a *suboptimally* diver-

sified position in their own firm, exposing themselves unnecessarily to unsystematic risk (as in Leland and Pyle (1977)). Since, for simplicity of exposition, we did not allow the insiders to invest in the market portfolio, the full-information benchmark level of shareholding happens to be zero. What is important is the deviation of the insider's shareholding from the full-information benchmark level, its relation to his or her private information, and his or her concurrent investment announcement.

C. *Equilibrium Strategies*

Now we can characterize the choices of firms in the efficient signaling equilibrium. Because insiders in less valuable firms need not worry about mimicry, they solve (A9) or (A11) and do the best they can in equilibrium. Such a solution involves zero welfare loss. For firm 1, insiders simply choose their shareholding and investments which are optimal under symmetric information $\alpha_1^* = 0$, $I_1^* = I_1^o$. In other words, each one of the less valuable firms invests in all projects with nonnegative NPVs and pays out the residual $C - I_1^o$, and their insiders hold optimally diversified positions.

The choices of the more valuable firms are more complicated. Before we characterize their solution, let us rewrite (A7) using (2), (4), and the substitution $\alpha_1^* = 0$, $I_1^* = I_1^o$, to obtain

$$(1 - \alpha) f_2(I) + \alpha f_1(I) + C - I - \frac{h\sigma^2}{2} \alpha^2 \leq f_1(I_1^o) + C - I_1^o. \tag{A13}$$

If, for firm 2, the optimum under symmetric information, $\alpha_2^o = 0$, $I_2^* = I_2^o$ (given by (A12)), had satisfied the nonmimicry constraint (A13), then $\alpha_2^* = 0$ and $I_2^* = I_2^o$ would have been the signaling choices of firm 2, and the resulting efficient signaling equilibrium would have entailed *no* welfare loss due to signaling. It would have been a costless signaling equilibrium. However, $(0, I_2^o)$ violates (A13). Substituting $(0, I_2^o)$ in (A13) yields $f_2(I_2^o) + C - I_2^o \leq f_1(I_1^o) + C - I_1^o$. This implies $f_2(I_2^o) - I_2^o \leq f_1(I_1^o) - I_1^o$. (A13) does not hold *since* $f_2(I_2^o) - I_2^o > f_2(I_1^o) - I_1^o$ by optimality of I_2^o, and $f_2(I_1^o) - I_1^o > f_1(I_1^o) - I_1^o$ since $f_2(I) > f_1(I)$ for all $I \geq 0$. This implies that (A13) is a binding constraint at the optimal solution α_2^*, I_2^*. The condition $f_2'(0) = \infty$ always induces some investment, i.e., $I_2^* > 0$. As a result, the optimal solution will have $\alpha_2^* \geq 0$, $I_2^* > 0$. Recall that we have shown that $\alpha_2^* = 0$, $I_2^* = I_2^o$, is *not* a solution. Using λ as the *nonnegative* multiplier of constraint (A13) and μ as the *nonnegative* multiplier of $\alpha_2 \geq 0$ constraint, we can write down the first-order conditions of firm 2's constrained optimization:

$$f_2' - 1 - \lambda[(1 - \alpha) f_2' + \alpha f_1' - 1] = 0, \tag{A14}$$

$$-h\sigma^2\alpha + \lambda[f_2 - f_1 + h\sigma^2\alpha] + \mu = 0, \tag{A15}$$

in addition to the complementary slackness conditions and the constraints. It is straightforward to verify that any solution with $\alpha_2^* = 0$ has $I_2^* = I_2^o$. However, we have established that $(0, I_2^o)$ violates constraint (A13). So, all solutions to the

above program must satisfy $\alpha_2^* > 0$ (and consequently $\mu^* = 0$) Now (A15) implies

$$\lambda^* = \frac{h\sigma^2\alpha_2^*}{f_2 - f_1 + h\sigma^2\alpha_2^*}. \tag{A16}$$

Given $f_2 > f_1$, for risk-averse insiders, i.e., for $h > 0$, we have $0 < \lambda^* < 1$. Given $\alpha_2^* > 0$ and $0 < \lambda^* < 1$, (A14) implies that, at I_2^*,

$$\lambda^*\alpha_2^*(f_2' - f_1') = (1 - \lambda^*)(1 - f_2'), \tag{A17}$$

which in turn implies

$$\text{sign}(f_2' - f_1') = \text{sign}(1 - f_2'). \tag{A18}$$

The condition (A18) characterizes the investment policy I_2^* of the higher quality firm (of type θ_2) in the efficient signaling equilibrium. Here, the right-hand side of (A18) characterizes whether the signaling-equilibrium level of investment I_2^* represents overinvestment, full-information optimal investment, or underinvestment, i.e.,

$$\text{sign}(f_2' - f_1') = \text{sign}(I_2^* - I_2^o). \tag{A19}$$

Using equations (A1), (A2), and (A3) along with (A18) and (A19), we can directly characterize the investment policy I_2^* of all but the poorest firms (recall $I_1^* = I_1^o$) in terms of the family of technologies in the economy (growth, mature, or declining). It should also be pointed out that, although we have restricted ourselves to the case where there are only two types of firms, the results extend to the case of multiple types (where the cardinality of Θ is larger than 2). For the growth family of technologies, that is, when $\frac{\partial^2 f}{\partial I \partial \theta} > 0$ for $I \geq 0$ and for all $\theta \in \Theta$ $\left(\text{or equivalently if } \frac{\partial f}{\partial I} \text{ is increasing in } \theta \text{ for } I \geq 0 \text{ and for all } \theta \in \Theta\right)$, all but the poorest firms *overinvest* in the efficient signaling equilibrium. In the case where all the firms in the family are of the declining category, $\frac{\partial^2 f}{\partial I \partial \theta} < 0$ for all $I \geq 0$ and $\theta \in \Theta$, and the signaling levels of investments $I^*(\theta)$ are less than $I^o(\theta)$ for all but the poorest firms. Only the mature firms invest at their full-information optimal levels.

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