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ABSTRACT

This paper examines optimal corporate financing arrangements under asymmetric information for different patterns of temporal resolution of uncertainty in the underlying technology. An agency problem, a signalling problem and an agency-signalling problem arise as special cases. The associated informational equilibria and the optimal financing arrangements are characterized and compared. In the agency-signalling equilibrium the private information of corporate insiders at the time of financing is signalled through capital structure choices which deviate optimally from agency-cost minimizing financing arrangements, which in turn induce risk-shifting incentives in the investment policy. In the pure signalling case the equilibrium is characterized by direct contractual precommitments to implement investment policies which are riskier than pareto-optimal levels. Empirical implications for debt covenants and the announcement effect of investment policies and leverage increasing transactions on existing stock and bond prices are explicitly derived.

THIS PAPER is an exploratory attempt to relate optimal corporate financing arrangements to patterns of temporal resolution of uncertainty in the underlying technology. Since, in general, the timing of the uncertainty resolution could be different for different agents (say corporate insiders vs. outsiders) some of the issues which arise are those of financing under asymmetric information. However, a systematic analysis of the implications for corporate finance of the interaction of private information and temporal resolution of uncertainty has not been undertaken.[1] It is hoped that such a program of research will yield better answers to questions of timing of various corporate financing decisions. For instance, is there an optimal maturity structure of corporate claims (debt claims in particular) to be used to finance a technology with given characteristics? Why are projects in their initial phase often financed differently from projects in more advanced phases? For example, growth firms use a larger component of retained earnings for their financing than mature firms, and project financing (incorporated as legally segregated entities) is often used for the start-up phase of some ventures to switch later to more conventional modes. Why do leveraged buy-outs often

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[1] The role of temporal resolution of uncertainty in a full information setting has been studied before, e.g., see Epstein and Turnbull [10], Robichek and Myers [42] and Nabor, Stapleton and Subrahmanyam [40].

involve technologies at advanced (mature) phases of their operation? Why do the dividend policies of mature firms differ markedly from those of growth firms?

This paper is an initial attempt to provide a framework to study some of these issues. In our specification of the problem firm technologies are characterized by uncertainty about two elements of the cash flow generating process (in addition to the final cash flow itself). In our three-date (two period) model, we can examine different patterns of resolution of uncertainty (possibly at different times to corporate insiders and outsiders). It will be shown that the timing of financing and investment decision in relation to the timing of the resolution of uncertainty can determine the optimal mode of financing. For example, consider the following three patterns of resolution of uncertainty: (P1): Uncertainty about the first element of the technology is publicly resolved at initial date while the second element is privately revealed to insiders after financing is done but before investment choices are made. (P2): The first element of information is privately received by insiders at the prefinancing stage but uncertainty about the second element is publicly resolved after financing is done but before investment choices are made. (P3): Both pieces of information are privately revealed to insiders, the first before financing and the second after financing is done but before investment choices are made. The above configurations correspond to (1) an agency problem, (2) a signalling problem and (3) an agency-signalling problem, respectively. It will be shown that the optimal financing arrangements for the above cases will be different. For our specification of the technology, the agency problem in (P1) will be optimally handled by an all equity financing mode whereas the signalling problem in (P2) necessitates detailed covenants specifying investment choices contingent on the value of the second piece of information. The joint problem of agency and signalling in (P3) involves optimal capital structures which include risky debt as well as equity. Deviations from capital structures optimal for the pure agency problem in (P1) are required to induce revelation of information at the financing stage.[2]

A second objective of this paper is to examine in a unified framework aspects of agency and signalling which arise in a corporate financing setting. An agency problem, a signalling problem and an agency-signalling problem arise naturally for different plausible patterns of resolution of uncertainty in our model. A comparative study of the optimal financing arrangements for these related scenarios of asymmetric information provides integrative insights.

A significant portion of the theory of corporate finance under asymmetric information can be categorized into two distinct paradigms, agency models and financial signalling models. In the agency-theoretic studies, the focus is on the structure of claims to corporate assets and the resulting conflicting interests. Moral hazard and incomplete contracting ability lie at the heart of the agency

[2] The model of this paper allows only a single date of financing and a single subsequent date of investment. It still admits a variety of interesting configurations of resolution of uncertainty. Uncertainty may resolve at different times (pre-financing, post-financing but pre-investment, and post-financing-investment at terminal date), at different rates (partially or completely) and publicly or privately to corporate insiders. However, to address the ambitious menu of issues raised at the beginning of the paper we need a richer model with multiple dates of financing and investment. See John and Nachman [27] and John [23] where aspects of optimal timing of financing and maturity structure of claims are addressed.

relationship where monitoring costs and widely dispersed securities prevent outside claimants from observing completely some actions by corporate insiders, e.g., their consumption of prerequisites and investment risk choices.[3] Financial signalling models, on the other hand, deal with the asymmetric information between corporate insiders and the outsiders in the market about some crucial aspect of the cash-flow generating technology of the firm at the time of financing. Since outsiders need such information to compute the true value of their external claims, insiders in undervalued firms may try to signal the "quality" of their firm through appropriate observable corporate actions, e.g., mix of external claims sold, the contracts which accompany these claims, dividend or investment policy, etc.[4]

The major theme in the agency models in corporate finance has been that outside claimants are only able to observe incompletely actions by corporate insiders (or situations in which actions are taken) which affect the value of their claims.[5] With outsiders unable to enforce contracts conditional on unobserved actions, insiders in each firm take as given their structure of outside claims, act privately, and maximize their personal gain. When purchasing corporate securities, outsiders rationally anticipate these subsequent actions and pay in the perfectly competitive capital market correct prices. This then produces an agency problem if insiders finance their firm's projects partly by selling risky corporate securities to outsiders. Because insiders must ultimately bear all agency costs, they initially choose their firm's capital structure to minimize these costs. Such optimal capital structures have been suggested in several agency models, e.g., Jensen and Meckling [20], Myers [36], John and Williams [28], Grossman and Hart [13], and Green [12].[6] In comparing the agency and agency-signalling scenarios in patterns (P1) and (P2) of this paper, it is evident that pure agency scenarios are restrictive in the informational requirements they impose on outside

[3] The literature on the principal-agent paradigm and the related theory of contracting is now voluminous. For an excellent recent review see Hart and Holmstrom [16]. In the corporate finance setting, a partial list of recent papers include Jensen and Meckling [20], Myers [36], Smith and Warner [46], Grossman and Hart [13], John and Kalay [24, 25], John and Williams [28] and Green [12]. A dynamic version of the agency problem is analyzed in John and Nachman [27].

[4] Market signalling was first developed by Spence [47] in the setting of labor markets and extended by Riley [41] and others. Ross [43] and Leland and Pyle [31] pioneered the study of financial signalling. Other papers which examine financing choices as signals include Heinkel [17], John and Williams [28, 29], Ambarish, John and Williams [1], John and Kalay [25], Shah and Thakor [44], Darrough and Stoughton [8], Vishwanathan [48], Harris and Raviv [14], Brennan and Kraus [5], and Constantinides and Grundy [7].

[5] Moral hazard models subsume the following two cases: the case where the agent takes unobservable actions and the case where his actions may be observed but not the contingencies under which his actions were taken. Arrow [2] suggests the names *Hidden Action Model* and *Hidden Information Model* for these two cases. The worker supplying unobservable effort is the prototypical hidden action case while the corporate insider making observable investment decision (in a state that he privately observes), as is modelled in this paper, might be a typical hidden information case. Empirically the second case seems to be a more useful characterization. For an example, see John and Kalay [24] for an analysis of optimal pay-out constraints in an agency model of the *Hidden Information* type.

[6] These studies which suggest that a particular structure of claims (capital structure) formed out of a pre-specified menu of contractual forms (say, debt and equity) needs to be used for incentive purposes beg the question why direct incentive schemes would not be cheaper. For preliminary work which attempts to endogenize the contractual form of external corporate claims, see Gale and Hellwig [11] and Williams [49].

investors. To anticipate the optimal private insider actions in the pricing of their claims the outsiders need to know as much as the insiders about the structure of the agency problem, i.e., the details of insiders' preferences and their firm's technology. In the realistic scenario where some of these details may be private information at the time of financing, we have the more plausible agency-signalling case which corresponds to pattern (P3).

Models of financial signalling, e.g., Ross [43] and Leland and Pyle [31], on the other hand assume that outsiders cannot directly observe corporate characteristics in sufficient detail to calculate the values of all marketed securities. Thus, outsiders rationally attempt to infer these values from observed corporate policies such as corporate capital structures, debt contracts, dividend or investment policies. Based on their conjectures about the relationship between corporate actions, say capital structure, and true value, outsiders then bid competitively for corporate securities. In turn, insiders in each firm respond to the resulting pricing functions for corporate securities, and pick the financing package which maximizes their personal gain. If a signalling equilibrium exists, outsiders can then distinguish between firms through the capital structures selected optimally by their insiders. Moreover, competition in the capital market forces outside investors to pay in this equilibrium the correct prices for all securities. The agency-signalling case in pattern (P3) suggests a natural augmentation of the signalling case as follows: after the claims are issued but before investment decisions are made corporate insiders obtain additional private information about the technology. This brings about an agency probem (of the *hidden information* type) in addition to the adverse selection problem due to precontractual informational asymmetry. Again, the agency-signalling problem in (P3) analyzed here is a realistic generalization of the pure signalling scenario.[7]

In the agency-signalling problem corresponding to pattern (P3) outside investors observe neither the firm's detailed characteristics at financing time nor future resolution of uncertainty based on which insiders may take crucial investment decisions in the firm. Since contracts specifying insider decisions are unenforceable, insiders act privately producing an agency problem. An agency-signalling equilibrium is shown to exist in which outsiders correctly distinguish among firms conditional upon insiders' optimal capital structures, anticipate insiders' subsequent private actions, and then pay correct prices for all corporate securities.

The model is developed in Section I. It is a three-date (two-period) model.

[7] In John and Kalay [25], an agency-signalling equilibrium is studied where the optimal debt contracts specified to minimize the agency costs of underinvestment serve as signals of pre-contractual private information. In John and Williams [28], a signalling equilibrium driven by the agency costs of unobservable managerial perk consumption is studied. As in this paper, capital structures using higher leverage than those in a pure agency solution characterize the agency-signalling equilibrium. In subsequent work Darrough and Stoughton [8] also model managerial effort as private action in a Leland and Pyle [31]—type signalling model. With managerial perk consumption, effort choice and risk aversion as crucial aspects of these models, the John–Williams and Darrough–Stoughton models seem plausible only as models of small entrepreneurial firms. The focus in this paper is on the agency-signalling problems in a widely held firm. For examples of models which study moral hazard and adverse selection issues in a unified framework in other contexts, see Myerson [39], Baron [3], Bhattacharya and Gale [4] and Chan and Thakor [6]. The sequential equilibrium in John and Nachman [27] can also be viewed as an agency-signalling equilibrium.

Initially the insiders in each firm identify a risky portfolio of projects (or a technology) whose profitability depends on the terminal cash flow to be realized at $t = 2$. This final cash flow depends on two crucial parameters which is uncertain at time $t = 0$. In our specification these parameters correspond to a risk dimension and the quality of return dimension (to be formalized later). Uncertainty about these parameters can resolve at $t = 0$ or $t = 1$ either privately to the insiders or as public information. At $t = 0$ insiders contribute some capital to the firm and raise additional capital by issuing claims to outsiders. At $t = 1$ any uncertainty about the crucial parameters which has not already resolved resolves (either privately or publicly) and insiders take the investment decision. They choose to invest either in the risky project or the capital market. At $t = 2$, the realized cash inflows from the investment are allocated according to the specified sharing rules. In this paper we focus on *five* of the possible patterns of resolution of uncertainty. These five cases are listed in terms of the underlying information structures in section I, and referred to as (P0), ($\overline{\text{P0}}$), (P1), (P2), and (P3).

The first two patterns, (P0) and ($\overline{\text{P0}}$), are symmetric information scenarios which differ only in the timing of resolution of the second crucial parameter of the technology. In (P0) this resolution takes place pre-financing at $t = 0$ whereas in ($\overline{\text{P0}}$) it happens post-financing but pre-investment at $t = 1$. In both cases the structure of financing claims issued at $t = 0$ is a matter of irrelevance; however for ($\overline{\text{P0}}$) the external claims should contain contractual specification of optimal investment policies to be implemented at $t = 1$. The remaining three patterns are (P1), (P2) and (P3) which have been mentioned before. They all involve asymmetric resolution of the uncertainty and correspond respectively to a pure agency problem, a pure signalling problem and an agency-signalling problem as viewed from $t = 0$. Patterns (P1) and (P2) are analyzed in section II and pattern (P3) is analyzed in section III where the solutions to the various scenarios are compared. The empirical implications and extensions are discussed in section IV.

In pattern (P1) uncertainty about the "return quality" parameter is publicly resolved at $t = 0$ before the financing claims are sold but the second (risk) characteristic is revealed only to insiders at $t = 1$ before investment choices are made. This is clearly a pure agency problem. Here using any level of risky debt gives rise to risk-shifting incentives which in turn results in agency costs. In other words, outside claimants anticipate the risk-shifting behavior which is "optimal" from the insider's perspective for any given level of debt, price it correctly therefore imposing on the insiders any decrease in value resulting from their distorted incentives. If, however, the firm can finance its value-maximizing investment without any risky debt, then it does so and thereby avoids all agency costs.

In pattern (P2), also analyzed in section II, information about the "return quality" parameter is privately obtained by insiders at the pre-financing stage but uncertainty about the second (risk) characteristic is publicly resolved after financing is done but before investment choices are made. The solution to this pure signalling problem involves precommitting to investment policies contingent on the value of the second parameter in the covenants issued with outside claims at $t = 0$. A separating signalling equilibrium is shows to exist at $t = 0$ with the investment precommitments serving as signals. All but the poorest firms precommit to implement investment policies riskier than the full-information optimal ones, and the resulting loss in value serve as endogenous signalling costs. Empirical implications for debt covenants and the effect of investment announcements on stock and bond prices are derived.

In section III, we analyze pattern (P3) where uncertainty about the "return quality" parameter is privately revealed to insiders at $t = 0$ before the financing claims are sold and the second (risk) characteristic is revealed only to insiders at $t = 1$ before investment decisions are made. This situation viewed at the financing stage at $t = 0$ combines aspects of signalling and agency. We establish the existence of an agency-signalling equilibrium and an informationally consistent pricing function for the bonds and equity optimally issued by firms. In equilibrium, all firms (except the one with the lowest value of the return-quality parameter) issue some risky debt and follow riskier investment policies compared to that in the agency or signalling cases analyzed in section II. In other words, almost all firms deviate from capital structures which minimize agency costs. (This is in contrast to the implications of pure agency models, e.g., Jensen and Meckling [20], Green [12]). The resulting agency costs drive the signalling equilibrium (i.e., the agency-signalling equilibrium exists without recourse to any exogenous costs of false signalling).[8]

Comparing the signalling equilibria in (P2) and (P3) provides interesting insights. In both cases the signalling costs arise endogenously from implementing investment policies which are riskier than full-information optimal levels. In (P2) direct precommitments to implement such investments can be made at $t = 0$ and enforced at $t = 1$. However, in (P3) since contracts cannot be enforced on investment policy this can only be accomplished indirectly by choosing capital structures at $t = 0$ which would then make it incentive-compatible for insiders to implement these investment policies at $t = 1$.

The announcement effect which characterizes the agency-signalling equilibrium is explicitly derived. It seems to provide an explanation for the previously puzzling results on the announcement effects of financial restructuring on stock and bond prices. Jensen and Smith ([21], Table 2) and Smith ([45], Tables 1 and 3) summarize more than a dozen studies of stock price changes at announcements of transctions which change capital structure. Many of these documented regularities are consistent with the predictions of the agency-signalling equilibrium here.[9]

I. The Model

The three date (two-period) model is designed to capture some essential aspects of temporal resolution of uncertainty in a simple framework. At $t = 0$ insiders in

[8] A managerial penalty function for bankruptcy—one common specification of signalling costs—can be either unenforceable given limitations on personal liability under the bankruptcy code, or subject to manipulation through side payments from interested stockholders (see, e.g., Ross [43]).

[9] Previous explanations of these phenomena have been attempted based on bankruptcy cost effects, wealth redistribution among classes of security holders and effects of corporate and personal taxes (see Masulis [32], Jensen and Smith [21]), resolution of uncertainty (Huberman [18]), and agency-theoretic considerations (Jensen [19]). However, symmetric information models with tax/bank-

the firm identify a risky project. The projects are indexed by a pair of parameter values $\{r, H\}$. The interpretation of these parameters are as follows: If a fixed amount I is invested in the risky project $\{r, H\}$ at $t = 1$ it results at $t = 2$ in a high cash flow H with probability r and a low cash flow L with a probability $(1 - r)$. At $t = 0$ the values of r and H are uncertain, although it is common knowledge that r is uniformly distributed on $[0, 1]$, H is distributed on $[\underline{H}, \bar{H}]$ according to the distribution function G (where $\bar{H} > \underline{H} > I > L$) and r and H are independently distributed. Uncertainty of r and H may resolve either at $t = 0$ or $t = 1$ and the resolution may be either as private information to insiders only or publicly. The pattern of resolution of uncertainty in a given risky project (i.e., the specification of what uncertainty resolves when and to whom) is also assumed to be common knowledge.

The amount I has to be raised at $t = 0$ which is the single date of financing in this model. (Financing or refinancing at $t = 1$ is precluded.)[10] At this time insiders contribute capital of amount Q, $Q > 0$, to the firm and raise additional funds by selling claims to outsiders. The optimal financing package or capital structure is thus chosen by insiders at $t = 0$ conditional on any resolution of uncertainty at $t = 0$ about r or H. The menu of outside claims they can issue is restricted to equity and riskless/risky debt along with covenants containing any enforceable (informationally feasible) restrictions on investment decision.[11] At $t = 1$, conditional upon the capital structure and any information revealed at $t = 0$ or $t = 1$ to insiders, they choose their investment strategy subject to contractual restrictions. They can either invest in the risky project or capital market opportunities (zero net present value investment). For simplicity of exposition, let us assume that the investment alternative available in the capital market is a riskless asset and that the riskless interest rate is zero. At $t = 2$, the firm liquidates and distributes the terminal cash flow I, H or L to the claimholders.

Insiders act to maximize the wealth of the current shareholders (under asymmetric information, the true value of their claims conditional on the private information). We abstract from discounting in all time periods. In our frictionless capital market with no taxes or transactions costs a firm's securities are valued using risk neutral valuation, i.e., taking the relevant conditional expectation of the cash flows (say, with respect to the state price density function).

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ruptcy/liquidity effects or pure agency models *cannot* convincingly explain these announcement effects. Unless one makes the implausible assumption that important resolutions of uncertainty only happen in coincidence with these not-too-frequent events of financial restructuring the above factors can only apply to cross-sectional regularities but not to announcement effects. The obvious implausibility of announcement effects in symmetric information models is true for pure agency models, as well. In the pure agency models, outsiders cannot observe insiders' private actions but can anticipate their optimal actions given symmetric information about firm's technology and insiders' preferences. In other words, insiders' optimal private actions are common knowledge and optimal financial restructurings should be fully anticipated *precluding* any announcement effects on the firm's securities (except in cases where these announcements happen simultaneously with major resolutions of uncertainty by pure coincidence). In our agency-signalling model capital structure rearrangements convey private information to the market eliciting announcement effects in security prices consistent with documented evidence.

[10] See Huberman [18] for an assumption which is similar in spirit and some justifications. John [23] relaxes this assumption and allows multiple dates of financing.

[11] John [23] allows a richer menu of external claims.

Five patterns of resolution of uncertainty are analyzed in this paper. They are: (P0): Both r and H become public information at $t = 0$. ($\overline{\text{P0}}$): H is publicly revealed at $t = 0$ and r at $t = 1$). (P1): H is publicly revealed at $t = 0$ and r is privately revealed to insiders at $t = 1$. (P2): H is private information available to only insiders at $t = 0$ and r is publicly resolved at $t = 1$. (P3): H is private information at $t = 0$ and r is privately observed by insiders at $t = 1$.

The full information scenarios (P0) and ($\overline{\text{P0}}$) as well as the agency problem in (P1) and the signalling problem in (P2) are analyzed in section II. The agency-signalling problem in (P3) is analyzed in section III and compared with the results for other patterns.

II. The Pure Cases

A. Full Information Cases

(P0) is the classical full-information case. Here financing is irrelevant. Given symmetric information at $t = 0$ about r and H, the optimal investment at $t = 1$ can be determined at $t = 0$. That policy is to invest in the risky project if

$$rH + (1 - r)L \geq I \tag{1}$$

i.e., invest in the risky project as long as it yields nonzero net present value; otherwise invest in the riskless assets. Thus any mix of financial claims sold at $t = 0$ are equivalent and the contracts would simply specify the optimal invest/not invest (in risky project) decision taken at $t = 0$.

In ($\overline{\text{P0}}$), the investors in the market as well as the insiders know the type of the firm H and will observe precisely the value of r that will be obtained at $t = 1$. In this case for any r realized at $t = 1$ a firm of H-type should optimally invest at $t = 1$ in the risky project as long as (1) is satisfied. Denote as $r^0(H)$ the lowest (cut-off) value which makes the risky investment dominate the riskless investment for an H-type firm.

$$r^0(H) = \frac{I - L}{H - L} \tag{2}$$

Since (1) specifies the value-maximizing investment policy, in this full-information scenario, the firm's insiders would contractually precommit to invest for all $r \geq r^0(H)$.[12] Given this enforceable contract to undertake the pareto-optimal investment policy the insiders can choose any capital structure (i.e., amount of risky debt and fraction of equity sold to outsiders) and realize the full-information value of the firm,

$$V^0(H) = r^0(H)I + \tfrac{1}{2}[1 - r^0(H)]^2L + \tfrac{1}{2}[1 - r^0(H)^2]H \tag{3}$$

[12] An investment policy of investing in the risky asset for all $r \geq \hat{r}$, will be denoted as investment policy $\{\hat{r}\}$ when there is no room for confusion. Given that r is uniformly distributed on [0, 1], an investment policy $\{\hat{r}\}$ results in a distribution of terminal cash flows as follows: H with a probability $\tfrac{1}{2}(1 - \hat{r}^2)$, I with a probability $\hat{r}$ and L with a probability $\tfrac{1}{2}(1 - \hat{r})^2$. For $\tilde{r} < \hat{r}$, investment policy $\{\tilde{r}\}$ produces a terminal distribution which is riskier (in the Rothschild-Stiglitz sense) than that produced by the investment policy $\{\hat{r}\}$. In this case, we will say that investment policy $\{\tilde{r}\}$ is risker than investment policy $\{\hat{r}\}$.

This value is independent of the mix of outside claims issued by the insiders against the terminal $t = 2$ cash flows.

B. The Pure Agency Case

Now let us consider pattern (P1). Here there is no asymmetry of information about the type H of the firm, i.e., the outsiders and insiders have that information at $t = 0$ while the firm chooses its capital structure and issues outside claims. At $t = 1$ the insiders become privy to the realization of r the probability of the high outcome. Since the outsiders do not observe r, they cannot write or enforce contracts conditional upon r. At $t = 1$, insiders would invest to maximize the value of the claims they hold. Here the investment decision at $t = 1$ can depend on the claims outstanding. If the outside claims include risky debt then insiders invest more often in the risky project, i.e., with risky debt outstanding they will invest in values of r below $r^0(H)$. These incentives to implement at $t = 1$ a riskier investment policy will be correctly priced by the bond holders such that any loss in value resulting from deviating from the investment policy $\{r^0(H)\}$ is borne entirely by the insiders.

The end period optimal strategies of insiders for any level of debt outstanding is characterized below. Let F denote the promised payment of the pure discount bond issued at $t = 0$ and maturing at $t = 2$.

PROPOSITION 1. *For any $F > 0$, insiders will implement the investment policy $\{r_F(H)\}$ where $r_F(H)$ is given by*

$$\begin{aligned} r_F(H) &= r^0(H) && \text{when} \quad F \le L \\ &= \frac{I - F}{H - F} && \text{when} \quad L < F < I \\ &= 0 && \text{when} \quad F \ge I. \end{aligned}$$

Whenever the debt is risky, $F > L$, then the investment policy $\{r_F(H)\}$ is riskier than pareto optimal one, i.e., $r_F(H) < r^0(H)$.

Proof. When a promised payment F is outstanding the insiders will invest in states r, $r \ge r_F(H)$, where $r_F(H)$ is given by

$$r_F(H)(H - F)^+ + (1 - r_F(H))(L - F)^+ = (I - F)^+ \tag{4}$$

where $q^+ = \max\{0, q\}$. The characterization of $r_F(H)$ now follows from equation (4) for the three ranges of F. When $F > L$, the debt is risky and $r_F(H) < r^0(H)$, i.e., the firm invests in the risky project for a larger range of r, for $r \in [1, r_F(H)]$ instead of the pareto optimal range $r \in [1, r^0(H)]$.

COROLLARY 1. *For $L < F < I$ the investment policy is strictly increasing in riskiness with increasing F, i.e., r_F is decreasing in F. (Recall $\underline{H} > I$).*

We formalize the magnitude of the agency costs resulting from a given level of debt in the next corollary. Let $A_F(H)$ stand for the agency costs, which is the difference between the total value of the firm resulting from investment policy $\{r_F(H)\}$ and that from $\{r^0(H)\}$.

COROLLARY 2. *For any level $F > L$, there is positive agency costs. These agency costs are increasing in F, for $L < F < I$.*

Proof. Substituting and simplifying we obtain $A_F(H) > 0$. $A_F(H)$ is increasing in F for $I > F > L$ *is seen by computing*

$$\frac{\partial A_F}{\partial F} = [r_F H + (1 - r_F)L - I] \frac{\partial r_F}{\partial F}$$

The first term is negative by the defintion of r_F and the second term is negative by corollary 1 of Proposition 1 making $\frac{\partial A_F}{\partial F}$ positive.

Given corollary 2 that for any amount of risky debt $F > L$ there is positive agency costs the optimal solution of the insiders is straightforward; they should choose a capital structure with no risky debt, i.e., only riskless debt ($F \leq L$) and equity. In this case the investment policy remains that in the full information setting and there is no agency costs.[13] We have,

PROPOSITION 2. *The optimal financing for the pattern* (P1) *involves no risky debt. Any financing package with riskless debt and equity achieves the pareto-optimal investment policy in* (2) *and firm value in* (3).

For any level of risky debt, although outsiders cannot observe directy insiders' investment policy because of the unobservability of r, they are able to compute the optimal investment policy $\{r_F(H)\}$ which the insiders of an H-type firm would pursue given a debt level F. The outsiders incorporate this in the pricing of their outside claims. But this requires knowledge of a firm's type H. In (P2) and (P3), since H is private information at $t = 0$ outsiders will have to infer its value from observable actions (signals) by the informed insiders. In (P2) we have a pure signalling problem whereas (P3) combines aspects of agency and signalling.

C. Signalling with Investment Precommitments

In (P2), the insiders come to know the value of the quality parameter H at time $t = 0$ prior to financing. Further it is common knowledge that uncertainty about r will resolve publicly at $t = 1$. In this case, contracts stipulating particular investment policies are enforceable at $t = 1$. However, outsiders are unable to compute the prices for their claims at $t = 0$ because they do not know the value of H.[14] Here, given that the firm has to issue some external claims in addition to riskless debt, it may be in the interests of the insiders to signal the parameter H to the market through some observable action taken at $t = 0$. Capital structure

[13] Note that we did not explicitly describe the underlying dynamic programming procedure. However, implicitly that is precisely what we did. In proposition 1 we characterize the optimal investment policy which would be undertaken at $t = 1$, i.e., whenever $r \geq r_F$ the insiders would undertake the risky project. Given this investment policy the $t = 0$ value function implies that the optimal financing is to use no risky debt (corollary 2 of Proposition 1).

[14] With insider contribution Q the required outside financing is $I - Q$. If $L \geq I - Q$, then riskless debt alone can provide the required financing and all firms would optimally limit themselves to such financing. Henceforth, we assume $I - Q - L > 0$ such that some form of risky outside claims have to be issued, say debt of face value $F \geq L$ and an equity fraction α, $1 > \alpha \geq \alpha^* > 0$ where $\alpha^* V_0(\underline{H}) = I - Q - L$.

choices and investment policy precommitments made contractually at $t = 0$ are candidates for signals.[15] Here we will analyze a signalling equilibrium driven by investment precommitments alone (which is valid for any given capital structure).[16] From the point of view of comparing with the equilibrium for (P3) this is the most relevant.

For concreteness let us assume that the outside claims issued at $t = 0$ are risky debt of face value F, $I > F > L$, and outside equity of fraction α, $0 < \alpha < 1$. The contracts which accompany these would also include optimal investment policy precommitments made by the insiders. Since r is publicly resolved at $t = 1$ these precommitments are enforceable. A precommitment to invest in the risky technology for all $r \geq \hat{r}$, will be parametrized by $p = 1 - \hat{r}$. The larger the value of p the larger the precommitment to invest in the risky project. Now it will be shown that these investment precommitments p made at $t = 0$ will be a credible signal. We will prove the existence of an informationally consistent pricing function $B(p)$ for all the outside claims (see Riley [41]) parametrized by $\{F, \alpha\}$. In other words, the outsiders can look at the optimal precommitments p made by firms and correctly impute the price of the outside claims they hold. If a firm of quality H invests according to precommitment p, the total true value of the outside claims will be:

$$V(H, p) = (1 - \tfrac{1}{2}p^2)F + \tfrac{1}{2}p^2 L + \alpha\{(1 - p)(I - F) + (p - \tfrac{1}{2}p^2)(H - F)\} \quad (5)$$

If it exists, let $B(p)$ denote the market-pricing function, i.e., the total price of all outside claims as assessed by the market. The insiders' objective at $t = 0$ can be formalized as follows:

$$\mathrm{Max}_{0 \leq p \leq 1}(1 - \alpha)\{(1 - p)(I - F) + (p - \tfrac{1}{2}p^2)(H - F)\} + B(p) \quad (6)$$

Let $U(H, p, B(p))$ stand for the maximand in (6) and $p(H)$ be a solution to (6). Proving the existence of a signalling equilibrium is to prove the existence of a pricing function $B(p)$ such that

$$B(p(H)) = V(H, p(H)) \quad (7)$$

A pricing function which satisfies both the above conditions (6) and (7) is called an INC pricing function (see Riley [41]). Together conditions (5), (6) and (7) define a signalling equilibrium $\{p, B(\cdot)\}$.

[15] See John and Kalay [25], Mishra [35] and John and Mishra [26] for earlier examples of signalling with investment policy precommitments or investment announcements. See Brennan and Kraus [5], Heinkel [17] and Constantinides and Grundy [7] for *pure* signalling models with special structures where choices of financing packages (capital structures) act as nondissipative signals of firm quality.

[16] It can be shown, see John [22], that either (1) capital structure choices alone without investment policy precommitments, or (2) investment policy precommitments alone for any given capital structure can credibly signal H to the market. The signalling costs in the equilibrium in (1) will be the same as that in the agency-signalling equilibrium of (P3). The signalling costs in (2) will depend on the given capital structure. An efficient (least-cost) signalling equilibrium which uses multiple signals (capital structure choices as well as investment policy precommitments) can be analyzed using the techniques in Ambarish, John and Williams [1] and Milgrom and Roberts [34]. Although the signalling costs in such an equilibrium will be less than (1) or (2), the nature of the signalling equilibrium will be similar to the one in (2) analyzed here.

We prove the existence of a signalling equilibrium by verifying the sufficient conditions identified by Riley [41]. Since the next section discusses these issues in the context of an agency-signalling equilibrium we do not provide the details here. The crucial condition (5) of Riley requires that the marginal rate of substitution in (6) between the signal p and the compensation for the signal $B(p)$ decreases in the firm's type H. This is easily verified, given $\alpha < 1$ and $p < 1$:

$$\phi = \frac{\partial}{\partial H}\left(-\frac{\partial U/\partial p}{\partial U/\partial B}\right) = (1-\alpha)(p-1) < 0.$$

From the above arguments, there exists from Riley [41], Theorem 1 an informationally consistent pricing function for the outside claims and therefore a signalling equilibrium.[17] In addition the signalling function $p(\cdot)$ satisfies $p(\underline{H}) = 1 - r^0(\underline{H})$. In fact it can be shown that all firm types $H > \underline{H}$ would precommit to overinvest in the risky project, i.e., in equilibrium, $p(H) > 1 - r^0(H)$, for all $H > \underline{H}$. The announcement effect of investment precommitments can be explicitly derived, and it is positive. (For details, see John [22].)

Proposition 3. *For* (P2) *there exists a signalling equilibrium* $\{p, B(\cdot)\}$ *at* $t = 0$, *satisfying* (5), (6) *and* (7). *Almost all firms precommit to overinvest in the risky project. The announcement effect of investment precommitments is positive.*

The solution obtained above will be compared to that in the agency-signalling equilibrium for (P3) analyzed in section III.

III. Agency-Signalling Equilibrium

In (P3) the insiders privately observe H at time $t = 0$ before financing and r at time $t = 1$ before they make the investment decision. It should be clear that the optimal investment decision taken at $t = 1$ contingent on privately observed r gives rise to an agency problem of (P1) which is compounded by the asymmetry of information about H which exists at financing time, $t = 0$. In the pure agency equilibrium of (P1) the insiders and outsiders are equally informed about the type H of the firm at $t = 0$. Although the outsiders do not observe the realization of r they can compute precisely the investment policy $\{r_F(H)\}$ (given in Proposition 1) based on the insiders incentives using (4) and use it to price the value of outside claims. Now in (P3) with asymmetry of information about H, the quality of the firm's technology, it is no more possible for outsiders to compute the true value of the firm's outside claims (say outside equity and debt). Instead they must price the outside securities after observing only the promised payment F (in this model) or a suitable such signal (signals) used by the insiders. The major thrust of proving the existence of the agency-signalling equilibrium is to show that there is a pricing function $B(F)$ which is informationally consistent,

[17] This signalling equilibrium with investment precommitments can be viewed as equivalent to one with the following direct mechanism: ask the firms to report their type. For a report $\hat{H}$ impose the investment precommitment $p(\hat{H})$ and pay the price $V(\hat{H}, p(\hat{H}))$. Truthful reports $\hat{H} = H$ will be elicited in equilibrium. The Revelation Principle which has been discussed in several recent papers (see Dasgupta, Hammond and Maskin [9], Harris and Townsend [15] and Myerson [38]) argues that without any loss in generality the firm may be restricted to those mechanisms which require the firm to report its type H and which give the firm no incentive to lie.

i.e., given optimal choices of capital structures, say $F(H)$, the market can correctly impute the values of all the claims outstanding, i.e., $B(F(H))$ will be equal to the true value of outside claims issued by firm H. In our perfectly competitive capital market, both insiders and outsiders regard the pricing functions $B(\cdot)$ as fixed by market forces.

Before we define an agency-signalling equilibrium formally, we have to focus on the objective function of the insiders. By assumption, insiders always act to maximize the wealth of the current shareholders, which in turn is equal to the true value of the fraction of the stock held by current shareholders plus the proceeds from the sale of the outside equity and debt. The market price of the total outside claims depends on the market's perceptions about H the quality of the firm as well as the anticipated investment policy $r_F(H)$ of the firm to be implemented at $t = 1$.

If $B(F)$ is the valuation function to be used by the market (if it exists) to price the total outstanding claims, the insiders' objective can be formalized as follows:[18]

$$\text{Max}_{I>F\geq L}(1 - \alpha)\{r_F(H)(I - F) + \tfrac{1}{2}[1 - r_F(H)^2](H - F)\} + B(F) \tag{8}$$

For any value of F chosen by the insiders at $t = 0$, the investment policy $\{r_F(H)\}$ implemented by them at $t = 1$ will be as characterized in Proposition 1, which is incorporated in (8). For $F > L$, the investment policy $\{r_F(H)\}$ deviates from $\{r^0(H)\}$. Let $U(H, F, B)$ stand for the maximand in (8). We will use $V(H, F)$ to stand for the total true value of all external claims held by outsiders (including equity and risky/riskless debt).

$$\begin{aligned} V(H, F) = r_F(H)F + \tfrac{1}{2}[1 - r_F(H)^2]F + \tfrac{1}{2}[1 - r_F(H)]^2L \\ + \alpha\{[r_F(I - F) + \tfrac{1}{2}[1 - r_F(H)^2](H - F)\} \end{aligned} \tag{9}$$

for $L \leq F < I$ (which is the interesting range of F).

An agency-signalling (delegation-signalling) equilibrium is characterized as follows. In our perfectly competitive capital market, both insiders and outsiders take the pricing functions for external claims $B(\cdot)$ as given. Insiders in a firm of type H pick a promised payment F on their bond to solve (8) and subsequently investment $\{r_F(H)\}$ to solve (4). In turn, outsiders bid actively for the firm's securities so that in equilibrium they pay the correct prices. In other words,

[18] In the objective function (8), α as well as F could have been modelled as control variables and the associated signalling equilibrium would have involved multiple signals α and F. Using the methodology of Ambarish, John and Williams [1], the "efficient" agency-signalling equilibrium $\{\alpha, F, r_F(\cdot), B(\alpha, F)\}$ can be analyzed. However, such an analysis would considerably complicate the model and clutter the exposition of this paper without providing any additional insights. Since the fraction of outside equity does not distort the investment policy $r_F(H)$, the following modelling strategy will be used. Set α (a parameter of the economy) such that,

$$\alpha = \max\{(I - Q - L)/V_0(\underline{H}),\ 2(I - L)^2/(\underline{H}^2 - I^2)\}$$

Here α is chosen such that (1) all firms can finance the investment from insider contribution, riskless debt and proceeds from the sale of a fraction α of the equity. (2) All firms are selling enough equity claims to give them an incentive to signal.

Since $r_F(H)$ does not decrease with F for $F \geq I$, $F \geq I$ will not have any changing incentive effects i.e., for all $F \geq I$ the firm will simply invest the risky technology (see Proposition 1). Therefore, we will restrict the domain of F to be below I.

observing only the optimal capital structures F the market is able to impute the true value to the securities of the respective firms. Formally, we will prove the existence of a pricing function $B(\cdot)$ which satisfies the following conditions:

$$F(H) = \arg\max_{I>F\geq L} U(H, F, B) \tag{10}$$

$$B(F(H)) = V(H, F(H)). \tag{11}$$

(10) has been referred to as incentive compatibility and (11) as the competitive rationality conditions. A pricing function which satisfies both the above conditions is called an INC (Informationally Consistent) pricing function (see Riley [41]). Together conditions (4), (10) and (11) define an agency-signalling equilibrium $\{F, r_F(\cdot), B(\cdot)\}$.

Sufficient conditions for existence of a signalling equilibrium can be identified using the results of Riley [41]. Following Riley, there exists an informationally consistent pricing function for outside securities, and thereby a signalling equilibrium $\{F, r_F(\cdot), B(\cdot)\}$ satisfying (4), (10) and (11) under his assumptions 1 through 6. Here, Riley's assumptions 1 through 3 follow from previous assumptions. For details, see John [22].

Riley's assumptions (4), (5) and (6) are more important from an economic point of view. Assumption (4) requires that $V(H, F)$ the true value of the bonds in (9) is increasing in the unknown attribute H and non-decreasing in the signal F. This is easily verified for the expression in (9).[19]

Riley's assumption (5) is critical. Here, assumption (5) requires that the marginal rate of substitution in (8) between the signal F and the compensation for the signal $B(F)$ decreases in the firm's type H. In other words,

$$\psi \equiv \frac{\partial}{\partial H}\left(-\frac{\partial U/\partial F}{\partial U/\partial B}\right) < 0 \tag{12}$$

Computing the derivative in (12) we have for $F < I$, sign $\psi = \text{sign}(I - H)$, which is negative since $\underline{H} > I$.

Finally, Riley's assumption (6) is satisfied. $F = L$ is the unique solution to the pure-agency problem, in the relevant range of F, i.e., $F \geq L$.

From the above arguments, there exists from a minor modification of Riley [41], Theorem 1, informationally consistent pricing functions for the outside claims and thereby a signalling equilibrium. Also, from a minor modification of Riley's Lemmas 3 and 5, and a straightforward extension of his Theorem 2, the resulting signalling function $F(\cdot)$ is continuous and increasing in the type H on $\underline{H} \leq H \leq \bar{H}$ and differentiable. In addition, the signalling function $F(\cdot)$ satisfies $F(\underline{H}) = L$.

The agency-signalling equilibrium has additional properties. Since all but the $\underline{H}$-type firm uses some risky debt, all of them implement investment policies

[19] Differentiating (9) we obtain

$$\frac{\partial V}{\partial H} = (1 - r_F)\left[\frac{\partial r_F}{\partial H}(F - L) + \frac{\alpha}{2}(1 + r_F)\right]$$

For $\frac{\alpha}{2} \geq \frac{(I - L)^2}{\underline{H}^2 - I^2}$, as in footnote (18), the above term can be shown to be positive. See footnote (18).

riskier than their pareto optimal (full information) levels in (P0) or ($\overline{\text{P0}}$). For all firms of type $H > \underline{H}$, $r_F(H) < r^0(H)$ since $F(H) > L$. The resulting agency costs $A_F(H)$ constitutes the endogenous costs of signalling. From the competitive rationality condition (11), these firms' outside securities are correctly priced in equilibrium, hence, all signalling costs are borne solely by insiders.

PROPOSITION 4. *For* (P3), *the optimal financing for all* (*but the* $\underline{H}$) *firms involve risky debt and equity. The investment policy* $\{r_F(H)\}$ *implemented is riskier than that in* (P0), ($\overline{\text{P0}}$), (P1) *and* (P2). *Moreover, there exists an agency-signalling equilibrium* $\{F, r_F(\cdot), B(\cdot)\}$ *satisfying* (4), (10) *and* (11). *In this signalling equilibrium, the optimal promised payment* $F(H)$ *reveals a firm's true type* H *to outsiders at* $t = 0$.

An interesting comparison can be made between the signalling equilibrium of (P2) and that of (P3). Both are driven by the costs of implementing a riskier-than-pareto-optimal investment policy. In (P2) direct precommitments of over-investment in the risky technology are used as signals. In (P3) since investment policies are not directly observable or enforceble such a mechanism cannot be used. However, the optimal investment policy that insiders would implement at $t = 1$ for any level of F they choose at $t = 0$ is common knowledge. In other words, by choosing $F > L$, the insiders can effectively precommit to implement investment policies $\{r_F(H)\}$ which are riskier than the pareto-optimal one $\{r^0(H)\}$ (since $r_F(H) < r^0(H)$ for $F > L$). In the agency-signalling equilibrium the insiders have one signal less than that in the pure signalling equilibrium. If, in both cases, the "efficient" signalling equilibria with multiple signals (see footnotes (16) and (18)) is constructed and compared (P3) will be less efficient than (P2), and the investment policies implemented in (P3) are riskier than those in (P2).

An empirical implication of our agency-signalling equilibrium is the announcement effect of debt issues by firms, or other leverage-increasing financial restructuring by firms.

PROPOSITION 5. *The announcement effect of leverage increases by firms on the price of its outside claims will be positive.*

Proof. Follows immediately from the first order condition for the solution of (8). Rearrange and simplify to obtain an expression for B_F:

$$B_F = \{r_F + \tfrac{1}{2}(1 - r_F^2)\}(1 - \alpha)$$

which is clearly positive. In fact, $\dfrac{(1-\alpha)}{2} \leq B_F < (1 - \alpha)$.

The above proposition implies the coarse hypothesis that bond issues larger than the average expected value (or financial restructuring involving unexpected increases in leverage) would elicit a positive announcement effect in the price of its outside claims.

IV. Conclusion, Extensions and Empirical Implications

In this paper we have examined the optimal financing and investment policies in a multiperiod model as a function of five different configurations of resolution of uncertainty and private information (or equivalently, five pairs of information structures for corporate insiders and outsiders). This exploratory analysis clarifies that the financing choices and the investment policy can be materially affected by the timing of financing and investment vis a vis crucial resolutions of uncertainty in the underlying technology. A related insight is that plausible patterns of resolution of uncertainty can give rise to a pure agency model, a pure signalling scenario or one where aspects of agency and signalling occur together.

In the agency-signalling scenario outsiders have less information than insiders not only about the private actions of insiders, but also about the exogenous characteristics of the firms. The information equilibrium obtained involves capital structure choices by insiders which not only minimize the costs of conflict among the various claimants, but also reveal their private information credibly to the market. The minimal agency costs of the above solution, however, are larger than in the pure agency solution (P1). Further, all but the least quality firms issue risky debt and subsequently invest riskier than in the pure agency case.

The agency-signalling scenario generalizes both the pure agency setting and the signalling models. In the agency setting, introducing plausible informational asymmetries about the structural characteristics of the agency model (e.g., technologies or preferences of insiders) enlarges the scope of its applicability. In the signalling model allowing subsequent private action makes the model more realistic in a corporate finance setting. Moreover, in some cases, the cost of signalling is endogenized as incremental agency costs arising naturally from optimal financing-investment decisions of the firm.

In this exploratory effort the model has been kept extremely simple to demonstrate the central thesis. Useful extensions include (1) multiple dates of financing and investment, (2) richer menu of contractual forms for outside claims, (3) exploration of optimal contractual forms and sharing rules for different patterns of temporal resolution of uncertainty, (4) more general technologies with variable scale of investment and (5) issues of efficient signalling with multiple signals. (See Ambarish, John and Williams [1]).

We will conclude by sketching very briefly some empirical implications of our analysis, especially Propositions 3, 4, and 5. For details, see John [22]. Proposition 3 implies that firms which have precommitted to invest in their projects either through contractual restrictions or through announcements of capital expenditure plans should elicit positive stock and bond price increases. McConnell and Muscarella [33], Mishra [35], and John and Mishra [26] document evidence consistent with such an implication. Another implication of Proposition 3 is that firms which have a lot of discretionary investments in the future and for whom its quality is private information, tight (restrictive) investment constraints would be useful. If we identify such firms as growth firms, then we get two implications. (1) The bonds of growth firms should have very restrictive covenants, whereas more established firms will have less restrictive ones. (2) The restrictiveness should be increasing in the growth prospects of the firms. Many firms in the early phase of their development seem to include tight dividend constraints precommitting no payouts for a number of years. The tightness of dividend constraints have been documented to be increasing in measures of growth potential. (See Kalay [30]). Moreover, higher quality bonds of established and mature firms have few restrictive covenants. The empirical evidence on direct and indirect maximum dividend restrictions which can be interpreted as minimum investment constraints are also consistent with our implications. See also John and Kalay [25].

Announcement effects of leverage-increasing financial changes by firms derived in Proposition 5 also seems to provide an explanation for previously puzzling empirical results. Jensen and Smith ([21], Table 2) and Smith ([45], Tables 1 and 3) summarize more than a dozen studies of stock price changes and bond price changes at announcements of transactions which change capital structure. (See footnote 9 for problems with some of the existing explanations.) Our Propositions 4 and 5 imply that although increasing risky debt increases agency costs the signalling effect leads to a favorable re-evaluation of the firm by the market. Most of the empirical evidence document responses by the market which is consistent with our results.

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