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Capital Structure, Information Acquisition and Investment Decisions in an Industry Framework

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Abstract. This paper analyzes the relationship between a firm's capital structure and its information acquisition prior to capital budgeting decisions. It is found that low-growth industries can sustain a large number of levered firms. In these industries, leverage is negatively related to a firm's incentive to acquire information during the capital budgeting process. In contrast, high-growth industries only sustain a small number of levered firms. In these industries, levered firms acquire more information than all-equity financed firms. The model yields empirical predictions regarding the effects of leverage on the expected amount and the volatility of corporate investment. While leverage does not affect firm value, highly levered firms generate a more volatile cash flow than firms with low debt levels.

Key words: capital structure, capital budgeting.

JEL classification codes: G31, G32.

1. Introduction

Capital budgeting frequently involves decisions about the amount of information which should be acquired before the investment is undertaken. For example, firms may decide to invest in prototypes or test marketing in order to gather information about the prospects of subsequent investment at a larger scale.[1] Also, firms use elaborate capital budgeting procedures in order to collect "decentralized" information which resides with different departments and is of relevance for the management's investment decisions.

[1] As an example, when Sony Corp. unveiled plans to build a plant in Hungary this small scale investment laid 'the groundwork for "an even more comprehensive regional manufacturing presence" [...] and was a careful and cautious approach: to first learn about the market and to find quality suppliers, while waiting for the region's political and economic infrastructure to stabilize', "Sony to Build Hungary Plant And Plans Others in Region", The Wall Street Journal Europe, Vol. XIV No. 46, Wednesday, April, 3 1996.

Despite the importance of information acquisition, the traditional literature on capital budgeting generally ignores this aspect of corporate investment behavior.[2] This paper contributes to fill this gap. We focus on the incentives to acquire information if the management acts in the shareholders' best interest. The analysis is cast in an industry setting in which a large number of firms have access to an investment opportunity which is affected by a stochastic industry-wide cost parameter. The incentives of an individual firm to acquire information about the cost parameter are shown to depend not only on its own capital structure but also on the capital structures of its rival firms.

The analysis distinguishes between two types of industries. First, we focus on a low-growth industry in which firms have built up slack so that they can finance a new investment project internally. We contrast this with an industry in which firms must obtain financing from the capital market. We refer to the latter industry as a high-growth industry. The paper analyses both the information acquisition decision of an individual firm as well as the equilibrium distribution of capital structures across firms in an industry when the subsequent information acquisition stage is taken into account.

Our results are consistent with the stylized fact that firms in a high-growth industry typically choose low leverage whereas firms in a low-growth industry issue significant amounts of debt. While this fact is usually linked to imperfections in the supply of external finance to an industry[3], our model shows that product market characteristics imply similar industry-specific typical capital structures even in the absence of such imperfections. The intuition for this result is driven by the fact that the relation between information acquisition and leverage is reversed in low- versus high-growth industries.

In high-growth industries, firms need to raise external finance to invest. The equityholders of a levered firm prefer to acquire information in equilibrium. To see this, suppose that the investment opportunity produces a positive net present value (NPV) if production costs are low and a zero NPV if production costs are high. An all equity financed firm can therefore always invest and has no incentive to incur costs to find out which level of production costs is more likely. In contrast, equityholders of a firm with risky debt would not undertake the investment if they knew that production costs are high, since some of the project's cash flows accrue to the debtholders, making the investment unattractive for the equityholders. Thus, in equilibrium equityholders of highly levered firms have a stronger incentive to acquire information than equityholders of firms with low debt levels.

Now consider a low-growth industry in which firms have built up financial slack which may not be fully paid out as a dividend. In this case the risky investment can

[2] In his presidential address to the Financial Management Association, Pinches (1982) states that academicians' view of capital budgeting is characterized by an "overemphasis" on the selection phase and too little attention given to other aspects of the capital budgeting process, especially the information requirements.

[3] For an analysis of such imperfections, see, for example, Fazzari, Hubbard and Petersen (1988).

be funded internally. The relationship between leverage and information acquisition is reversed. Equityholders of a highly levered firm have little incentive to acquire information even if the NPV of the risky project is negative when production costs are high: in this case, the resulting losses would be mainly incurred by the debtholders.

The analysis provides a link between product market characteristics and the distribution of capital structures across firms in an industry. Since firms in a high-growth industry face high demand for their output, it is optimal for a large number of firms to invest even if production costs turn out to be high. It is therefore only necessary for a smaller number of firms to purchase costly information about the production costs than in an industry facing low future demand. The typical capital structure of firms in a high-growth industry reflects the small benefit of information. Few firms issue debt. Information acquisition prior to investment allows such a levered firm to raise external finance when production costs are likely to be low. In contrast, the majority of firms remains equity financed. For these firms it is sequentially rational to invest without prior information acquisition.

In contrast, firms in a low-growth industry face less future demand for their output such that it is efficient for a large number of firms to acquire information about production costs. As discussed above, these firms may issue debt up to a critical level. Increasing leverage beyond this critical level eliminates the incentive to acquire information. Since this is optimal for only few firms, the typical capital structure in a low-growth industry is characterized by low leverage.

The relationship between corporate leverage and the firm's investment behavior is therefore determined by the typical mode of financing investment in an industry. In high-growth industries, leverage increases the information intensiveness of a firm's capital budgeting decisions and, hence, the volatility of its investment expenditures. Expected corporate investment expenditures decrease since such a firm proceeds with investment only conditional on favorable information. In low-growth industries, highly levered firms base their capital budgeting decisions on less information and exhibit higher average and less volatile investment expenditures than mainly equity financed firms.

The results of this paper shed light on empirical findings about "debt-conservatism". Graham (1998) explores debt-conservatism using a firm's marginal tax rate as a measure for the tax benefit of an increase in its leverage. He presents evidence that firms use debt conservatively even though these firms would benefit from higher leverage due to the tax-deductibility of interest. This finding raises the question whether there is "money left on the table". The results in our paper indicate that this may not be the case. Instead, firms which can internally finance new investments restrict leverage in order to commit to efficient use of information about investment alternatives.

The paper is related to the papers by Harris and Raviv (1996) and (1998). These authors analyze capital budgeting by a firm which lacks information about the profitability of investment in one of its divisions. They rationalize real world capital

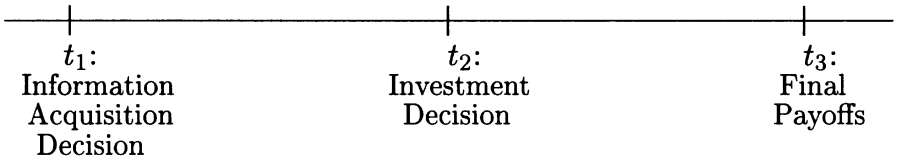

Figure 1. The time line.

budgeting procedures as a response to asymmetries of information and conflicts of interest between headquarters and the division manager. Our paper also analyzes the role of information in the capital budgeting process but we do not focus on informational asymmetries within the firm. Instead, we analyze determinants of the information intensiveness of corporate capital budgeting decisions in an industry framework.

Finally, this paper is closely related to contributions by Maksimovic and Zechner (1991) and Williams (1995).[4] Maksimovic and Zechner (1991) analyze capital structures in an industry framework in the presence of conflicts of interest between equityholders and bondholders. Williams (1995) analyzes how corporate agency affects financial and industrial structures via its effect on firms' access to capital. Both of these contributions analyze firms' capital structures in an industry. However, neither of these papers permits firms to acquire information about the profitability of investment opportunities.

The remainder of the paper is organized as follows: In Section 2 we introduce the model and analyze the equilibrium when firms are unlevered. In Section 3 we allow firms to issue debt. The final section concludes and summarizes the empirical predictions of the model.

2. The All-Equity Case

We consider an industry in which a large number, n, of price-taking firms produce a homogeneous product. These firms face uncertainty about the industry-wide variable costs of production. They may acquire information in order to reduce this uncertainty prior to the decision to invest in production capacity or they may invest without acquiring additional information. Figure 1 summarizes the sequence of events.

At time t_1, firms decide whether or not to pay I in order to acquire information about the future production cost, $c \in \{l, h\}$. This information takes the form of a noisy signal, $\tilde{y}$. The cost I may represent the cost of an elaborate capital budgeting procedure which seeks to collect " decentralized" information about production costs residing with the employees of the firm. Alternatively, I may be thought of

[4] For a survey of this literature, see Maksimovic (1995) or Zechner (1996). Maksimovic and Titman (1991) also relate the firm's capital structure to product market characteristics. They show that capital structure reflects the importance of a firm's reputation for product quality and the ease with which the firm's assets can be redeployed in case of bankruptcy.

as the cost of a prototype plant which provides information about the costs of a full scale plant. Also, corporate investment may be postponed in order to wait for the arrival of further information. In this case I represents the increase in the expected future production cost due to the resulting delay in production.

Firms which purchase a signal observe its realization, y, immediately, where

$$y \in \{y_l, y_h\}.$$

We define $\pi(y \mid c)$ as the probability of the signal realization, y, conditional on the future cost of production being c. For notational simplicity, we assume that the signals observed by different firms which invest in information are independently and identically distributed conditional on the cost realization.

For notational simplicity, we focus on the symmetric case where both realizations of the production costs are equally likely and the probability of receiving the correct signal is symmetric, i.e. $\pi(y_l \mid l) = \pi(y_h \mid h) \equiv \pi$. We assume that the signal is informative, that is[5]

$$0.5 < \pi \leq 1.$$

We refer to the probability π as the signal quality since the variance of $\tilde{c}$ conditional on the signal realization decreases monotonically with π. The signal is private information of the acquiring firm.[6] We assume that the firm's capacity to process information is limited; this is modelled by allowing each firm to purchase at most one signal.[7] A firm which acquires information prior to investment is referred to as an "informed" firm as opposed to an "uninformed" firm.

At time t_2, firms decide whether or not to invest $K > 0$ in order to set up one unit of production capacity. One unit of capacity allows the firm to produce one unit of output.

At time t_3, production takes place at a cost c and the cash flows are realized. We refer to the state in which production costs are high (low) as the high-cost (low-cost) state, denoted by h (l). We normalize the production cost in the low-cost state by setting $l = 0$. The firms are price-takers and face the following inverse demand function,

$$p = a - bQ, \tag{1}$$

[5] If $\pi < 0.5$ we would relabel y_l with y_h and vice versa.

[6] A key difference to the literature on information in financial markets (e.g. Grossman and Stiglitz (1980) or Kyle (1989)) is the fact that firms cannot condition on a market price which aggregates the agents' information.

[7] As long as the cost of aggregating information within a firm increases at an increasing rate with the number of signals, there is an interior joint solution for the number of signals per firm.

where Q denotes the aggregate output of the industry.[8] To simplify the analysis below, we assume that in expectation it is profitable for all firms in the industry to invest in production capacity,[9]

$$a - bn > 0.5h + K, \tag{2}$$

where the term on the right-hand side is the unconditional expected cost of production plus the cost of capacity. We assume that all players are risk neutral and normalize by setting the riskfree rate equal to zero. In the remainder of this section, we analyze the model recursively in order to derive a subgame-perfect Nash equilibrium.

2.1. THE INVESTMENT DECISION

We first note that inequality (2) implies that those firms which choose to remain uninformed always invest in capacity in equilibrium. In contrast, firms which have chosen to purchase information can condition investment on the signal realization. Proposition 1 shows that in equilibrium informed firms invest if and only if the low-cost signal, y_l, has been observed.

PROPOSITION 1.
An informed firm invests in production capacity if and only if it observes the low-cost signal realization, y_l. An uninformed firm always invests in production capacity.

Proof. See the Appendix.

2.2. THE INFORMATION ACQUISITION DECISION

As long as the incremental firm value realized by conditioning the investment on the signal exceeds the cost, I, firms have an incentive to acquire information. This subsection derives the equilibrium number of firms which purchase a costly signal.

Suppose that there are i informed firms. By Proposition 1, these firms invest with probability π when production costs are low and with probability $(1 - \pi)$ when production costs are high. The remaining $(n - i)$ firms invest with probability one. We now derive the expected product market price in the low- and the high-cost state denoted by p_l and p_h respectively. We thereby assume that once a firm has invested in capacity, it is optimal for this firm to produce output even in the

[8] Q equals the number of firms which invest in one unit of production capacity.

[9] Assumption (2) implies that firms invest in production capacity with probability one when they cannot base their investment decision on a signal realization. If this assumption is violated, these firms would randomize in their investment decision. A model without this assumption and endogenous entry into the industry is available from the authors.

high-cost state, i.e. $p_h > h$.[10] This implies that the expected product market price is given by

$$p_l = a - b[i\ \pi + (n - i)], \tag{3}$$

$$p_h = a - b[i\ (1 - \pi) + (n - i)] \tag{4}$$

in the low-cost and the high-cost state respectively. We can now define the net present value of a firm which intends to become informed, NPV_I, and that of a firm which intends to remain uninformed, NPV_{UI},

$$NPV_I = 0.5\ [\pi(p_l - 0) + (1 - \pi)(p_h - h) - K] - I, \tag{5}$$

$$NPV_{UI} = 0.5\ [(p_l - 0) + (p_h - h)] - K. \tag{6}$$

Since firms choose the information acquisition strategy which maximizes firm value the number of informed firms adjusts until the net present values (5) and (6) are equated or until a corner solution obtains. The equilibrium is derived in Proposition 2

PROPOSITION 2.

(a) If the cost of information satisfies $I_1 < I < I_2$, where I_1 and I_2 are defined in the Appendix, then the number of firms which acquire information is strictly positive and given by:

$$i = \frac{nb - a + K + h\pi - 2I}{b[\pi^2 + (1 - \pi)^2]}. \tag{7}$$

This number of informed firms decreases in the intercept, a, of the inverse demand curve and in the cost, I, of information and increases in the uncertainty about the industry-wide production costs, h, and the cost of production capacity, K.

(b) If the cost of information is less than I_1, then all firms purchase information: $i = n$.

(c) If the cost of information exceeds I_2 then no firm purchases information: $i = 0$.

Proof. See the Appendix.

The comparative statics in Proposition 2 are intuitive. For a given number of firms which invest in production capacity, the loss from producing in the high-cost state increases with the production cost h and the cost of capacity K and decreases with the demand intercept, a. Thus, the smaller is the margin, $a - h - K$, the more firms choose to acquire information in order to avoid investment in production capacity in the high-cost state.

[10] Without this assumption firms would randomize in their production decision such that the expected product market price equals the cost of production.

In the next section, we allow firms to issue debt and analyze how an individual firm's decision to acquire information is related to its capital structure. We also derive the set of equilibrium distributions of capital structures across firms in the industry.

3. Information Acquisition and Capital Structure

In the remainder of the paper we focus on "interior" equilibria for which $0 < i < n$. We consider the case where the capital structure affects firm value only indirectly via its effect on the firm's information acquisition decision.

Suppose that initially all-equity financed firms choose a capital structure at time t_0 prior to the information acquisition decision at time t_1. The capital structure is characterized by the face value of debt, D, issued by a firm and we assume that this debt level is chosen to maximize the firm value. If alternative capital structures yield the same firm value, we assume that the firm prefers the one with the higher leverage. This "tie-breaking rule" reflects unmodelled debt-related benefits such as a tax advantage.[11]

We first take the equilibrium number of informed and uninformed firms derived in Proposition 2 as given, and examine how capital structure determines a firm's information acquisition decision. In a second step, we derive the equilibrium distribution of capital structures across firms in the industry.

The effect of a firm's capital structure depends on whether or not corporate investment can be funded by means of financial slack. In reality, a market's life-cycle typically determines to which extent firms in an industry are endowed with internally generated financial slack. For example, the Boston Consulting Group (BCG) refers to firms operating in a slowly growing or shrinking output market as "cash-cows". These firms generate funds which can be used to internally finance investment in growth options. In contrast, firms in rapidly growing industries must typically finance their growth options externally.

We distinguish between two polar cases. In the first case, the firms' financial slack suffices to fund the entire investment in capacity and in information. This case can be thought of as being representative for a "low-growth industry" characterized by a low intercept, a, of the inverse demand curve given by expression (1).

In the second case, the required funds for firms' investment in information and capacity must be raised through sales of securities. This case is representative of "high-growth industries" which typically lack internally generated financial slack and face an inverse-demand curve with a high intercept, a. We first consider the case of a low-growth industry in which the firms have sufficient financial slack to internally finance the investment in information and capacity.

[11] A full-fledged model with corporate taxation and endogenous entry into the industry is available from the authors.

Table I. The Cash Flows when $F \geq K + I$ ("Low-Growth Industry")

State	Signal	Cash Flow	Prob.
Low-cost	None	$CF_l^u = F + (p_l - 0) - K$	0.5
Low-cost	y_l	$CF_l^i = F + (p_l - 0) - K - I$	0.5π
Low-cost	y_h	$CF_0^i = F - I$	$0.5(1-\pi)$
High-cost	None	$CF_h^u = F + (p_h - h) - K$	0.5
High-cost	y_l	$CF_h^i = F + (p_h - h) - K - I$	$0.5(1-\pi)$
High-cost	y_h	$CF_0^i = F - I$	0.5π

F = financial slack; K = cost of one unit of production capacity; I = information acquisition expenditures; $(p_l - 0)$ = payoff upon investment in low-cost state; $(p_h - h)$ = payoff upon investment in high-cost state

3.1. THE LOW-GROWTH INDUSTRY

To analyze the effect of capital structure on the equityholders' incentives, we derive the cash flows when the firm acquires information and when it does not. We assume that prior to the information acquisition decision, all firms in the industry are endowed with financial slack, $F \geq I + K$. Table I summarizes the cash flows generated by informed and uninformed firms respectively together with the probability with which each of these cash flows is realized.

If the firm decides to acquire information, then it will subsequently invest if and only if signal y_l is observed. As a result, the informed firm generates one of three different cash flows. If the firm has invested and state l occurs, then cash flow CF_l^i is realized. If the firm has invested and state h occurs, then cash flow CF_h^i is realized. Finally, if the firm has observed signal y_h, then it does not invest and generates the cash flow CF_0^i. If the firm decides to remain uninformed, then we have shown in Proposition 1 that it will always invest in capacity. Depending on which state occurs, its cash flow will either be CF_h^u or CF_l^u. We show in Lemma 1, that the five cash flows stated in Table I can be ranked uniquely.

LEMMA 1.
In equilibrium, the cash flows satisfy the ranking, $CF_l^u > CF_l^i > CF_0^i > CF_h^u > CF_h^i$.

Proof. See the Appendix.

We next examine which debt-levels are consistent with the decision to become informed or to remain uninformed respectively. The equity-values, E_I and E_{UI}, of an informed and an uninformed firm respectively as a function of the debt level, D, are given by

$$E_I(D) = 0.5 \max[CF_0^i - D, 0] + 0.5[\pi \max[CF_l^i - D, 0] + (1-\pi) \max[CF_h^i - D, 0]], \tag{8}$$

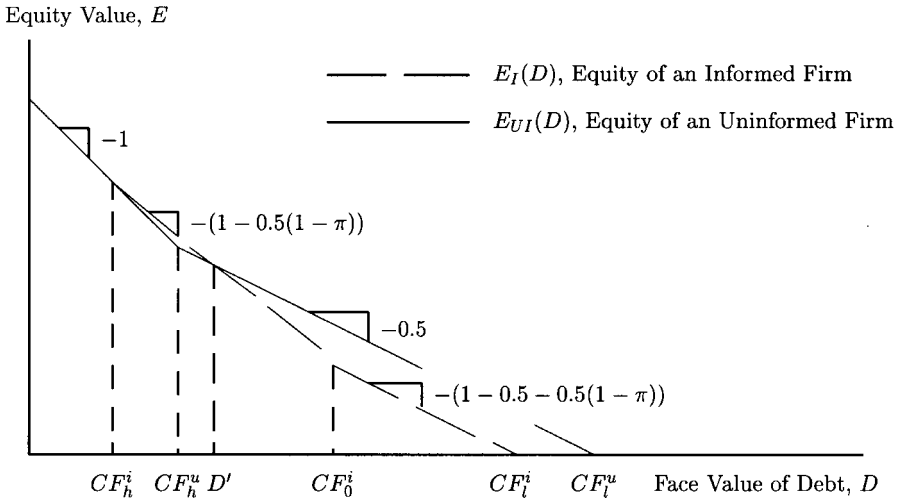

Figure 2. The Equity-Value of a Firm in a Low-Growth Industry ($F \geq K + I$). This figure illustrates the effect of a firm's capital structure on the equityholders' investment incentives if no new outside capital is required for investment. The solid line is the graph of the equity value, $E_{UI}(D)$, of an uninformed firm while the broken line gives the equity value, $E_I(D)$, of an informed firm. CF_c^i and CF_c^u denote the cash flows produced by an informed firm and an uninformed firm respectively given that state $c \in \{l, h\}$ occurs, where l denotes the low-cost state while h denotes the high-cost state. CF_0^i is the cash flow produced by an informed firm which does not invest since it has observed signal realization y_h. The ordering of cash flows satisfies the ranking derived in Lemma 1. For a debt level $D \leq CF_h^i$ the debt is riskless for both firms. Hence, the equity value decreases by one dollar per dollar of debt issued. For debt levels $D > CF_h^i$ the debt is risky for an informed firm which defaults with probability $0.5(1-\pi)$. This implies that the equity value decreases with a slope of $-(1-0.5(1-\pi))$. For $D > CF_0^i$ the informed firm defaults with probability $0.5 + 0.5(1-\pi)$. Hence, the equity-value of an informed firm decreases with a slope of $-(1-0.5-0.5(1-\pi))$ for $D > CF_0^i$. The debt issued by an uninformed firm is risky whenever $D > CF_h^u$ in which case the uninformed firm defaults with probability 0.5. This implies that the uninformed firm's equity value decreases with slope -0.5 for $D > CF_h^u$.

$$E_{UI}(D) = 0.5 \max[CF_l^u - D, 0] + 0.5 \max[CF_h^u - D, 0]. \tag{9}$$

Figure 2 illustrates the effect of a firm's capital structure on the equityholders' investment incentives: For face values below the cash flow, CF_h^i, the debt is risk free and thus the equity-value decreases by one unit per unit increase in the face value of debt independent of the firm's information acquisition decision. This implies that equityholders are indifferent between purchasing information and remaining uninformed for any debt-level below the cash flow CF_h^i.

For debt levels between the cash flows CF_h^i and CF_h^u, debt is still riskless if the firm decides to remain uninformed and invests with certainty. However, debt becomes risky if the firm chooses to purchase information. It can be seen from Table 1 that the difference between CF_h^i and CF_h^u equals the cost, I, of the signal. Thus, for debt levels in excess of CF_h^i, creditors effectively bear a part of the signal's

cost equal to $D - CF_h^i$ whenever the firm defaults on its obligations. However, the equityholders are the main beneficiaries of the "insurance" against investment in the high-cost state which is offered by the signal: in this state, the payoff to equityholders of an informed firm which has not invested in production capacity equals $CF_0^i - D$ and exceeds the payoff of the equityholders of an uninformed firm which is zero. As a result, the equityholders of a firm with risky debt with a face value between CF_h^i and CF_h^u strictly prefer to purchase information.

As the debt level increases beyond CF_h^u, the creditors share in the benefit of the insurance against investment in the high-cost state offered by the signal of an informed firm. The higher the debt-level issued by the firm, the more of this benefit accrues to the creditors.

To see this, consider the case when the firm's debt level is greater than or equal to CF_0^i. Then the entire expected increase in the cash flow due to not investing in the high-cost state accrues to the creditors. From the equityholders' perspective, the decision to acquire information only lowers their payoff in the low-cost state by the cost, I, of the noisy signal. Thus, for debt levels $D \geq CF_0^i$, equityholders have no incentive to purchase information since the benefits of "insurance" accrue to the creditors while the "insurance premium" comes out of their pockets.

Summarizing, we have shown that equityholders of firms with moderate debt levels, $CF_h^i < D \leq CF_h^u$, strictly prefer to purchase information, whereas firms with high debt levels, $D > CF_0^i$ strictly prefer to remain uninformed. For debt levels $CF_h^u < D \leq CF_0^i$, the creditors share both in the cost I and the benefit of the "insurance" offered by a signal about production costs. The higher the firm's leverage, the more of this "insurance effect" accrues to the creditors. As a result, there is a critical debt level, $CF_h^u < D^c \leq CF_0^i$, for which the equityholders' expected gain from information just outweighs the reduction in their non-default payoff when the firm purchases a signal. For debt levels below D^c, equityholders prefer to acquire information, for debt levels exceeding D^c they prefer not to do so.

Proposition 3 derives these results. For simplicity, we normalize by setting $F = K + I$ such that the firm's financial slack is just sufficient to fund the investment in capacity and information.[12]

PROPOSITION 3.

Consider a low-growth industry in which the firms' financial slack is sufficient to finance the investment in information and in production capacity. A firm with a low level of debt, $D \leq CF_h^i$, is indifferent between purchasing information and remaining uninformed. A firm with an intermediate debt-level, $CF_h^i < D \leq D^c$, with

$$D^c = CF_l^i - \frac{CF_l^u - CF_0^i}{\pi} \tag{10}$$

[12] If the available financial slack is greater, then the graphs of $E_I(D)$ and $E_{UI}(D)$ in Figure 2 shift to the right by $F - (K + I)$. The qualitative results remain unchanged.

strictly prefers to purchase information. Finally, a firm with a high level of debt, $D^c < D \leq CF_l^u$, strictly prefers to remain uninformed.

Proof. By Lemma 1, the expressions (8) and (9) imply the following derivatives,

$$\frac{\partial E_I}{\partial D} = \begin{cases} -1 & : \quad D < CF_h^i \\ -(1-0.5(1-\pi)) & : \quad CF_h^i < D < CF_0^i \\ -(1-0.5-0.5(1-\pi)) & : \quad CF_0^i < D < CF_l^i \end{cases}$$

$$\frac{\partial E_{UI}}{\partial D} = \begin{cases} -1 & : \quad D < CF_h^u \\ -0.5 & : \quad CF_h^u < D < CF_l^u \end{cases}$$

Since $E_I(0) = E_{UI}(0)$, these slopes imply that the critical debt-level D^c where the equation $E_I(D^c) = E_{UI}(D^c)$ holds exceeds CF_h^u. Equating the equity value of a firm which plans to acquire information, given in equation (8) to that of a firm which remains uninformed, given in equation (9), where $D = D^c$, and solving for D^c yields the expression stated in the Proposition. QED

3.2. THE HIGH-GROWTH INDUSTRY

In this subsection we assume that the firms' financial slack is insufficient to fund the required investment in information. For simplicity, we consider the case in which a firm's entire spending on information acquisition and production capacity must be financed externally, $F = 0$.[13] We assume that a firm's existing creditors are protected by seniority covenants such that any new investment is financed by issuing junior claims. Without loss of generality, we focus on the case where firms issue new equity in order to raise finance. Table II summarizes how the firms' cash flows depend on their information acquisition decision and the realized cost of production. The effect of debt on the value of equity is depicted in Figure 3.

In the equilibrium in part (a) of Proposition 2, the value of the equity of an unlevered firm which intends to become informed equals that of an unlevered firm which intends not to acquire information. Note that any debt issued by an informed firm is risky since such a firm does not invest in capacity when the signal y_h is observed, in which case its final cash flow is zero. Thus, for debt levels $D < (p_h - h)$ the informed firm defaults with probability 0.5 whenever it observes the high-cost signal realization, y_h. As the face value of debt increases beyond $(p_h - h)$, an informed firm defaults not only if it does not invest but also if it invests and the high-cost state occurs.

If the firm does not acquire information, it invests with probability one. Debt issued by such a firm is therefore riskless up to a face value of $(p_h - h)$. For debt levels in excess of $(p_h - h)$, an uninformed firm defaults whenever the high-cost state occurs, i.e. with probability 0.5.

[13] Situations where $0 < F < I + K$ are cumbersome to analyze. Since the results are combinations of the case where $F \geq K + I$ and that where $F = 0$, we restrict the analysis to these polar cases.

Table II. The Cash Flows realized when $F = 0$ ("High-Growth Industry")

State	Signal	Cash Flow	Prob.
Low-cost	None	$(p_l - 0)$	0.5
Low-cost	y_l	$(p_l - 0)$	0.5π
Low-cost	y_h	0	$0.5(1-\pi)$
High-cost	None	$(p_h - h)$	0.5
High-cost	y_l	$(p_h - h)$	$0.5(1-\pi)$
High-cost	y_h	0	0.5π

$(p_l - 0)$ = payoff upon investment in low-cost state; $(p_h - h)$ = payoff upon investment in high-cost state.

Inspection of Figure 3 shows that any positive debt level induces a firm to become informed. The intuition for this result is as follows. Since there is no financial slack, the investment in production capacity must be financed externally by the equityholders.[14] The equityholders of a levered firm therefore have a strong incentive to avoid investment in the high-cost state since in this state, the creditors receive all or most of the cash flow generated by new investment. A signal that reduces the probability of investing in the high-cost state is relatively more valuable to the equityholders of a levered firm than to those of an unlevered firm. As a result, levered firms acquire information. Proposition 4 summarizes these results.

PROPOSITION 4.
Consider a high-growth industry in which the firms externally finance their entire investment in information and production capacity. An unlevered firm is indifferent between purchasing information and remaining uninformed. A firm with a debt-level $0 < D \leq \bar{D}_I$ strictly prefers to purchase information where $\bar{D}_I$ is the debt-level which satisfies $E_I(\bar{D}_I) = 0$.

Proof. Let E_I and E_{UI} denote the equity value of an informed firm and that of an uninformed firm respectively,

$$E_I(D) = 0.5[\pi \max[(p_l - 0) - D, 0] + (1-\pi)\max[(ph - h) - D, 0]],$$

$$E_{UI}(D) = 0.5\max[(p_l - 0) - D, 0] + 0.5\max[(ph - h) - D, 0].$$

These definitions imply the inequality,

$$\frac{\partial E_I}{\partial D} > \frac{\partial E_{UI}}{\partial D}.$$

[14] The equityholders either finance the new project directly by contributing capital or indirectly by giving up a share of their future dividends to the holders of newly issued securities.

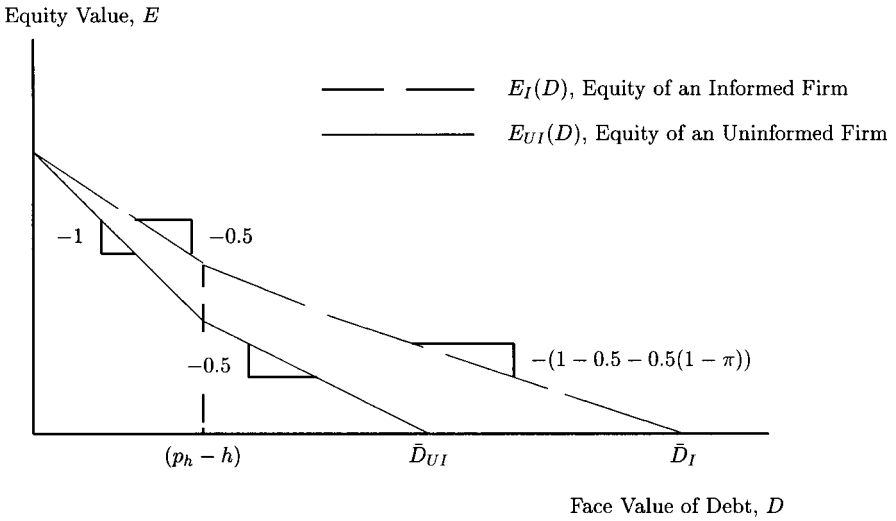

Figure 3. The Equity Value of a Firm in a High-Growth Industry ($F = 0$). This figure illustrates an example for the effect of a firm's capital structure on the equityholders' investment incentives if new outside capital is required for investment. The solid line is the graph of the equity value, $E_{UI}(D)$, of an uninformed firm while the broken line gives the equity value, $E_I(D)$, of an informed firm. $(p_h - h)$ denotes the high-cost state cash flow produced by a firm which has invested in one unit of capacity where p_h denotes the price and h denotes the production cost in the high cost state. $\bar{D}_I$ and $\bar{D}_{UI}$ denote the upper bound on a firm's debt level: holding the information acquisition decision constant, for face values in excess of these upper bounds the equityholders have no incentive to invest. Since the uninformed firm always invests, its debt is riskless for $D \leq (p_h - h)$ that is the value of equity decreases by 1 unit per unit of debt D issued. For $D > (p_h - h)$ the uninformed firm defaults with probability 0.5 which implies that the equity value decreases with a slope of -0.5. The informed firm's debt is always risky since the informed firm's equityholders only invest conditional on observing signal realization y_l, that is with probability 0.5. As the debt level exceeds $(p_h - h)$, the informed firm defaults whenever it observes y_h and whenever it invests and the high-cost state occurs, i.e. with probability $0.5 + 0.5(1 - \pi)$. Hence, for $D \leq (p_h - h)$ the equity value decreases with a slope of -0.5 while for $D > (p_h - h)$ the equity value decreases by $-(1 - 0.5 - 0.5(1 - \pi))$.

Moreover, for $D = 0$, the equilibrium conditions in Proposition 2 imply that $E_I(0) = NPV_I = E_{UI}(0) = NPV_{UI}$. This equation and the inequality stated above imply that $E_I(D) > E_{UI}(D)$ for any $D > 0$. QED

Proposition 4 sheds light on the interaction between the debt-overhang problem and the information acquisition decision. Firms with risky debt outstanding are able to mitigate the debt-overhang problem by obtaining more information about the state of the world. Financing of growth options is possible as long as the debt-overhang is not too severe since leverage induces a firm to spend on information acquisition prior to investment. In the limiting case of perfect information, that is the case in which $\pi = 1$, the debt overhang problem can be completely eliminated.

3.3. THE EQUILIBRIUM DISTRIBUTION OF CAPITAL STRUCTURES

In Propositions 3 and 4 we have shown that, for a given number of informed firms, only certain debt levels are consistent with the subsequent decision to purchase information. At the same time, other debt levels make it optimal for the equityholders to remain uninformed. We next derive the equilibrium distribution of capital structures across the industry.

Since each firm chooses its capital structure to maximize firm-value, the equilibrium distribution of capital structures must provide incentives which result in the equilibrium number of informed firms derived in Proposition 2. If the number of firms with capital structures that lead to information acquisition increases beyond a critical value, then the value of information falls below its cost, I. This is the case since too many firms purchase information and invest in production capacity only if they observe the low- cost signal realization. As a consequence, the expected product-market price in the high-cost state increases due to reduced production in this state. Note that it is mainly the uninformed firms which benefit from the low output of the industry in the high-cost state since they invest with certainty. As a result, some firms have an incentive to alter their capital structure in order to create incentives to remain uninformed. These incentives vanish once the NPVs of informed and uninformed firms are equalized.

Figures 2 and 3 illustrate that a whole range of debt- levels is consistent with the same information acquisition decision and therefore implies the same firm value. As discussed above, we assume that the firm chooses the highest possible debt-level which is still consistent with a given decision whether or not to acquire information.

PROPOSITION 5.

(a) Consider a low-growth industry in which the firms' financial slack is sufficient to finance investment in information and in production capacity. In equilibrium i firms choose a debt-level, $D_I = D^c$, where D^c is defined in Proposition 3. These firms acquire information and invest in production capacity only if they observe the low-cost signal. The remaining $n - i$ firms choose the debt-level, $D_{UI} = CF_l^u$, and do not acquire information prior to investing in production capacity.

(b) Consider a high-growth industry in which the firms externally finance their entire investment in information and production capacity. In equilibrium i firms choose a debt-level, $D_I = \bar{D}_I$, where $\bar{D}_I$ is defined in Proposition 4. These firms acquire information and invest in production capacity only if they observe the low-cost signal. The remaining $n - i$ firms do not issue debt, $D_{UI} = 0$, and and do not acquire information prior to investing in production capacity.

Proof. By Proposition 2, i firms choose the highest debt-level which induces information acquisition. The remaining $n - i$ firms choose the highest debt-level for which it is sequentially rational to remain uninformed. Propositions 3 and 4 define the respective debt-levels. QED

The remainder of this section analyzes how the capital structure affects corporate investment behavior and the cash flow generated by firms in a low- and a high-growth industry respectively. Consider first a high-growth industry which faces an output market characterized by a high demand intercept, a, where firms externally finance corporate investment. The high demand for the output of such an industry implies that it is efficient for only few firms in the industry to acquire costly information about the production costs. As a consequence, few firms can issue debt since Proposition 4 has shown that levered firms prefer to acquire information.

Consider next a low-growth industry which faces an output market characterized by a low demand intercept, a, where corporate investment is funded using internally generated financial slack. In such an industry it is efficient for many firms to acquire information about the production costs prior to investment in production capacity. As a consequence, many firms choose intermediate leverage since Proposition 3 has shown that these firms then prefer to acquire information.

Propositions 3 and 4 imply that the mode of financing new investment in an industry determines the relation between corporate leverage and the firm's information acquisition expenditures. In a low-growth industry, corporate leverage is negatively related to the firm's spending on information prior to investment in production capacity. In contrast, in a high-growth industry, levered firms have an incentive to acquire information while unlevered firms invest in production capacity without prior information acquisition. Given the effect of leverage on the firm's information acquisition policy, the capital structure also affects corporate investment behavior and the riskiness of the cash flow generated by a firm. Proposition 6 derives these results.

PROPOSITION 6.

(a) In both low- and high-growth industries, highly levered firms generate a more volatile cash flow than firms with low levels of leverage.
(b) In a low-growth industry, highly levered firms exhibit higher average and less volatile investment expenditures than mainly equity-financed firms.
(c) In a high-growth industry, levered firms exhibit lower average and more volatile investment expenditures than equity-financed firms.

Proof. See the Appendix.

4. Conclusions

This paper shows that industry characteristics crucially determine the relation between leverage and information acquisition in the capital budgeting process. In rapidly growing industries in which corporate investment is primarily financed externally, levered firms acquire information in order to mitigate the debt-overhang problem. These firms use information intensive capital budgeting procedures to reduce uncertainty about production costs. However, the high demand for the output

of such an industry implies that it is efficient for only a small number of firms to incur the cost of collecting relevant information whereas it is optimal for the majority of firms in the industry to invest without prior information collection. These firms commit to such a policy by remaining unlevered. As a result, few firms in high-growth industries are levered.

In contrast, in low-growth industries firms typically finance their investment using internally generated financial slack. In such an industry, the equityholders of a highly levered firm have an incentive to substitute a risky investment project for riskless financial slack. As a consequence, only little spending on information about production costs precedes such a firm's investment in production capacity. However, in a low- growth industry, it is efficient for a large number of firms to acquire information about the production costs prior to further investment. As a result, firms in such industries typically choose low rather than high levels of leverage in order to eliminate the asset-substitution incentive and commit to information acquisition.

The relation between a firm's leverage and the information-intensiveness of its investment policy gives rise to an "informational role" of capital structure.[15] According to this interpretation of the results, a firm chooses its capital structure to indicate to rival firms whether it intends to acquire costly information about the prospects of investment alternatives when information acquisition itself is unobservable. Then, the distribution of capital structures across firms in an industry helps these firms to co-ordinate in purchasing such information.

The model generates new hypotheses with regard to the relation between capital structure and the time series behavior of investment expenditures. In high- growth industries, leverage decreases the expected amount but increases the volatility of the firm's investment expenditures. This is the case since levered firms acquire information about the expected profitability of investment and invest if and only if this information is favorable. In contrast, in low-growth industries, highly levered firms invest more on average and exhibit less volatile investment expenditures than mainly equity financed firms. Thus, this paper suggests that in an empirical analysis of the relation between leverage and corporate investment behavior, it is essential to control for industry characteristics and the mode of financing.

Information acquisition can be interpreted as a delay in the investment decision in order to wait for the uncertainty about industry-wide production costs to be resolved. If such a delay is costly, then our model provides predictions on how capital structure, slack and industry characteristics interact to determine how many firms will invest early and how many will delay.

Other mechanisms may have effects similar to those created by leverage in this model. While our analysis assumes that the management acts on behalf of the shareholders, one obvious extension would recognize managerial self-interest. Then, the design of executive compensation and the threat of dismissal would

[15] We thank the referee for this interpretation of the model.

jointly determine the management's incentive to base investment decisions on the outcome of an information-intensive capital budgeting process.

Another extension would study the relation between leverage and corporate investment behavior in a dynamic context in which the firm uses its cash flow to internally finance investment in the next period. Consider for example a levered firm whose cash flows unexpectedly decline. Such a firm may reduce its investment expenditures even if new capital can be obtained without frictions.

Appendix

Proof of Proposition 1. Assume that it is optimal for a strictly positive number of firms, i, to acquire information. This requires that the informed firms' optimal investment decisions are a function of the signal realizations. To obtain a contradiction we conjecture that informed firms invest in production capacity if and only if the high-cost signal y_h is observed. Then, the net present value of an informed firm's investment conditional on the signal realization y_h is given by

$$NPV_{y_h} = \pi\{a - b[(n-i) + i\pi] - h\} + (1-\pi)\{a - b[(n-i) + i(1-\pi)] - 0\} - K,$$

where the first (second) term in curly brackets is the expected profit from production in the high-cost (low-cost) state. These terms reflect the conjectured strategy of the informed firms which invest with probability π and $1-\pi$ in the high-cost and the low-cost state respectively.

Suppose an informed firm deviates. Then, the net present value of this firm's investment in production capacity conditional on the low-cost signal realization y_l is given by

$$NPV_{y_l} = (1-\pi)\{a - b[(n-i) + i\pi] - h\} + \pi\{a - b[(n-i) + i(1-\pi)] - 0\} - K.$$

Note that in the expressions for NPV_{y_h} and NPV_{y_l}, the first term in curly brackets is smaller than the second term in curly brackets since $\pi > 0.5$. This implies that $NPV_{y_l} > NPV_{y_h}$ which renders the firm's deviation from the conjectured strategy profitable. Therefore, the equilibrium strategy for informed firms must be to invest if and only if signal y_l is observed. QED

Proof of Proposition 2. Equating the NPV expressions (5) and (6), substituting the expressions (3) and (4) for the expected prices and solving for i yields expression (7) in Proposition 2. Setting i, given by expression (7), equal to n and solving for I yields the lower bound on the signal's cost for an interior equilibrium to prevail:

$$I_1 = \frac{n\, b[1 - \pi^2 - (1-\pi)^2] - (a - K - h\,\pi)}{2}.$$

Setting i, given by expression (7), equal to zero and solving for I yields the upper bound on the signal's cost for an interior equilibrium to prevail:

$$I_2 = \frac{n\ b - (a - K - h\ \pi)}{2}.$$

Inspection of the two bounds on the signal's cost reveals that $I_1 < I_2$ for $\pi \in (0.5, 1]$. QED

Proof of Lemma 1. First, note that in equilibrium the inequality

$$p_l - 0 > p_h - h \tag{11}$$

must be satisfied or else informed firms would invest conditional on the high-cost signal realization – in contradiction to Proposition 1. Inequality (11) implies the following rankings:

$$CF_h^i = F + (p_h - h) - K - I < CF_l^i = F + (p_l - 0) - K - I, \tag{12}$$

$$CF_h^u = F + (p_h - h) - K < CF_l^u = F + (p_l - 0) - K. \tag{13}$$

Moreover, the definition of the cash flows in Table I implies the following inequalities,

$$CF_h^i = CF_h^u - I < CF_h^u \quad \text{and} \quad CF_l^i = CF_l^u - I < CF_l^u. \tag{14}$$

In order to complete the Proof of Lemma 1, it remains to show that:

$$CF_0^i = F - I > CF_h^u = F + (p_h - h) - K. \tag{15}$$

This inequality must hold in any interior equilibrium since otherwise the cash flows produced by an uninformed firm would dominate those produced by an informed firm. Inequalities (12), (13), (14) and (15) imply the ranking of cash flows stated in Lemma 1. **QED.**

Proof of Proposition 6.

(a) Consider a low-growth industry. Suppose the signal is perfect, $\pi = 1$. Then the variance of the cash flow, $\tilde{CF^i}$, generated by an informed firm is given by

$$\text{Var}(\tilde{CF^i} | \pi = 1) = \frac{(CF_l^u)^2}{4},$$

where CF_l^u is defined in Table I. The variance of the cash flow, $\tilde{CF^u}$, generated by an uninformed firm is given by

$$\text{Var}(\tilde{CF^u} | \pi = 1) = \frac{(CF_l^u - CF_h^u)^2}{4}.$$

For the firm value of an informed firm to equal that of an uninformed firm when $\pi = 1$, it must be the case that

$$0.5CF_l^i - I = 0.5CF_l^u + 0.5CF_h^u.$$

Since, by definition, $CF_l^i = CF_l^u - I$, it must be the case that $CF_h^u < 0$. This implies that $\text{Var}(C\tilde{F}^u|\pi = 1) > \text{Var}(C\tilde{F}^i|\pi = 1)$ or

$$\text{Var}(C\tilde{F}^i|\pi = 1) - \text{Var}(C\tilde{F}^u|\pi = 1) < 0. \tag{16}$$

Now, consider the difference $\Delta = \text{Var}(C\tilde{F}^i) - \text{Var}(C\tilde{F}^u)$ for general values of π. Using the cash flow definitions in Table I, it can be shown that Δ increases in π. This result and inequality (16) imply that

$$\text{Var}(C\tilde{F}^i) < \text{Var}(C\tilde{F}^u)$$

for general values of π.

It remains to be shown that in a high-growth industry, levered (informed) firms generate more volatile cash flows than unlevered (uninformed) firms. This follows from the cash flow definitions in Table II and the inequality $p_h - h > 0$: while uninformed firms generate one of the two cash flows, $p_h - h$ and $p_l - 0$, informed firms may in addition generate a third payoff which is zero.

(b), (c) These results are direct implications of Proposition 5. QED

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