The Capital Structure Decision When Markets Have Information That Firms Do Not Have*

Charles J. Cuny

and

Christo A. Pirinsky

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* Both authors are from Mays School of Business, Texas A&M University, 4218 TAMU, College Station, TX 77843-4218. Cuny can be reached at 979-845-3656 or ccuny@cgsb.tamu.edu, Pirinsky at 979-845-4894 or cpirinsky@cgsb.tamu.edu. We thank Praveen Kumar and Avanidhar Subrahmanyam for helpful suggestions.

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Abstract

We explore equilibrium corporate capital structure under the tradeoff that additional debt generates the familiar corporate tax benefit, while additional equity generates more information about the value of growth opportunities, allowing a more precise estimate of the return on real investment. This precision creates value by leading to better real investment decisions. Unlike agency costs of debt, whose magnitude can be expected to be small at low leverage levels, this information benefit of equity need not necessarily be small at low leverage levels. Therefore, an all-equity corner solution for optimal capital structure may reasonably arise. Such an outcome is most likely to occur for firms that are profitable, have many growth opportunities, or are relatively unique. The model provides valuable insight in the most important cases for which capital structure tradeoff theories have failed to predict corporate practice.

"But the daily revaluations of the Stock Exchange, though they are primarily made to facilitate transfers of old investments between one individual and another, inevitably exert a decisive influence on the rate of current investment."

John M. Keynes, The General Theory, p.151

Traditionally, capital structure theories based on informational asymmetries emphasize the information flow from managers to outside investors.[1] An independent strand of research in finance, however, suggests that capital markets enable information flow in the opposite direction, as private valuations of investors get reflected in security prices. The communication of investor information to managers and its implications for efficient allocation of capital in the economy have been analyzed extensively in the academic literature[2]. Although researchers tend to agree that this information flow from markets to managers has significant economic impact on corporate capital budgeting decisions, to the best of our knowledge, its implications for corporate financing decisions have not been explored in the literature so far.

In this paper, we study equilibrium capital structure under the tradeoff that increased debt generates the familiar corporate tax benefit, while increased equity generates a more precise estimate of the return on real investment. In our framework, the level of information aggregated in equity prices depends upon the market value of firm equity. This assumption is made on the grounds that an increase of the market value of equity leads to an increase in either the expected

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[1] These include Ross (1977) and Myers and Majluf (1984).

[2] The literature on rational expectations analyzes the process of information aggregation in capital markets (see e.g., Grossman and Stiglitz, 1976; Hellwig, 1980). Feedback from market prices to firms is discussed as early as Schumpeter (1912) and Keynes (1936), and underlies the q-theory of Tobin (1969). Dow and Gorton (1997) model the role of the information transfer in connecting efficient stock prices with efficient capital allocation.

total number of shareholders or the average size of the ownership stakes of existing shareholders or both. The first possibility should lead to more informative prices by increasing the total number of information signals aggregated in prices, while the second possibility should lead to more informative prices by creating stronger incentives for information collection in existing shareholders[3].

The feedback from stock prices to real investment in our model is formalized by a set of parameters governing a production technology with decreasing returns to scale. The return on this technology is uncertain and managers learn about it based on their prior beliefs as well as on the private information of investors as revealed in the market price of equity. We carry out our analysis under very general assumptions of the link between the amount of information incorporated in the stock price and the market value of equity.

An important property of the equilibrium capital structure in our model is that it may exhibit relatively low leverage ratios, even all-equity financing. This is in stark contrast to the other extreme of all-debt financing in Modigliani and Miller (1963). This property is important given that the classical tradeoff theory of capital structure (balancing tax benefits of debt with bankruptcy costs) implies leverage ratios much higher than the ones observed in reality. For example, Leland (1994) derives optimal debt ratios on the order of 50-60% in a model with bankruptcy costs. The reason for this discrepancy between theoretical and empirical leverage ratios is that tax benefits significantly outweigh the direct bankruptcy costs of debt financing, which appear to be fairly small (see e.g., Warner, 1977; Haugen and Senbet, 1978; and Ang, Chua, and McConnell, 1982).

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[3] Although the level of information impounded into equity prices should naturally increase with the market value of equity, we acknowledge that there could be substantial variation in the rate of increase. For example, potential tendencies of investors to engage in imitative behavior (herding) could slow down the aggregation process, while the presence of more sophisticated investors could speed it up.

In an attempt to balance the tax benefits of debt at lower levels, researchers have explored additional potential costs of debt financing, such as indirect bankruptcy costs (Altman, 1984), asset substitution costs (Jensen and Meckling, 1976), and underinvestment costs (Myers, 1977). The empirical evidence on the economic significance of these costs, however, is still mixed. For example, while Opler and Titman (1994) present some evidence for the significance of indirect bankruptcy costs, Leland (1998) shows that the agency costs of debt related to asset substitution are negligible.

We take a different approach – instead of analyzing direct costs of debt, we identify an additional benefit of equity, its role as an information source about future growth opportunities. The idea that capital markets influence real investment decisions can be traced back to Schumpeter (1912) and Keynes (1936). There is also extensive empirical evidence on the relation between market valuations and investment: Morck, Shleifer, and Vishny (1990) show that returns tend to lead capital expenditures; Durnev, Morck, and Yeung (2003) further show that capital allocation is strongly related to firm-specific information in returns; while Wurgler (2000) presents international evidence that the link between markets and real investment is stronger in countries with stock markets that impound more firm-specific information.

In our model, firms with many or large investment opportunities will have lower optimal leverage levels. The failure of tradeoff models of capital structure to account for profitable, growing firms holding insignificant levels of debt has long been perceived to be a major weakness in those models (see e.g., Long and Malitz, 1985; Smith and Watts, 1992; Wald, 1999; and Fama and French, 2002). We note that it is in exactly these firms, where much of the equity value reflects the value of growth opportunities, that it is most critical to allocate capital effectively. The importance of making correct real investment decisions for such firms may well dominate potential tax savings associated with debt financing.

We also predict that firms that are relatively unique should have more equity in their capital structure since external information production for these firms is more valuable. Similarly, firms that are profitable over long time periods should have lower leverage. For a fully competitive industry, economic rents should be driven to zero over time due to free entry and exit of firms. Therefore, firms that exhibit profitability over long time periods are likely to have monopoly power or other unique characteristics that are not easily mimicked, impeding full competition from arising.

Finally, we extend the model to consider the possibility of equity prices being affected by investor sentiment or investor herding behavior. We view sentiment as a common valuation error applied by investors to a particular asset. In the case of herding, there is the possibility of equity prices being driven by a *narrow* set of investor signals due to mutual imitation. In both cases, the presence of either investment sentiment or herding behavior adds noise to the equity price signal. Therefore, using equity in the capital structure is relatively less desirable. In the case of sentiment, however, we believe that managerial expertise in distinguishing sentiment-driven from fundamental-driven valuations could restore the preference for equity.

Related to this paper is the paper by Subrahmanyam and Titman (1999) who analyze the relative advantages of private and public financing for information production. They show that if investors have different signals, public markets could generate better information than private forms of financing. Boot and Thakor (1993) also explore the information extraction role of security prices but focus on its implications for security design. They predict that it is optimal for issuers to split the claims on their assets' cash flows into two components – one more informationally sensitive and one less informationally sensitive, since this will stimulate more information production in markets by making informed trading more profitable. The above papers demonstrate the importance of the informational aspect of capital markets in directions different from the directions of this study.

The paper is organized as follows. Section 1 presents the model and the main results; Section 2 discusses the implications; Section 3 compares our predictions with existing empirical evidence on capital structure; Section 4 extends the model, allowing for investor sentiment and herding behavior; and Section 5 concludes.

1. The Model

The model has three dates, labeled 0, 1, and 2. At time 0, the manager chooses a capital structure for the firm by selecting a debt level D (which is repaid at time 2). Between times 0 and 1, stockholders receive information about the value of the firm's real investment opportunities. The aggregate information of the stockholders is reflected in the firm's stock price at time 1. After observing the stock price at time 1, the manager chooses a level of real investment X for the firm. At time 2, the cash flow for the firm, including that generated by real investment, is realized. Stockholders and debtholders receive their claims on the firm. Managerial decisions are made to maximize the expected value of the firm.[4] For simplicity, investors are risk neutral and the discount rate is zero.[5]

The cash flow generated by the firm at time 2 has three components. First, even absent any real investment made at time 1, there is a base level of cash flow $\tilde{C} \geq 0$, a random variable with unconditional (time 0) mean $\overline{C}$. Common beliefs are held about $\tilde{C}$ at all times. Second, aggregate real investment X made at time 1 generates aggregate cash flow $\tilde{A}X - (B/2)X^2$ at time 2,

[4] After the first managerial decision (the capital structure choice) is made, maximizing equity value and maximizing firm value are equivalent in the model.

where $\widetilde{A} \geq 1$ is a random variable independent of $\widetilde{C}$ with unconditional (time 0) mean $\overline{A}$, and $B > 0$. The optimal level of real investment is guaranteed to be non-negative since $\widetilde{A} \geq 1$. (Investors receive information about $\widetilde{A}$ before the real investment commitment.) The positive value for B reflects decreasing marginal returns on real investment. The third component of cash flow is generated by corporate taxes and the corporate tax shield of debt. The firm faces a corporate tax rate τ. Thus, the firm value at time 2, determined by the after-tax cash flow generated by the firm, equals[6]

$$\widetilde{V}_2 = (1-\tau)(\widetilde{C} + \widetilde{A}X - BX^2/2 - X) + \tau D \qquad (1)$$

Assuming the quadratic form $(\widetilde{A}X - BX^2/2)$ as the production technology for aggregate real investment X is equivalent to assuming $\widetilde{A}$ - BX as the cash flow generated by marginal dollar X of real investment. Since the manager can be expected to rank available projects and take on those with higher returns first, marginal real investment should display decreasing returns. Linear marginal cash flow, and therefore quadratic aggregate cash flow, is the simplest functional form to display this property.

The variable $\widetilde{A}$ reflects return on real investment in the sense that an increase in $\widetilde{A}$ translates to a higher marginal return at all levels of investment, an upward shift in the marginal cash flow on investment function $\widetilde{A}$ - BX. Thus, managerial uncertainty about $\widetilde{A}$ implies uncertainty about the return on real investment (at all investment levels), and may lead to investment choices which are too high or too low *ex post* (i.e., after the value of $\widetilde{A}$ is realized). Stockholders' information about $\widetilde{A}$, communicated to the manager through the mechanism of the

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[5] As the model emphasizes a tradeoff of an informational generation advantage of equity with a stylized tax advantage of debt, the model is robust to risk neutrality and discount rate assumptions.
[6] For simplicity, we assume here that the debt is riskless.

stock price, reduces managerial uncertainty of $\widetilde{A}$ and leads to managerial real investment decisions which tend to be more correct *ex post*.

The (inverse of the) parameter B captures the magnitude or scale of real investment opportunities. To see this, note that B is the slope of the marginal cash flow on investment function $\widetilde{A}$ - BX. Lower B implies an outward shift in the function, allowing more dollars to be invested at any given level of return. Alternatively, note that in the presence of full information about $\widetilde{A}$, the optimal level of real investment (the point at which marginal investment has zero NPV) is $(\widetilde{A}-1)/B$, decreasing in B.

At time 1, the expected value of the firm is given by

$$E_1[\widetilde{V}_2] = (1-\tau)(E_1[\widetilde{C}] + E_1[\widetilde{A}]X - BX^2/2 - X) + \tau D \tag{1}$$

where E_1 represents the expectation taken with respect to information available to the manager at time 1. This includes information that can be inferred from the stock price at time 1, as well as priors commonly held by all. The optimal level of real investment for the firm is therefore $X^* = (E_1[\widetilde{A}]-1)/B$, and the expected value of the firm at time 1 can be written as

$$E_1[\widetilde{V}_2] = (1-\tau)(E_1[\widetilde{C}] + (E_1[\widetilde{A}]-1)^2/2B) + \tau D \tag{2}$$

The value of the stockholders' claim at time 1 is given by the expected firm value less the debtholders' claim, $\widetilde{S}_1 = E_1[\widetilde{V}_2] - D$. The value of the stockholders' claim at time 0 is given by

$$S = E_0[\widetilde{S}_1] = E_0[\widetilde{V}_2] - D = (1-\tau)\left(\overline{C} + \frac{E_0[(E_1[\widetilde{A}]-1)^2]}{2B} - D\right), \tag{3}$$

where E_0 represents the expectation at time 0 based on commonly held priors. Specifically, stockholders have not yet received investment-relevant information about $\tilde{A}$, although the corporate debt level D chosen is common knowledge. The time 0 stock value can be written

$$S = (1-\tau)\left(\overline{C} + \frac{(\overline{A}-1)^2}{2B} - D + \frac{E_0[(E_1[\tilde{A}]-\overline{A})^2]}{2B}\right). \tag{4}$$

As already noted, between times 0 and 1 investors receive information about $\tilde{A}$, a variable characterizing the value of the firm's real investment opportunities. Notice that expectations of $\tilde{A}$ enter into S in two ways. Through the first term above, S is affected by $\overline{A}$, the unconditional first moment of $\tilde{A}$; higher expected returns on investment increases the firm and stock value. Through the second term above, S is affected by $E_0[(E_1[\tilde{A}]-\overline{A})^2]$, which is a second moment effect. Denoting the unconditional (time 0) variance of $\tilde{A}$ by σ_A^2 allows us to write

$$E_0[(E_1[\tilde{A}]-\overline{A})^2] = \sigma_A^2 \cdot Z, \tag{5}$$

where Z is defined as

$$Z = E_0[(E_1[\tilde{A}]-\overline{A})^2] \big/ E_0[(\tilde{A}-\overline{A})^2]. \tag{6}$$

Thus, Z is the ratio of the unconditional (time 0) variance of $E_1[\tilde{A}]$ to the unconditional (time 0) variance of $\tilde{A}$. In other words, Z measures the fraction of variation in $\tilde{A}$ that is captured in variation of $E_1[\tilde{A}]$. Alternatively, Z measures the ratio of the uncertainty in $\tilde{A}$ resolved between times 0 and 1 to the uncertainty in $\tilde{A}$ resolved between times 0 and 2 (as expectations of $\tilde{A}$ are progressively updated from $\overline{A}$ at time 0, to $E_1[\tilde{A}]$ at time 1, and finally to $\tilde{A}$ at time 2). If we think of regressing $\tilde{A}$ on $E_1[\tilde{A}]$, then the Z ratio corresponds to the R^2 of the regression.

Thus, the second moment effect of $\widetilde{A}$ on the stock price S captures the expected value created when the manager receives additional information about $\widetilde{A}$ before the real investment decision, leading to an investment level more *ex post* correct. In this sense, Z measures the quality of the price signal.

We assume that the quality of the information received by the stock investors (as a whole) between times 0 and 1 is increasing in the market capitalization of the firm at time 0. As the initial market capitalization S of the firm increases, either the stockholder base of the firm must widen or individual stockholders must hold larger positions, or both. As a result, this should lead to either a larger set of informed equity investors for the firm, or better quality information received by each individual investor. Proposition 1 shows that either of these results in price signal improvement.

Proposition 1. *The quality of the equity price signal, as measured by* Z*, is (weakly) increasing in additional investor information.*

Proof: See Appendix A.

Thus, the estimate $E_1[\widetilde{A}]$ implied by the time 1 stock price S_1 should provide a more precise estimate of $\widetilde{A}$ as initial market capitalization increases. In the context of the model, this is formalized by assuming that Z, the fraction of variation in $\widetilde{A}$ observed by the stockholders in aggregate, is increasing in initial market capitalization, that is $dZ/dS \geq 0$. Because Z is bounded by [0, 1], and we generally expect that the usefulness of marginal information is diminishing, it is also assumed that $d^2Z/d^2S \leq 0$.

The optimal capital structure decision faced by the manager is to choose the debt level D at time 0 to maximize expected firm value $S + D$, based on information available. The tradeoff involved is that increased debt generates the familiar corporate tax benefit, while increased equity generates a more precise estimate of real investment value (inferred from the stock price at time 1) leading to a more effective real investment decision by the manager. The optimal capital structure decision can be written as

$$\underset{D}{Max} \quad E_0[\widetilde{V}_2] = S + D, \tag{7}$$

$$\text{subject to: } S = (1-\tau)\left[\overline{C} + \frac{(\overline{A}-1)^2}{2B} + \frac{\sigma_A^2}{2B} Z(S) - D\right].$$

Appendix B shows that S is decreasing in the chosen debt level D. Such a monotonic relationship is required to meaningfully talk about a tradeoff theory between the two variables. The maximum value of equity occurs with all-equity financing; define the value of the all-equity financed firm by S_0, which satisfies

$$S_0 = (1-\tau)\left[\overline{C} + \frac{(\overline{A}-1)^2}{2B} + \frac{\sigma_A^2}{2B} Z(S_0)\right]. \tag{8}$$

The optimal capital structure trades off the information benefit of equity (more precise estimation of real investment benefits leading to a better real investment level) with the corporate tax benefit of debt. As long as the marginal information benefit of equity outweighs the marginal tax benefit of debt, more equity should be added to the capital structure mix. As equity S is increased, its marginal informational benefit declines. However, if the marginal equity informational benefit remains greater than the marginal debt tax benefit even with all equity financing, then the optimal capital structure is all-debt financed. This is described in the following proposition.

Proposition 2. *If the marginal precision of information for the unlevered firm is sufficiently high,* $\frac{dZ}{dS}(S_0) \geq \frac{2B\tau}{(1-\tau)\sigma_A^2}$*, then the optimal capital structure is all equity and no debt.*

Proof: See Appendix C.

Thus, if there is a great informational benefit from equity, the corner solution opposite to the all-debt financing result of Modigliani and Miller (1963) is derived: all-equity financing. Unlike agency cost stories, which imply only small effects at low debt levels, our informational effect need not be small at low debt levels. Indeed, it is not the level of debt *per se*, but rather the level of equity, in our model that determines the magnitude of the marginal benefit of information. Debt will not be optimally employed in the model until there is a sufficiently disperse cross-section of informed investors such that the value of marginal information due to attracting additional informed investors becomes low.

The necessity of a disperse investor base for better information production would be further amplified by any investor tendency to engage in imitative behavior. Recent research on investor behavior and many commentators, famously including Peter Lynch, have remarked about the herd mentality of investors[7]. To the extent that this is true, investor information becomes either highly correlated across investors, or many investors effectively have information of very low precision. Therefore, it becomes even more necessary to have a wide cross-section of investors to ensure informational content of the stock price to be as clean as possible. In this context, we would expect that the marginal informational content associated with additional equity would decline slowly, leading to a larger likelihood of an all-equity corner solution.

Furthermore, the informational benefit story is most compelling in the case of firms with many real investment opportunities, potentially of large magnitude (that is, small B). Intuitively, these are likely to be growth firms with significant investment plans. The failure of tradeoff models of capital structure to account for profitable, growing firms holding insignificant levels of debt has long been perceived to be a major weakness in those models. We note that it is in exactly these firms, where much of equity value is driven by the value of growth opportunities, that it is most critical to allocate capital effectively. The importance of making correct real investment decisions for such firms may well dominate potential tax savings associated with debt financing.

Corollary. *As* $\overline{A}$ *or* $\overline{C}$ *increase, the constraint in Proposition 2 tightens [is less likely to hold]. As* B*,* τ*, or* σ_A^2 *increase, the constraint may tighten or loosen, depending upon the other parameters.*

Proof: See Appendix C.

This corollary about the comparative statics of the all-equity corner solution has the following intuition. If $\overline{A}$ or $\overline{C}$ increase, the value of the firm increases, and an all-equity capital structure requires a larger dollar amount of equity. For all-equity to remain optimal, the marginal informational benefit of equity (which is declining in the level of equity) must remain above the marginal tax benefit of the first dollar of debt (which is independent of $\overline{A}$ or $\overline{C}$). If B or τ decrease, or if σ_A^2 increases, the value of the firm increases. If the firm remains all-equity, the marginal information as measured by dZ/dS decreases. However, the *value* of this information to the firm may increase or decrease. Lower B also means a higher scale of real investment, while lower τ means investment returns are taxed at a lower rate, and higher σ_A^2 means that the absolute level of investment uncertainty is higher. Each of these three makes information about growth opportunities more valuable to the firm. Since information is more valuable, while the information provided at the margin is declining, the value of marginal information may increase or decrease. Thus, the comparative statics of B, τ, and σ_A^2 are indeterminate.

In Proposition 2, the marginal value of the information contained in equity prices is sufficiently high to generate an all-equity corner solution. Naturally, if the value of the equity price

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[7] We elaborate more on this issue in Section 4.

information is sufficiently low (for example, if the manager expects to have very few interesting real investment opportunities), then the optimal capital structure may be the other extreme of the Modigliani and Miller all-debt corner solution. For moderate marginal values of the equity price information, an interior optimum is generated, trading off the marginal value of equity price information with marginal tax benefits of debt. This is described in Proposition 3.

Proposition 3. *At an interior optimum capital structure with equity and debt values of S^* and D^* at time 0, the marginal value of more precise information with more equity is equated with the marginal tax benefit of debt,* $\frac{dZ}{dS}(S^*) = \frac{2B\tau}{(1-\tau)\sigma_A^2}$.

Proof: See Appendix C.

Corollary. *At an interior optimum capital structure, the following comparative statics hold. Higher values of $\overline{A}$ or $\overline{C}$ lead to more debt and an unchanged equity level. Lower values of B or τ, or higher values of σ_A^2, lead to more equity.*

Proof: See Appendix C.

This corollary has the following intuition. In the interior optimum region, the marginal tax benefit of debt is constant, while the marginal information benefit of equity declines with the amount of equity. Thus, equity financing is preferred until the marginal information benefit of equity declines to the level where it equals the marginal tax shielding benefit. Debt then forms the residual financing. Higher values of $\overline{A}$ or $\overline{C}$ increase the value of the firm, the former due to an increased expected value of real investment opportunities and the latter due to an increased expected base cash flow. Neither has an effect on the marginal information benefit of equity, so the same amount of equity is used. Since the value of the firm increases, more financing is required; as the residual financing choice, this implies more debt financing.

Lowering B increases the scale of the firm's real investment opportunities, so the benefit of equity financing increases. Similarly, in raising σ_A^2, the higher uncertainty in the value of real investment makes it more imperative that more information about the value of those opportunities is made available to the manager, and the benefit of equity financing increases. Finally, lowering the tax rate τ decreases the benefit of debt financing. In all three cases, this makes equity financing relatively more attractive at the margin. Furthermore, the firm value rises in all three cases as well. However, the firm value can rise either more or less than the equity value, leaving the effect on the debt level indeterminate.

2. Predictions and Implications

The previous section derived an equilibrium capital structure based on the tradeoff that more equity leads to more informative stock prices, while more debt leads to more tax savings. A central determinant of the optimal capital structure in our model is the marginal value of information derived from equity prices. In this section, we explore what type of firms are likely to have high marginal value of information, and thus are more likely to have a capital structure weighted heavily toward, or even composed entirely of, equity.

2.1. Investment Opportunities

Our first prediction is that firms with more investment opportunities will have more equity in their capital structure. As shown in the Corollary to Proposition 3, firms that have greater investment opportunities (measured by a small value of the parameter B), are better able to use the information in equity price because of scale effects: any information about the value of real investment opportunities is applicable to a larger real investment base. This could either be in the form of a larger number of available investment opportunities or a larger size of investment opportunities. For such a firm, information is more valuable because it helps allocate a larger dollar value of assets appropriately.

The size of the firm, however, may or may not play a role in the capital structure choice, as there are two offsetting effects. On one hand, the marginal quality of generated information dZ/dS is decreasing in the outstanding equity S. Thus, dZ/dS tends to be smaller for firms with larger market capitalization. On the other hand, larger firms are more likely to have a larger available set of potential real investments, characterized by a smaller value B. Thus, for a larger firm, although the marginal quality of information extracted from the stock price is smaller, it can be applied to more projects. In terms of the inequality of Proposition 2 or the equality in Proposition 3, both the left-hand and right-hand sides tend to be smaller, and the model implication is mixed with respect to firm size.

2.2. Managerial Endowment of Information

Firms where the manager starts with a relatively low level of information will also tend to value information highly. In the context of the model, $Z(S_0)$ represents the quality of information available to the manager under all-equity financing, while $Z(0)$ represents the quality of information available under all-debt financing (the limit as equity shrinks to a negligible amount). Since there are no equity-holders at the latter extreme, $Z(0)$ represents the information already available to the manager. The spread in possible information quality across the extremes of capital structure is thus $Z(S_0)$ - $Z(0)$. If the manager starts with a low level of information, that is, $Z(0)$

is small, then the possible gain in information from employing equity financing, $Z(S_0) - Z(0)$, is large, and the manager tends to value equity financing more highly.

Another implication of our results is that the informational benefit of equity should be more valuable for firms with fewer alternative sources of information, such as professional analysts following the firm. Analysts collect and process a variety of information about companies and issue forecasts about future earnings and ratings about the investment potential of each stock. Brennan, Jegadeesh, and Swaminathan (1993) show that returns on portfolios of firms that are followed by many analysts tend to lead those of firms that are followed by fewer analysts, adjusting for size. Thus, we predict that, everything else held constant, firms with less analyst coverage would be characterized by more equity in their capital structures.

2.3. Industry Lifecycle

We would also predict more equity in the capital structure of young companies especially at the early stages of an industry lifecycle. Life-cycle theories argue that younger firms would be characterized with higher marginal value of information, since they operate in more uncertain business environment. Over time, the value of this information is likely to decline for the following reasons:

- Growth opportunities decline.
- Alternative sources of investment information emerge: for example, other companies in the same industry. In this respect, industry leaders create a positive information externality for followers by determining the industry trends.

- Equity prices become more informative due to increased analyst coverage; more sophisticated investor base (for example, more institutional investors); increased visibility and investor recognition.

2.4. Uniqueness and Profitability

Unique firms would be also more likely to have higher marginal value of information. To the extent that the firm is unique, we may expect $Z(0)$ to be lower, and therefore the spread $Z(S_0)$ - $Z(0)$ to be greater. For a firm in an industry with many competitors creating very similar outputs, employing very similar physical production technologies, and having available very similar real investment opportunities, investor information about the value of future investment opportunities is likely to be very similar to investor information about the value of future investment opportunities for their competitors. Thus, much of the real investment-related information that could be extracted from their stock price could also be extracted from their competitors' stock prices. Therefore, we would expect $Z(0)$ to be relatively higher in industries with many similar firms and relatively lower in industries with more unique firms. Thus, we would predict that firms that are relatively unique should have more equity in their capital structure.

Titman (1984) also predicts that firm uniqueness is negatively related to debt ratios because more unique firms would be characterized with higher bankruptcy costs for their workers, suppliers and other stakeholders. Firm uniqueness in his framework, however, is a different concept from the uniqueness in our framework. With respect to bankruptcy costs, most important is the uniqueness of the real assets employed in the production process. With respect to information extraction, most important is the uniqueness of the growth opportunities involved. For example, a firm producing a common product would be still viewed as unique in our framework if all of its competitors are privately held companies. Titman and Wessels (1988) find that firm uniqueness is negatively related to leverage.

Along these lines, firms that are profitable over long time periods should have more equity in their capital structure. For a fully competitive industry, economic rents should be driven to zero over time due to free entry and exit of firms. Therefore, over the long run, profitability in such an industry should be no more than the opportunity cost of capital over time. Thus, firms that exhibit profitability over long time periods are likely to have monopoly power, unique products, production efficiencies that are not easily mimicked, or other unique characteristics impeding full competition from arising. The argument previously made for unique firms should apply to firms that are regularly profitable.

2.5. Asset Composition

We also argue that the informational benefit of equity will depend on the overall asset composition of the firm. For firms with more complex asset structures, such as firms operating on a variety of projects in multiple industries, this informational benefit on equity will be substantially reduced. The equity claim on diversified firms is a claim on a portfolio of projects. As a result, equity prices of diversified firms represent noisier signals for the quality of a particular investment opportunity within the firm. The amount of this noise would depend on the level of firm diversification. Our overall prediction is that, *ceteris paribus*, more diversified firms would have more debt in their capital structures.

Researchers debate the costs and benefits of corporate diversification policies. Some costs of diversification include inefficiencies in internal capital markets and value-destroying cross-subsidization; while some potential benefits are synergies and tax-savings (see e.g. Lang and Stulz, 1994; Berger and Ofek, 1995; and Lamont and Polk, 2002). We argue that corporate diversification is also associated with the additional cost of less informative stock prices. This cost has direct consequences for corporate investment and financing policies.

3. Empirical Evidence

In summary, we predict that firms with more real investment opportunities, higher levels of profitability, and more unique firms will have less debt in their capital structures. The existing empirical evidence is consistent with these predictions. For example, Smith and Watts (1992) and Rajan and Zingales (1995) document a negative relation between growth opportunities and leverage. Hovakimian, Hovakimian, and Tehranian (2004) further show that high market-to-book firms have low target debt ratios.

Consistent with our predictions, Long and Malitz (1985) and Fama and French (2002) also find that firms with more investments and research and development expenditures have lower leverage ratios. The latter is also consistent with predictions of agency-based tradeoff theories since investment-intense firms have less free cash flow (Jensen and Meckling, 1976) and as a result, less need for the discipline of debt. Leland (1998), however, argues that the real impact of these costs on leverage ratios is fairly small. Our framework provides an alternative rationale for the negative relationship between capital expenditures and leverage ratios – firm's demand for information about growth opportunities.

Our model could be also helpful in understanding the relationship between firm size and leverage. Most studies on capital structure find that size is positively related to leverage ratios (see e.g. Fama and French, 2002). A common explanation of this pattern is that large firms are better diversified and have lower expected bankruptcy costs than small firms. Our model suggests an alternative intuition for the relationship between size and capital structure based on the conjecture that large firms have a better information environment due to increased analyst coverage, more sophisticated investor base, and a longer history. As a result, the marginal value of additional information for large firms is potentially smaller and they could afford to borrow more. On the other hand, it should be noted that large firms may also have more and larger investment opportunities than smaller firms, making information relatively valuable. This concern may be less important to the extent that large firms are diversified or in mature industries, which make the stock price information less relevant or less valuable, respectively.

One of the most robust findings in cross-sectional studies of capital structure is that more profitable firms borrow less (see e.g., Titman and Wessels, 1988; Rajan and Zingales, 1995; and Fama and French, 2002). This negative relationship between leverage and profitability is in a stark contrast with traditional versions of trade-off theories. According to these theories, agency costs and bankruptcy costs push more profitable firms toward higher leverage ratios. Our framework, on the other hand, predicts that leverage and profitability are negatively related to the extent that firm profitability is a proxy for firm uniqueness and growth opportunities.

4. Extensions

In this section, we extend the model to allow for the possibility of equity prices being affected by investor sentiment or investor herding behavior. We do this by specifying the structure of the investor information revealed to the manager through equity market prices, specifically the structure of the information that investors receive between times 0 and 1 about the firm's real investment opportunity variable $\tilde{A}$.

In the case of investor sentiment, investors' signals related to $\tilde{A}$ share a common error term. In the case of investor herding behavior, there is the possibility of equity prices being driven by a *narrow* set of investor signals due to mutual imitation. In both cases, the basic intuition is that the presence of either investment sentiment or herding behavior adds noise to the equity price signal. Therefore, in these cases, managers find equity in the capital structure less desirable than otherwise. However, we believe the ways in which managers may improve the quality of the signals differ between investor sentiment and herding.

4.1. Investor Sentiment

Researchers debate the possible effect of investor sentiment on stock prices. Shiller (1984, 1987) suggests that shifts in investor sentiment (fads and fashion) could affect asset prices in addition to fundamentals. DeLong, Shleifer, Summers, and Waldman (1990) argue that average discount on closed-end funds can serve as a proxy for individual investor sentiment. Of course, investor sentiment could affect prices only if it has a systematic component and if there are limits to arbitrage[8]. If sentiment significantly affects stock prices than it would affect real economic decisions within the firm.

We model investor sentiment by assuming that there are N informed investors, indexed by *i*, each with a signal about the corporate investment opportunity variable $\widetilde{A}$. N is assumed to be an increasing concave function of the time 0 market capitalization S. The investment opportunity variable $\widetilde{A}$ consists of an observable portion y_O and unobservable portion y_U (with y_O and y_U independent), so that $\widetilde{A} = \overline{A} + y_O + y_U$. Signal *i* is given by $\theta_i = y_O + \varepsilon_S + \varepsilon_i$, where ε_S is a common estimation error shared by investors, reflecting common sentiment, while ε_i represents the idiosyncratic estimation error of investor *i*. The random variables y_O, y_U, ε_S, and ε_i are

[8] Two examples of the limits to arbitrage are the noise trader risk of DeLong, Shleifer, Summers, and Waldmann (1990) and the interaction of agency costs and wealth constraints of Shleifer and Vishny (1997).

independent, with mean zero, and with respective variances σ_O^2, σ_U^2, σ_S^2, and σ_i^2. It follows that $\sigma_A^2 = \sigma_O^2 + \sigma_U^2$. Investor signals are treated symmetrically, and the manager can infer the mean of the signals, $\overline{\theta} = \Sigma_i \theta_i / N$, from the stock price at time 1, $\widetilde{S}_1$.

The manager's belief at time 1 about the opportunity variable $\widetilde{A}$ equals (see Proof of Proposition 4 in Appendix C)

$$E_1(\widetilde{A}) = \overline{A} + \left(N\sigma_O^2 \Big/ N\sigma_O^2 + N\sigma_S^2 + \sigma_i^2 \right) \cdot \overline{\theta} . \tag{9}$$

Aggregate real investment information transmitted by investors satisfies

$$E_0[(E_1[\widetilde{A}] - \overline{A})^2] = N\sigma_O^4 \Big/ N\sigma_O^2 + N\sigma_S^2 + \sigma_i^2 , \tag{10}$$

and the fraction of information transmitted equals

$$Z = \left(\sigma_O^2 \Big/ \sigma_O^2 + \sigma_U^2 \right) \cdot \left(N\sigma_O^2 \Big/ N\sigma_O^2 + N\sigma_S^2 + \sigma_i^2 \right), \tag{11}$$

both of which are decreasing in the variance of the investor sentiment σ_S^2. We show (in Proposition 4) that the presence of investor sentiment decreases the marginal precision of information. Therefore, the presence of investor sentiment lowers the desirability of using equity financing.

We view investor sentiment as a common valuation error applied by investors to a particular asset. Sentiment may, in principle, derive from such factors as investor inexperience, the relative immaturity of a particular industry, or investor cognitive error. If sentiment is driven by the firm's shareholder base being dominated by investors inexperienced with the details of the firm's industry, then the countermeasure for sentiment may be a corporate manager who has enough industry-specific experience to be considered a "veteran." Such a manager, having previously experienced their industry's boom and bust cycles, and "seen it all before," is less likely to be swayed by investor sentiment. We model this by allowing some managers, the veterans, to observe investor sentiment ε_S at time 1. A veteran manager conditions his time 1 belief about $\widetilde{A}$ upon both $\widetilde{S}_1$ and ε_S. It can be shown (see Proof of Proposition 4 in Appendix C) that his time 1 belief about $\widetilde{A}$ is

$$E_1(\widetilde{A}) = \overline{A} + \left({N\sigma_O^2} \Big/ {N\sigma_O^2 + \sigma_i^2} \right) \cdot (\overline{\theta} - \varepsilon_S) \tag{12}$$

and the fraction of information transmitted equals

$$Z = \left({\sigma_O^2} \Big/ {\sigma_O^2 + \sigma_U^2} \right) \cdot \left({N\sigma_O^2} \Big/ {N\sigma_O^2 + \sigma_i^2} \right). \tag{13}$$

These results are summarized as follows.

Proposition 4. *Assuming an interior optimum capital structure:*

- *The marginal value of more precise information (the equity benefit) is decreasing in the magnitude of investor sentiment* σ_S^2.
- *Ceteris paribus, firms with veteran managers employ more equity in their capital structure.*

Proof: See Appendix C.

4.2. Investor Herding

So far, we have assumed that managers learn from stock prices. In reality, investors could learn from prices as well. Investor learning through prices, could lead to either efficient aggregation of information (as developed in the rational expectations literature) or inefficient aggregation of information.

Inefficient aggregation can result from an investor tendency for imitative (herding) behavior. Theoretical research has uncovered a series of reasons for imitative behavior, including: search for information (Bikhchandani, Hirshleifer, and Welch, 1992); reputation (Keynes, 1936 and Scharfstein and Stein, 1990); and emotional contagion (Shiller, 2000). There is also extensive empirical evidence that institutional investors tend to engage in herding and positive feedback trading (see e.g., Grinblatt, Titman, and Wermers, 1995; Nofsinger and Sias, 1999; and Wermers, 1999). Along these lines, Hong, Kubik, and Stein (2001) also demonstrate that stock market participation of individual investors depends on factors such as familiarity and person-to-person communications. Economists have argued that investor imitative behavior could trigger substantial mispricing in underlying securities whereby markets overincorporate some pieces of information and underincorporate others.

We model investor herding by assuming, as with sentiment, that there are N informed investors, indexed by *i*. With probability $1-p$, each investor has his own signal about $\widetilde{A}$ of the form $\theta_i = y_O + \varepsilon_i$, with y_O, ε_i, and mean signal $\overline{\theta} = \Sigma_i \theta_i / N$ defined as before. However, with probability p, each investor receives the same signal θ_H. For simplicity, it is assumed that the signal θ_H is "pure noise" (conveys no information about $\widetilde{A}$). Managers recognize when herding is occurring, that is, when all investors have received the θ_H signal. Therefore, the manager's belief about $\widetilde{A}$ at time 1 is (see Proof of Proposition 5 in Appendix C)

$$E_1(\widetilde{A}) = \overline{A} + \left(N\sigma_O^2 \Big/ N\sigma_O^2 + \sigma_i^2 \right) \cdot \overline{\theta} \ , \tag{14}$$

if herding does not occur and

$$E_1(\widetilde{A}) = \overline{A} \ , \tag{15}$$

if herding occurs. The aggregate real investment information transmitted by investors satisfies

$$E_0[(E_1[\tilde{A}]-\bar{A})^2] = {(1-p)N\sigma_O^4} \Big/ {N\sigma_O^2+\sigma_i^2}\,, \tag{16}$$

so the fraction of information transmitted equals

$$Z = \frac{\sigma_O^2}{\sigma_O^2+\sigma_U^2}\cdot\frac{(1-p)N\sigma_O^2}{N\sigma_O^2+\sigma_i^2}\,, \tag{17}$$

both decreasing in the probability p of herding occurring.

Proposition 5*. Assuming an interior optimum capital structure:*

- *The marginal value of more precise information (the equity benefit) is decreasing in the probability p of investor herding.*
- *The optimal level of equity is decreasing in the herding probability.*
- *The firm value is decreasing in the herding probability.*
- *Costly pre-emptive action to avoid herding is more likely to be taken as the probability of herding increases.*

Proof: See Appendix C.

Since investor herding decreases the marginal benefit of equity, it lowers the desirability of equity financing as well as the firm value at the optimal capital structure. It may be possible for a firm to avoid the investor herding phenomenon by taking pre-emptive action, at an exogenous cost. For example, this may be the higher cost of an equity placement putting the stock into "strong hands," such as a set of institutional investors recognized for their fundamental analysis or independent thinking. Thus, one way in which we distinguish investor sentiment and herding is through the appropriate counteractive measures. Although both decrease the value of equity financing by lowering the marginal quality of the information, the problem is counteracted by a type of managerial skill in the former case and by undertaking costly action in the latter. Since the value of the firm is decreasing in the probability of investor herding, it is more worthwhile to take costly pre-emptive action to avoid herding when the herding probability is higher.

5. Conclusion

Traditional tradeoff theories of capital structure are at their weakest in trying to explain why numerous profitable firms with many growth opportunities use virtually no debt. Profitable firms are, after all, the most likely to be able to use the tax benefits of debt. Furthermore, financial distress costs are unlikely to be significant at low debt levels. Agency costs, such as the asset substitution problem or underinvestment from debt overhang, rely on the idea that the presence of debt drives a wedge between equity claims and total corporate claims (the debt claim is the difference between total corporate and equity claims). This wedge generates payoff asymmetries which allow potential transfers between claimants. In the asset substitution problem, increasing operational risk transfers expected wealth from debtholders; with debt overhang, raising new capital would transfer expected wealth to debtholders. However, at low levels of debt, these effects are likely to become vanishingly small. Indeed, when debt claims remain riskless, both the asset substitution and underinvestment problems disappear.

Our tradeoff model emphasizes a benefit of equity rather than a cost of debt. This is more than semantics; in our model, the issue that the cost of debt can become vanishingly small at low debt levels does not arise, since we instead rely on a benefit of equity, which may remain of significant magnitude even with all-equity financing. This allows tax benefits to be offset even under all-equity financing. Our model therefore helps explain why profitable, growing firms avoid debt financing in a way that agency cost explanations cannot.

The role of information implied by our model is somewhat different from that in a traditional signaling model. Generally, in a signaling model, the choice of debt or equity issuance signals information, relevant to valuation of the firm at that point in time, from the manager to the investors. Thus, the current capital structure can be thought of representing a historical record of the firm. Our model differs in two ways from this. First, information flow runs from investors to the manager, rather than in the opposite direction. Second, in a standard signaling model, a security issuance choice sends a one-time signal. In contrast, in our model, the signal arrives via the stock price. Thus, over time, a sequence of stock prices sends a sequence of signals to the manager, reflecting changes in the value of growth opportunities over time. A single capital structure decision can therefore impact the quality of an entire sequence of signals, generating a stream of decision-making benefits, making our information-based explanation of capital structure even more compelling.

Appendix A: Proof of Proposition 1

We show that the marginal value of information Z is (weakly) increasing in additional information. Recall that, from (5), that Z is defined as

$$Z = E_0\,[(E_1[\widetilde{A}] - \overline{A})^2]\big/\sigma_A^2 \qquad \text{(A1)}$$

Now, let Z be based on aggregate information θ, and let Z' be based on information θ, ϕ. We show that $Z' \geq Z$. Applying the Law of Iterated Expectations repeatedly, we have

$$\sigma_A^2 \cdot (Z' - Z) = E_0\,[(E[\widetilde{A} \mid \theta, \phi] - \overline{A})^2 - (E[\widetilde{A} \mid \theta] - \overline{A})^2]$$

$$= E_0\,[E^2[\widetilde{A} \mid \theta, \phi] - E^2[\widetilde{A} \mid \theta]]$$

$$= E_0\,[E(E^2[\widetilde{A} \mid \theta, \phi] - E^2[\widetilde{A} \mid \theta] \mid \theta)]$$

$$= E_0\,[E(E^2[\widetilde{A} \mid \theta, \phi] - 2E[\widetilde{A} \mid \theta, \phi] \cdot E[\widetilde{A} \mid \theta] + E^2[\widetilde{A} \mid \theta] \mid \theta)]$$

$$= E_0\,[E[(E[\widetilde{A} \mid \theta, \phi] - E[\widetilde{A} \mid \theta])^2 \mid \theta)]] \geq 0, \qquad \text{(A2)}$$

and the result follows. ♦

Appendix B: Proof that S is decreasing in the debt level D

We show that the market value of equity (S) is decreasing in the level of debt (D). S is bounded by $0 \le S \le S_{\max}$, where $S_{\max}$ is defined by (noting that $D \geq 1$ and $Z \le 1$)

$$S_{\max} = (1-\tau)(\overline{C} + [(\overline{A} - 1)^2]\big/2B + \sigma_A^2\big/2B). \qquad \text{(B1)}$$

For a given $D \geq 0$, consider the function $f : [0, S_{\max}] \to [0, S_{\max}]$ defined by

$$f(S) = (1-\tau)(\overline{C} + [(\overline{A} - 1)^2]\big/2B - D + (\sigma_A^2\big/2B) \cdot Z(S)). \qquad \text{(B2)}$$

Since $0 < f(0) < f(S_{\max}) < S_{\max}$, and $d^2 f/dS^2 \le 0$, f has a unique fixed point $S = f(S)$, defining S for that debt level D. Differentiating $S = f(S)$ with respect to D yields

$$dS/dD = -(1-\tau)/(1-(1-\tau)(\sigma_A^2/2B)\cdot dZ/dS) < 0, \tag{B3}$$

since at the fixed point, $(\sigma_A^2/2B)\cdot dZ/dS = df/dS < 1$. Therefore, $S(D)$ is decreasing in D. ♦

Appendix C: Proofs of Propositions 2, 3, 4, and 5, and Corollaries

Proof of Propositions 2 and 3

Differentiating the constraint of (7) with respect to D implies

$$\frac{dS}{dD} = \frac{-(1-\tau)}{1-(1-\tau)(\sigma_A^2/2B)\cdot dZ/dS}. \tag{C1}$$

The first-order condition for an interior optimum (Proposition 3) equates $(dS/dD)+1$ with zero. Substituting dS/dD from (C1) yields Proposition 3. For an all-equity optimum (Proposition 2), $(dS/dD)+1$ will be negative for all D; the necessary and sufficient condition is that $(dS/dD)+1$ is negative when $D = 0$ and $S = S_0$. This gives Proposition 2. ♦

Proof of Corollary to Proposition 2

Consider the function $f_0 : [0, S_{\max}] \to [0, S_{\max}]$ defined by

$$f_0(S) = (1-\tau)(\overline{C} + [(\overline{A}-1)^2]/2B + (\sigma_A^2/2B)\cdot Z(S)). \tag{C2}$$

Similar to the proof in Appendix 2, f_0 has a unique fixed point $S_0 = f_0(S_0)$, defining S_0. Since $f_0(S)$ crosses S from above to below at S_0, it follows that S_0 is increasing in $\overline{A}$, $\overline{C}$ and σ_A^2, and decreasing in B and τ. Since dZ/dS is decreasing, $dZ/dS(S_0)$ is decreasing in $\overline{A}$,

$\overline{C}$ and σ_A^2, and increasing in B and τ. Of course, the term $2B\tau/(1-\tau)\sigma_A^2$ is increasing in B and τ, and decreasing in σ_A^2. Comparison of $dZ/dS(S_0)$ and $2B\tau/(1-\tau)\sigma_A^2$ is clear in the cases of varying $\overline{A}$ and $\overline{C}$, and depends on the precise shape of Z in the cases of varying B, τ, and σ_A^2. ♦

Proof of Corollary to Proposition 3

Consider the first-order condition from Proposition 3,

$$\frac{dZ}{dS}(S^*) = \frac{2B\tau}{(1-\tau)\sigma_A^2}. \tag{C3}$$

An increase in either $\overline{A}$ or $\overline{C}$ leaves the right-hand side of (C3) unchanged, so S^* will be unchanged, as will $Z(S^*)$. From the constraint in (7), solve for D^* and substitute to get the firm value under optimal capital structure V^*,

$$V^* = S^* + D^* = \overline{C} + \frac{(\overline{A}-1)^2}{2B} + \frac{\sigma_A^2}{2B} Z(S^*) - \frac{\tau}{1-\tau} S^*. \tag{C4}$$

It follows that an increase in either $\overline{A}$ or $\overline{C}$ increases V^*, and therefore increases $D^* = V^* - S^*$.

Next, consider either a decrease in B, a decrease in τ, or an increase in σ_A^2. The right-hand side of (C3) decreases; since dZ/dS is decreasing, it follows that S^* increases. ♦

Proof of Proposition 4

Standard techniques with normal random variables generate equation (9), the updating of beliefs to reflect the information from a noisy signal. Taking the expectation yields (10). Dividing by

$\sigma_A^2 = \sigma_O^2 + \sigma_U^2$ yields Z, equation (11). The marginal benefit of equity equals $\sigma_A^2 \cdot dZ/dS$. Write $L(S) = dZ/dS$. Noting that N depends upon S,

$$L(S) = \frac{dN}{dS} \cdot \frac{\sigma_O^4 \sigma_i^2}{\sigma_A^2 (N\sigma_O^2 + N\sigma_S^2 + \sigma_i^2)^2} > 0, \tag{C5}$$

while

$$\frac{dL}{dS} = \frac{\sigma_O^4 \sigma_i^2}{\sigma_A^2 (N\sigma_O^2 + N\sigma_S^2 + \sigma_i^2)^3} \left[(N\sigma_O^2 + N\sigma_S^2 + \sigma_i^2) \frac{d^2 N}{dS^2} - 2(\sigma_O^2 + \sigma_S^2) \left(\frac{dN}{dS} \right)^2 \right] < 0. \tag{C6}$$

An interior optimum is the level S* at which $L(S^*) = 2B\tau/(1-\tau)\sigma_A^2$. Since

$$\frac{\partial L}{\partial \sigma_S^2} = -2 \frac{dN}{dS} \cdot \frac{N\sigma_O^4 \sigma_i^2}{\sigma_A^2 (N\sigma_O^2 + N\sigma_S^2 + \sigma_i^2)^3} \le 0, \tag{C7}$$

it follows that *S** is decreasing in σ_S^2. Graphically, an increase in σ_S^2 is a downward shift in *L(S)*, implying that *L(S)* crosses $2B\tau/(1-\tau)\sigma_A^2$ at a lower level of *S**.

Equations (12) and (13) are derived using standard techniques similar to those for equations (9) and (10). Since the marginal benefit of equity for a veteran manager corresponds to setting $\sigma_S^2 = 0$, firms with veteran managers optimally use more equity in their capital structure.♦

Proof of Proposition 5

The proof of Proposition 5 is similar to the proof of Proposition 4. Equation (14) follows from standard techniques, while (15) is trivial. Taking the expectation yields (16), and dividing by $\sigma_A^2 = \sigma_O^2 + \sigma_U^2$ yields equation (17) for *Z*. Differentiate (17) twice to get $L(S) = dZ/dS$ and dL/dS,

$$L(S) = \frac{(1-p)\sigma_O^4\sigma_i^2}{\sigma_A^2(N\sigma_O^2+\sigma_i^2)^2}\cdot\frac{dN}{dS} > 0\,, \tag{C8}$$

and

$$\frac{dL}{dS} = \frac{(1-p)\sigma_O^4\sigma_i^2}{\sigma_A^2(N\sigma_O^2+\sigma_i^2)^3}\left[(N\sigma_O^2+\sigma_i^2)\frac{d^2N}{dS^2} - 2\sigma_O^2\left(\frac{dN}{dS}\right)^2\right] < 0\,. \tag{C9}$$

Similarly to the proof of Proposition 4, since

$$\frac{\partial L}{\partial p} = -\frac{\sigma_O^4\sigma_i^2}{\sigma_A^2(N\sigma_O^2+\sigma_i^2)^2}\cdot\frac{dN}{dS} < 0\,, \tag{C10}$$

it follows that S^* is decreasing in p. We show that the value $V(p)$ of the firm facing herding probability p is decreasing in p. Therefore, the value to the firm of eliminating herding is $V(0)$ - $V(p)$, which is increasing in p. From equation (4), the time 0 firm value satisfies

$$V = S + D = S + \overline{C} + \frac{(\overline{A}-1)^2}{2B} - \frac{S}{1-\tau} + \frac{E_0[(E_1[\widetilde{A}]-\overline{A})^2]}{2B}\,, \tag{C11}$$

and using equation (5),

$$V = \overline{C} + \frac{(\overline{A}-1)^2}{2B} - \frac{\tau}{1-\tau}S + \frac{\sigma_A^2}{2B}Z(S)\,. \tag{C12}$$

Note that the first-order condition for the optimal equity level S^* implies that $Z(S^*) = 2B\tau/(1-\tau)\sigma_A^2$. Since S^* can depend on p through the Z function, we have

$$\frac{dV(S^*(p))}{dp} = \frac{\sigma_A^2}{2B}\frac{\partial Z}{\partial p} = -\frac{\sigma_A^2 N\sigma_O^4}{2B(N\sigma_O^2+\sigma_i^2)} < 0\,. \tag{C13}$$

Therefore, $V(p)$ is decreasing in p and the result follows. ♦

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