Strategic Debt and Patent Races*

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August, 2001
revised May, 2003

Abstract

Most traditional studies of R&D do not consider that the use of leverage to finance R&D may affect total R&D expenditures in a patent race. We show that debt acts as a commitment to a smaller amount of total R&D spending (debt+equity) than would occur if firms were entirely equity financed. A commitment to lower R&D expenditure can be strategically beneficial; under a flow-cost model, debt induces lower R&D expenditure from its rival and thus increases its expected profit. Firms in this case are partially debt-financed in equilibrium. In a fixed cost model, debt has no strategic value in a symmetric equilibrium. In this case debt induces higher R&D expenditure from its rival and thus decreases its expected profit. Firms in this case use no strategic debt, and may in fact use "negative" strategic debt; that is, in a more general model where debt has other uses, the total debt level is reduced when the strategic effect is included. Our empirical study gives support to the fixed, up-front R&D result that higher debt levels are associated with lower overall R&D expenditures.

JEL classifications: L0, L1, L6, G3
Keywords: Strategic debt, Capital structure, R&D

*We thank Stephen Martin, an anonymous referee, and Mort Kamien for helpful suggestions on an earlier draft of this paper. We also thank seminar participants at the 2000 Southern Economic Association Meeting, the 1999 and 2000 European Association for Research in Industrial Economics Meetings, and the 1999 Southeast Economic Theory Meetings.

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I. Introduction

Since Schumpeter's (1946) seminal contribution, a considerable amount of attention has been devoted to the relationship between market structure and investment in innovation. With few exceptions, these models assume that firms finance R&D investment entirely through equity, and offer no insights into how the use of leverage may affect investment decisions (see Kamien and Schwartz (1975) and Reinganum (1988) for a survey of market structure and innovation, and a comprehensive survey of research and development).

In this paper, we show that the type of financing affects investment in innovation. We merge the literature on strategic debt with that on patent races and thereby reveal a link between financing and investment in innovation. In particular, we find that when R&D expenditures are made both up-front and over time, firms use at least some debt to finance R&D because it is strategically advantageous. Furthermore, firms spend less on R&D than if they were entirely financed through equity. However, we also find that if R&D expenditures are only an up-front, fixed cost, then firms do not use debt because it is strategically disadvantageous. Last, we show empirical results that support the hypothesis that up-front R&D expenditures are more important than flow R&D expenditures.

The investigation of capital structure and its effects on R&D investment is an especially topical issue in light of a late-1990's trend among high-tech startup companies in California, Massachusetts, and Texas to increasingly use borrowed funds to finance their initial operations. The *Austin-American Statesman* reported in June of 1998 that "venture banking" had become popular in Austin, Texas, where many software and computer chip start-up companies exist. Increased competition between two California banks, Silicon Valley Bank and Imperial Bank, in lending money to Austin start-ups had produced an attractive financing alternative (or complement) to traditional venture capital for these firms. Many start-ups, often without a product or track record, had been able to secure credit lines from these banks ranging from $250,000 to $1.5 million. Other banks such as Bank One and Chase had also developed high-tech lending departments to compete with venture bankers. In this paper, we show that the incentives of firms that use "venture loans" differ from the incentives of firms using the more traditional equity financing, thus the choice of financial structure is not trivial.

The sequence of the types of financing is important to our results, and it begs the question of whether financing actually occurs in this sequence. That is, do firms first seek a line of credit or borrow, and then issue equity, or vice-versa? Certainly one common type of start-up involves entrepreneurs who initially use equity in the form of their own personal wealth, and then borrow if and when their funds near exhaustion. However, there have been some dramatic changes in financial markets in the last decade, and the venture banking examples noted above do not seem to be isolated events. As further evidence of this phenomenon, in Table 1 we present data from all firms listed by COMPUSTAT that issued an initial public offering (IPO) of equity shares in the 10 year period from 1992 to 2001. For each year, we report both the number of firms that issued IPOs and the average of total debt as a percentage of total assets in the year *previous* to the IPO date for these firms. It is clear from this data that those firms which sold issued shares in this ten year period carried a significant amount of debt before doing so. Indeed, during this period, debt averaged 45.15 per cent of assets for these firms in the year prior to their IPO. Thus, given the number of IPOs in R&D intensive industries during this period, the sequence of financing in this paper is both realistic and relevant.

We also contribute to the strategic debt literature, most of which is derived from Brander and Lewis (1986). In their duopoly model of quantity competition, debt can be used by a firm to credibly commit to a large output stance, causing a favorable reduction the output of a rival firm. Firms thus carry debt in equilibrium. In a related paper, Showalter (1995) shows that in a modification of Brander and Lewis' framework where cost uncertainty and price-competition exist, debt is strategically disadvantageous. Debt commits a firm to a more aggressive pricing stance, which induces a harmful price reduction from its rival. Firms in this case choose to remain unlevered to encourage "soft" competition.

The use of debt by a firm acts as a credible commitment to a future R&D strategy. Upon taking debt, equityholders (or owner-managers) of an incumbent firm who are limited in liability optimize only over non-bankrupt states of innovation value. If the debt and equity proceeds are immediately sunk into R&D financing, the only funds available to repay lenders is the value of innovation. Firms will only be solvent over the innovation values that are high enough to repay debt and do not care about innovation values that are too low and cause bankruptcy. A change in debt value increases the "critical" state of innovation value, defined as the state in which the firm is just able to repay debt.

Introducing the strategic debt-equity choice into an analysis of innovation involves substantial technical complexity because the value of the innovation, as well as its discovery date, is uncertain. Thus, to keep the analysis tractable, we consider the two simplest models of patent races. In each of these, firms make R&D spending decisions sequentially. In the first stage, each firm chooses a level of R&D expenditure financed by debt that is used to pay part of the up-front, fixed cost of R&D. After these outcomes are observed, in the second stage each firm chooses a level of R&D expenditure financed by equity. The models differ in the second stage. In one model equity is also used to finance the up-front, fixed R&D cost, while in the other it is used to finance flow R&D expenditure.

We find that an increase in debt by a firm causes its total R&D expenditures to fall. A debt increase has two competing effects. First, a rise in debt and the critical state of innovation causes the firm to re-optimize over more favorable (on average) states of innovation value, leading to a higher equity contribution to R&D. Second, a rise in debt also leads to a substitution effect away from equity. We show that the substitution effect dominates; firms reduce equity when debt rises. Moreover, the absolute reduction in equity is larger than the increase in debt; thus, a rise in debt causes total R&D (debt+equity) to fall. The reactions of rivals to a rise in a firm's debt level is dependent on the timing of R&D expenditures.

In our first model, R&D expenditures are lump-sum precommitments, as in Loury (1979). In this case, R&D expenditures are typically strategic substitutes for the firms (i.e., their reaction functions are negatively sloped), and R&D competition is soft. That is, as R&D expenditure by firm i rises, the marginal expected payoff to firm j from its R&D expenditure falls, causing firm j to reduce its expenditures in equilibrium. In this case, debt carries a strategic disadvantage: debt commits a firm to lower total R&D expenditure, inducing a rise in R&D expenditure by the rival firm and thus lowering the expected payoff of the leveraged firm. This implies that the firms do not use debt to finance R&D in a symmetric equilibrium. However, there also may be asymmetric equilibria in which debt can be a strategic advantage for one, but only one, of the firms. This requires that one firm's reaction function is positively sloped.

In our other model, we consider that firms may make flow expenditures on R&D (Lee and Wilde, 1980). In particular, we use a hybrid "fixed plus flow" cost approach (similar to Dixit (1988)), in which R&D funds are expended both up-front and over time. Firms must finance a fixed amount of up-front R&D cost through a combination of debt and equity. Once the financing choice is determined and observed, the firms then choose per-period R&D expenditures that are financed by equity. In this case, R&D flow expenditures are strategic complements (i.e., their reaction functions are positively sloped); that is, a rise in flow expenditure by firm i causes a rise in the marginal expected payoff of firm j and induces a rise in firm j's equilibrium flow expenditure. Debt carries a strategic advantage in this case by committing a firm to lower flow expenditure, which induces a favorable reduction in flow expenditure by its rival. In equilibrium, two important results emerge: firms are at least partially debt-financed; and industry R&D spending is lower than under all-equity financing. The latter result implies that debt financing mitigates the well-known common pool problem of social overinvestment in R&D.

We compare the noncooperative results to the collusive outcome, and find that collusion results in lower overall levels of R&D. In the fixed cost model under collusion, firms do not use debt, but do use less equity-financed R&D compared to the noncooperative case. In the fixed plus flow cost model, the levels of both debt-financed fixed R&D expenditure and equity-financed flow expenditure are lower under collusion. Thus, the problem of overinvestment in R&D in these models could be further mitigated through merger or collusion.

We test the relationship between debt and R&D using a cross-sectional sample of 871 firms from 1991-2000. We use two-stage least squares to show that R&D had a significantly negative effect on debt use for firms in the sample, and firms that used more debt had significantly less R&D expenditures. Both of these empirical results support the theoretical results from the fixed cost case. The second-stage results from the fixed cost model show that firms that use larger debt levels spend less on R&D, while first stage results show that firms choose zero debt. The first stage result of the model is supported by the empirical results because firms that engage in R&D choose to use less debt relative to firms that do not engage in R&D; they seem to recognize that debt causes a strategic disadvantage in the fixed cost case.

The idea that pre-emptive debt can be used to influence entry is, of course, similar to familiar models of commitment. Spence (1977, 1979) and Dixit (1979, 1980) show that a firm can commit to a high level of output by investing in a high level of initial capacity. To the extent that the investment in capacity is sunk, the first-mover effectively induces an output reduction from a rival firm and thus increases its market share and profit.

Section II presents the analysis for the fixed cost approach to R&D, while Section III presents the results for the flow cost approach. Section IV examines corresponding outcomes under collusion. Section V presents the empirical model and results. Section VI then concludes and discusses some possible extensions. All proofs are gathered in a technical appendix at the end of the paper.

II. The Fixed Cost Approach

Suppose two firms are competing for an unknown perpetual flow of rewards that accrue to the first firm that discovers an innovation. Following Loury (1979), each firm i's investment in innovation is the lump-sum expenditure z_i, which effectively allows them to "purchase" a random date $\tau(z_i)$ at which the innovation occurs. The R&D expenditure is fully sunk once incurred. The date $\tau(z_i)$ is distributed exponentially with parameter $h(z_i)$, so the expected discovery date is $h(z_i)^{-1}$ and the probability that discovery occurs at or before any time t is $F(t) = 1-e^{-ht}$. The conditional probability that discovery occurs in the next instant after time t (between time t and t+dt), given that no discovery has occurred before t, is the hazard rate $F'(t)/(1-F(t)) = h(z_i)$. Thus, the firm effectively purchases a hazard rate $h(z_i)$. We assume the hazard function satisfies the following assumptions: $h(0)=0$, $h'(z_i) > 0 > h''(z_i)$ for $z_i \geq 0$, $h'(0) = \infty$, and $h'(\infty) = 0$. That is, there is no chance of success without some R&D spending, and the marginal product of R&D spending is positive but diminishing, infinite for the first dollar spent, and approaches zero as R&D approaches infinity.

Spending on R&D can be financed through debt b_i or equity x_i, so $z_i = b_i + x_i$. To keep the model tractable, it is assumed that the maturity date on debt occurs when one firm discovers the innovation, and therefore is not binding in the race for the innovation. The value of the innovation, given by 'v', is randomly distributed over $[\underline{v},\bar{v}]$ and is uncertain until after discovery. There exists a critical value of v, denoted as $\hat{v}$, such that the debt is just paid in full with no residual profit accruing to equityholders. Because the proceeds from debt or equity are sunk, only the revenue from an innovation can be used to pay off debt. The lending sector is competitive, thus the loan bears an interest rate equal to the risk-free rate (assumed to be r>0) plus an amount that fairly repays the lender for the risk of default, given the moral hazard incentives of the firms. Under this condition, $\hat{v}=b_i(1+r)$. If the value of innovation is larger than $\hat{v}$, an innovation will earn revenues over debt obligations, and any residual earnings will accrue to equityholders. If the value of the innovation is below $\hat{v}$, however, the levered firm that discovers the innovation goes bankrupt and lenders are residual claimants to the value of the innovation. Thus, the relevant residual claims states are $[\underline{v},\hat{v}]$ for debtholders and $[\hat{v},\bar{v}]$ for equityholders.

The expected discounted payoff to equityholders of firm i is a function of the conditional probability that firm i discovers the innovation before anyone else, which is given by:

$$P^i(z_i,z_j) = \int_{\hat{v}}^{\bar{v}} \int_0^{\infty} e^{-rt}\, h_i\, e^{-[h_i+h_j]t}\, [v-b_i(1+r)]\, dt\,dv - x_i$$

where the arguments of 'h' are suppressed (i.e. $h_i = h(z_i)$) .

$$= \int_{\hat{v}}^{\bar{v}} \frac{h_i[v-b_i(1+r)]}{r+h_i+h_j}\, dv - x_i. \tag{1}$$

A. Stage Two: Equilibrium Equity Contribution

Given fixed levels of debt-financed R&D expenditures, in the second stage each firm chooses a level of equity-financed R&D expenditure to maximize the expected payoff to its equityholders. The firm in this stage does not need to consider the returns to debtholders because the level of debt has been chosen and is fixed. If we let $a=r+h(z_i)+h(z_j)$, the first-order conditions are:

$$P_i^i = \int_{\hat{v}}^{\bar{v}} \frac{h_i'[v-b_i(1+r)][r+h_j]}{a^2}\, dv - 1 = 0. \tag{2}$$

where the subscript i denotes the partial derivative of P^i with respect to x_i. The second-order sufficient condition is $P_{ii}^i<0$, which we assume. Given debt levels $b=(b_i,b_j)$, the second stage Nash equilibrium equity contributions $x_i^*(b)$ and $x_j^*(b)$ are the values that simultaneously satisfy (2) for each firm. We also assume $B = P_{ii}^i P_{jj}^j - P_{ij}^i P_{ji}^j > 0$, which with the second-order conditions implies uniqueness and stability of the equilibrium (i.e., this is the standard Routh-Hurwicz stability condition). As expected, an increase in the level of firm j's investment reduces payoff to firm i:

$$P_j^i = \int_{\hat{v}}^{\bar{v}} \frac{-h_j' h_i[v-b_i(1+r)]}{(r+h_i+h_j)^2}\, dv < 0, \tag{3}$$

where the subscript j on P^i represents the partial derivative with respect to x_j. The next result follows immediately.

Lemma 1. If $h_i - h_j < r$, then firm i's reaction function in equity-financed R&D expenditure is downward-sloping in the level of firm j's equity-financed R&D expenditure.

If the hazard rates of the two firms do not differ by more than the discount rate (as in a symmetric equilibrium), then reaction functions are downward-sloping, and the equity-financed R&D expenditures of the two firms are "strategic substitutes." That is, R&D competition is "soft" in this case because firm i's best reply to an increase in its rival's level of equity-financed R&D expenditure is to reduce its own level. Similar to the output commitment effect in Cournot quantity competition, strategic substitutability in this model produces an incentive for one firm to commit to a large level of equity-financed R&D expenditure in an attempt to invoke a favorable reduction in equity from its rival. This also reflects a similar result in Loury, who shows that this implies an increase in rivalry (defined as an increase in the number of competitors) has the effect of reducing each incumbent firm's equilibrium R&D.

Theorem 1. An increase in debt-financed R&D expenditure by firm i commits it to lower equity-financed R&D expenditure. Moreover, the resulting decrease in equity-financed expenditure is larger (in absolute value) than the increase in debt-financed expenditure, so <u>total</u> R&D expenditure (debt+equity) decreases ($\partial x_i^*/\partial b_i<-1$). Furthermore, if $h_j - h_i < r$, then an increase in debt-financed expenditure by firm i causes the rival firm j to increase its equity-financed expenditure ($\partial x_j^*/\partial b_i>0$).

Each firm becomes less aggressive in total R&D spending as its debt level rises. The logic behind this reduced aggressiveness is reflected in the differences between debt and equity on expected payoff. Upon inspection of (1), it can be shown that one additional unit of debt-financed R&D increases the expected payoff to firm i by a larger amount than one unit of equity-financed R&D. The reason for this is that while a dollar of equity and a dollar of debt have identical benefits, a dollar of debt has a lower cost in that it only needs to be repaid if the firm discovers the innovation first. A dollar of equity is an up-front investment that is incurred no matter who discovers the innovation. Thus, as more debt is used, a larger amount of equity can be retired without reducing the expected payoff.

Further, a reduction in total R&D expenditure by firm i causes the rival firm j to become more aggressive by increasing its level of equity-financed R&D if its reaction function in equity-financed R&D is negatively sloped, so its equity level is a strategic substitute for firm i's equity level. From Lemma 1, a commitment to a lower equity level by firm i (through an increase in debt) induces rival firm j to increase its equity level. Further, through (3), the expected payoff of firm i decreases as a result. Therefore, the strategic effect of debt is negative; debt commits the firm to a less favorable stance in the market for innovation.

B. Stage One: Equilibrium Debt Choice

In stage one, each firm knows the effects that its debt choice will have on the second stage equity choices, and thus chooses debt (b_i) to maximize its expected payoff over both stages. In this stage, each firm also must realize that the level of debt it chooses will affect the market value of its debt. A large debt level increases the possible states of bankruptcy, which reduces debt value and causes the interest rate, r, to rise. In a competitive lending market, the proceeds (b_i) from any debt issue are equal to the expected value of the promised repayment plus the recovery value of the firm in case of default. It can be shown that under a competitive loan market, the firm effectively chooses debt to maximize its full value (debt+equity), given by[1]:

$$Y^i(x_i^*(b),x_j^*(b),b) = \int_{\underline{v}}^{\bar{v}} \frac{h(x_i^*(b)+b_i)v}{a} dv - (x_i^*(b)+b) \tag{4}$$

where now $a = r+h[x_i^*(b)+b_i]+h[x_j^*(b)+b_j]$. We assume that Y^i is strictly concave in b_i.

Because debt cannot be negative and cannot exceed the maximum innovation value, firm i chooses debt $b_i \in [0,\bar{v}]$ to maximize total value Y^i. Differentiating (4) and using the fact that $\partial h/\partial x_i = \partial h/\partial b_i = h'(z_i)$ yields

$$Y^i_{b_i} = a^{-2}\int_{\hat{v}}^{\bar{v}} [(r+h_j)\frac{\partial h_i}{\partial x_i}(\frac{\partial x_i^*}{\partial b_i}+1)v]dv + a^{-2}\int_{\underline{v}}^{\hat{v}} [(r+h_j)\frac{\partial h_i}{\partial x_i}(\frac{\partial x_i^*}{\partial b_i}+1)v]dv$$

$$- a^{-2}\int_{\underline{v}}^{\bar{v}} [\frac{\partial h_j}{\partial x_j}\frac{\partial x_j^*}{\partial b_i}h_i v]dv - [\frac{\partial x_i^*}{\partial b_i}+1], \tag{5}$$

where the subscript b_i on Y^i represents the partial derivative with respect to b_i.

The first two terms in (5) represent the negative direct effect of a debt increase; the firm's total expenditure drops, reducing the expected payoff from innovation to both equityholders (first term) and debtholders (second term). The third term represents the indirect strategic effect from a debt increase. This term is also negative; a debt increase causes lower total expenditure, and induces an increase in expenditure from the rival. The expected payoff to the leveraged firm is lower as a result. The fourth term in (5) represents the positive value of debt in the form of a lower overall cost commitment to R&D.

Theorem 2: In a symmetric equilibrium, firms do not use debt to finance R&D expenditure; i.e., $b_i^* = b_j^* = 0$.

Theorem 2 indicates that, when equity-financed R&D expenditures are strategic substitutes, debt is strategically disadvantageous in the market for innovation. While debt is a less-costly financing option, it causes a rival firm to increase its equity-financed R&D, thus reducing the payoff to the leveraged firm. The strategic effect dominates for a firm that is unlevered. The reason why the strategic effect dominates lies in the fact that, evaluated at zero debt, the first and fourth terms of (5) cancel. The first term in (5) represents the additional gain to equityholders of a unit of debt and the fourth term represents its additional cost. Assume a firm has chosen zero debt and some positive equilibrium equity level. Absent any strategic effect, a very small increase in *equity* would have offsetting marginal cost and benefit terms, so no change in equilibrium equity would occur. The key is that evaluated at zero debt, a small increase in *debt* for the firm has the same marginal benefit and cost to equityholders as the small increase in *equity*. Thus, absent strategic motives, the first unit of debt has offsetting benefits and costs to equityholders (as would an additional unit of equity), and the first and fourth terms in (5) cancel.

Further, the second term in (5), which represents the change in debtholder returns from an increase in debt, is zero for a firm that is initially unlevered. Only the strategic third term in (5) remains. Because this is negative, the first dollar of debt decreases the full value of the firm, and thus firms do not use debt in equilibrium. That is, because Y^i is strictly concave in b_i, that (5) is negative implies $Y^i_{b_i} < 0$ for all $b_i \in [0, \bar{v}]$. In fact, firms in this case would like to use 'negative' debt; that is, they may prefer to lend money for R&D. Perhaps this is one reason firms sometimes prefer to delegate R&D to independent labs, offering to partially fund expenditures. This may also explain, in part, the formation of research joint ventures, since this is one way in which the firms can lend money for R&D investment to each other.[2]

Finally, as a referee has observed, an asymmetric equilibrium in which one firm uses debt to finance R&D is possible. For example, as in the standard Cournot quantity-choice duopoly, firm j's reaction function in equity-financed R&D can be backward bending, or positively sloped over a range of equity-financed R&D levels by firm i. If the reaction functions intersect in this range, then at this equilibrium an increase in debt by firm i, which shifts its reaction function in equity downward (or inward), results in a decrease (not an increase) in the level of equity-financed R&D by firm j as well. In this event debt-financing of R&D by firm i can have the strategic advantage of inducing its rival to spend less on R&D, thus increasing its expected payoff. Note well, however, that both firms' reaction functions cannot be positively sloped at the same values of total R&D expenditure (z_i,z_j), as this requires both $h_i - h_j < r$ and $h_j - h_i < r$. Thus, at most one firm might use debt to finance R&D in any case.

III. Fixed Plus Flow Cost Approach

Now suppose that R&D investment has two components, as in Dixit (1988): an up-front expenditure; and a flow expenditure over time. Consider a model in which firms must begin by financing a fixed level of up-front expenditures, F_i, with either debt or equity. We focus on the up-front debt choice. Once this debt is chosen, the rest of the up-front expenditure (F_i-b_i) is financed by default through equity. After up-front debt levels are chosen and observed, each firm i then chooses an equity-financed *flow* s_i of R&D expenditure. This expenditure effectively allows them to "purchase" a random date $\tau(z_i)$ at which the innovation is discovered, where(z_i) is distributed exponentially with parameter $h(z_i)$ and now $z_i = F_i+s_i$. That is, we interpret the flow s_i as expenditure that must be maintained in every period in order to maintain the same hazard rate, so a firm's effective R&D expenditure at any date is $z_i = F_i+s_i$. We also assume that the firms cannot spend more on flow R&D in any period than the expected direct value of innovation; i.e. $\int h_i[v-b_i(1+r)]dv > s_i$. We find that in this case the use of debt is strategically advantageous, and firms use debt in equilibrium.

The expected discounted payoff to equityholders of firm i is

$$P^i(z_i,z_j) = \int_{\hat{v}}^{\bar{v}}\int_0^{\infty} e^{-rt}h_i e^{-[h_i+h_j]t}\ [v-b_i(1+r)]\ dt\,dv$$

$$- \int_0^{\infty} e^{-rt}e^{-[h_i+h_j]t}\ s_i\,dt\,dv\ \ - (F_i-b_i), \tag{6}$$

which can be rewritten as

$$P^i(z_i,z_j) = \int_{\hat{v}}^{\bar{v}} \frac{h_i[v-b_i(1+r)]}{r+h_i+h_j}\ dv - \frac{s_i}{r+h_i+h_j} - (F_i-b_i). \tag{7}$$

A. Stage Two: Equilibrium Equity Contribution

Given fixed, up-front debt and equity levels, the firm in the second stage chooses a flow level of equity-financed R&D to maximize the expected payoff to equityholders. Differentiating (7) and rearranging terms, the first-order conditions are:

$$P^i_i = \int_{\hat{v}}^{\bar{v}} \frac{h_i^{/}[(r+h_j)(v-b_i(1+r))]}{a^2}\, dv - \frac{a-h_i^{/}s_i}{a^2} = 0, \tag{8}$$

where the arguments of 'h' are suppressed. The second-order conditions are $P^i_{ii}<0$. Given debt levels $b=(b_i,b_j)$, the second stage Nash equilibrium equity contributions $s^*_i(b)$ and $s^*_j(b)$ are the values that simultaneously satisfy (8) for each firm. We again assume $B = P^i_{ii}P^j_{jj}-P^i_{ij}P^j_{ji} > 0$, which together with the second-order conditions implies uniqueness and stability of the equilibrium. The effect of an increase in rival investment on expected profit is:

$$P^i_j = \int_{\hat{v}}^{\bar{v}} \frac{-h_j^{/}[h_i(v-b_i(1+r))]}{a^2}\, dv + \frac{h_j^{/}s_i}{a^2} < 0, \tag{9}$$

which is negative whenever $\int h_i[v-b_i(1+r)]dv > s_i$. The next result follows immediately.

Lemma 2. Reaction functions in equity-financed flow R&D expenditures are upward-sloping.

R&D competition in flow expenditures is "tough" because firm i's best reply to an increase in flow R&D by firm j is to increase its flow R&D. The reason firms mimic each other's actions is that, unlike the fixed cost case, where commitments are made up-front, firms cease their flow spending when someone discovers the innovation, causing them to be more willing to match each other's "aggressiveness" in R&D spending. Notice that, when innovation expenditures are strategic complements, a collusive-type outcome can result. Each firm has an incentive to use debt to commit to a lower overall level of flow R&D expenditure, inducing its rival to follow suit. This result is similar to Lee and Wilde (1980), who show that an increase in rivalry causes an increase in equilibrium investment by the remaining firms. The effect of leverage on equity-financed flow R&D, effective R&D spending, and rival R&D spending follows immediately.

Theorem 3. An increase in debt-financed R&D expenditure by firm i causes a decrease in the equilibrium equity-financed flow R&D expenditures of both firms. Moreover, the resulting decrease in equity-financed flow expenditure is larger (in absolute value) than the increase in debt-financed expenditure, so effective R&D expenditure (F_i+s_i) decreases ($\partial s^*_i/\partial b_i<-1$).

As firm i increases use of debt-financed R&D spending, it commits to a lower level of equity-financed flow

R&D spending. Because flow R&D expenditures are strategic complements, firm j reacts to its rival's leverage by reducing its flow R&D spending, thus increasing the expected payoffs of the leveraged firm. Debt therefore carries a strategic advantage; a firm can use debt to commit to lower flow R&D expenditures, which induces its rival to follow

$$Y^i_{b_i} = a^{-2}\frac{\partial h_i}{\partial s_i}\left(\frac{\partial s_i^*}{\partial b_i}+1\right)\left[\int_{\underline{v}}^{\bar{v}} v[r+h_j]dv + s_i^*\right] - a^{-2}\frac{\partial h_j}{\partial s_j}\left(\frac{\partial s_j^*}{\partial b_i}\right)\left[\int_{\underline{v}}^{\bar{v}} h_i v dv - s_i\right]$$

$$- \frac{\partial s_i^*}{\partial b_i}\frac{1}{a} + 1 = 0. \tag{11}$$

suit.

B. Stage One: Equilibrium Debt Choice

In stage one, both firms know the effects that debt will have on second stage expenditures choices, and thus choose debt to maximize profits over both stages. As in the fixed cost approach, the firm at this stage maximizes the full value of the firm (debt+equity), given by:[3]

$$Y^i(s_i^*(b), s_j^*(b), b) = \int_{\underline{v}}^{\bar{v}} \frac{h_i(s_i^*(b)+b_i)v}{a}dv - \frac{s_i^*(b)}{a} - F_i \tag{10}$$

where $a = r+h_i[s^*_i(b)+F_i]+h_j[s^*_j(b)+F_j]$. We assume that Y^i is strictly concave in b_i.

Because debt cannot be negative and cannot exceed the required fixed R&D cost, firm i chooses debt $b_i \in [0,F_i]$ to maximize total firm value Y^i. Differentiating (10), using $\partial h_i/\partial s_i = \partial h_i/\partial b_i$ and $\partial F_i/\partial b_i = 1$, and rearranging terms, the first-order condition is:

The first term in (11) represents the negative direct effect of a debt increase; the firm's total effective R&D drops, reducing the expected payoff to innovation to both equityholders and debtholders. The second term represents the indirect strategic effect from a debt increase. Given $\int h_i v dv > s_i$ from the assumption above, this term is positive. Because flow R&D expenditures are strategic complements, the third term implies that a debt increase by one firm causes the firm to reduce effective R&D, inducing a decrease in effective R&D from the rival and thereby increasing the expected payoff to the leveraged firm. The remaining terms represent the positive value of debt in the form of less equity-financing of the up-front, fixed cost. In the proof, we show that, at b_i=0, the negative direct effect is outweighed by the other effects, or $Y^i_{b_i} > 0$ at b_i=0 for any b_j. This, plus the continuity and strict concavity of Y^i in b_i and similar conditions for firm j, guarantee the existence of a stage one equilibrium with positive debt.[4]

Theorem 4: In equilibrium, firms choose positive levels of debt to finance fixed R&D expenditures ($b^*_i>0$, $b^*_j>0$).

Theorem 4 shows that in the fixed plus flow cost case, debt holds a strategic advantage. In particular, because equity-financed flow R&D levels are strategic complements, a rise in debt by firm i commits it to lower effective R&D, inducing a favorable reduction in firm j's effective R&D. Debt therefore acts as tool to induce a more collusive-type outcome.

IV. The Collusive Equilibrium

In this section, we assume that both firms perfectly collude, choosing debt and equity to maximize total (industry) expected payoff. We then compare these collusive debt and equity results to the noncooperative (subgame perfect equilibrium) results derived above.

A. Fixed Cost Case:

Assume perfect collusion, where a cartel planner chooses a common level of equity-financed expenditure ($x_c=x_i=x_j$) and debt-financed expenditure ($b_c=b_i=b_j$) for each firm to maximize total expected payoff. Let the *noncooperative* equilibrium levels of equity and debt under symmetry be $x_n=x^*_i=x^*_j$ and $b_n=b^*_i=b^*_j$. In stage two, the cartel planner chooses x_c for each firm to maximize:

$$P^i(x_c) = \int_{\hat{v}}^{\bar{v}} \frac{h(x_c+b_c)[v-b_c(1+r)]}{r+2h(x_c+b_c)}\, dv - x_c \qquad (12)$$

Suppressing the arguments on the hazard function 'h', the first-order conditions are:

$$P^i_{x_c} = \int_{\hat{v}}^{\bar{v}} \frac{h'[v-b_c(1+r)][r+2h] - 2h'h[v-b_c(1+r)]}{[r+2h]^2}\, dv - 1 = 0. \qquad (13)$$

We find that $P^i_{x_c} < 0$ at x_n, so a cartel planner chooses less equity-financed R&D per firm.

Theorem 5. In the symmetric fixed cost model, for any given level of debt-financed R&D expenditure, the level of equity-financed R&D expenditure under perfect collusion is lower than in the noncooperative equilibrium.

In stage one, we consider how a cartel planner would choose common levels of debt-financed R&D to maximize the full value of the industry. Given equilibrium levels of equity (x_c), the cartel planner chooses b_c to maximize each firm's total value :

$$Y^i(x_c,b_c) = \int_{\underline{v}}^{\bar{v}} \frac{h(x_c(b_c)+b_c)v}{r+2h[x_c(b_c)+b_c]}dv - (x_c(b_c)+b_c). \tag{14}$$

If we differentiate (14), suppress the arguments on the hazard function, note that $h'=\partial h/\partial x_c$ and $x'=\partial x_c/\partial b_c$, and use $a=r+2h[x_c(b_c)+b_c]$, then we obtain:

$$Y^i_{b_c} = a^{-2}\int_{\underline{v}}^{\bar{v}} [rvh'(x_c'+1)]dv - [x_c'+1]. \tag{15}$$

We now find that $Y^i_{b_c} < 0$ at b_n, which implies the following.

Theorem 6. In the symmetric fixed cost model, the level of debt-financed R&D expenditure under perfect collusion is zero. If debt is taken for other reasons in the noncooperative equilibrium, then levels of debt are lower under perfect collusion. Further, with Theorem 5, total R&D expenditure (debt+equity) is lower under perfect collusion than in the noncooperative equilibrium.

Both the first and second stage equilibrium results above show that firms in a cartel choose both a lower level of equity-financed R&D and a lower (or zero) level of debt-financed R&D than the noncooperative equilibrium. Thus, in a cartel, a lower level of total R&D expenditure (debt+equity) is chosen; consistent with Loury, firms overinvest relative to the collusive optimum.

B. Fixed Plus Flow Cost Case:

If firms perfectly collude, a cartel planner in stage two chooses s_c for each firm to maximize industry expected payoff:

$$P^i(s_c) = \int_{\hat{v}}^{\bar{v}} \frac{h(s_c+b_c)[v-b_c(1+r)]}{r+2h(s_c+b_c)}\, dv - \frac{s_c}{r+2h(s_c+b_c)} \tag{16}$$

Suppressing the arguments on the hazard function 'h', the first-order conditions for the cartel planner are:

$$P^i_{s_c} = \int_{\hat{v}}^{\bar{v}} \frac{h'[v-b_c(1+r)][r+2h] - 2h'h[v-b_c(1+r)]}{[r+2h]^2}\, dv - \frac{[r+2h] - 2h's_c}{[r+2h]^2} = 0. \tag{17}$$

In this case, we find equity-financed flow R&D expenditures are lower in the cartel.

Theorem 7: In the symmetric fixed plus flow cost model, the optimal level of equity-financed flow R&D expenditure is lower under perfect collusion than in the noncooperative equilibrium.

In stage one, we consider how a cartel planner would choose common debt levels to maximize industry profit. The cartel planner chooses b_c to maximize each firm's total value :

$$Y^i(s_c,b_c) = \int_{\underline{v}}^{\bar{v}} \frac{h(s_c(b_c)+b_c)v}{r+2h[s_c(b_c)+b_c]}\, dv - \frac{s_c(b_c)}{r+2h[s_c(b_c)+b_c]} - (F-b_c) \tag{18}$$

The first order conditions for the cartel planner are:

$$Y^i_{b_c} = a^{-2}\int_{\underline{v}}^{\bar{v}} \{[h'(s_c'+1)v][r+2h] - 2h'(s_c'+1)hv\}dv$$

$$- a^{-2}(s_c'[r+2h] - 2h'(s_c'+1)s_c) + 1 = 0. \tag{19}$$

By comparing the first order conditions again, we find the following:

Theorem 8: In the symmetric fixed plus flow cost model, the optimal level of debt-financed R&D expenditure is lower under perfect collusion than in the noncooperative equilibrium. Further, using Theorem 7, total effective R&D under perfect collusion is also lower.

Theorem 8 shows that the advantage to debt is realized when there are at least some flow R&D expenditures; debt in this case carries a strategic advantage in inducing the rival firm to reduce total R&D.

V. Empirical Results

In this section, we present evidence that firms use capital structure as a strategic device to commit to R&D levels in the market for innovations. In particular, evidence we present shows that firms that engage in higher R&D expenditures tend to use less debt, suggesting that most firms' expenditures in R&D tend to be weighted more heavily in up-front costs and less-heavily in flow costs.

Since Modigliani and Miller's (1958) seminal paper in which debt and equity are shown to be identical forms of financing in a "frictionless" environment, much of the theoretical literature has focused on the relevance of capital structure choice when some of Modigliani and Miller's stringent assumptions are dropped. One of the benefits of debt over equity, for instance, is that interest payments on debt are tax deductible. Other factors shown to affect debt choice include the amount of other tax shields currently in place, the amount of collateralized assets the firm owns as a percentage of total assets, the volatility of firm earnings, and the ability of the firm to generate retained earnings as an alternative to debt financing. More recently, oligopoly theory has contended that firms may also alter their debt levels to enhance their strategic position in the product market. The seminal work in this area is a paper by Brander and Lewis (1986), who establish that Cournot firms subject to some output market uncertainty use debt to commit to large output stances in an attempt to gain a strategic advantage. The goal of this study is to control for these alternative reasons for debt usage in an effort to isolate the link between debt and R&D.

A. Data and Variables

As shown in the empirical literature, there are many arguments to the debt irrelevance theorem of Modigliani and Miller aside from the strategic debt hypothesis. Firms find that their cost of debt, and thus debt usage, changes with the composition of assets or volatility of earnings. Further, tax considerations and industry characteristics may cause firms to use debt.

While there are many ways to measure debt and the various theoretical factors that influence debt, proxies that tend to be most common within the capital structure literature are used in this study. The dependent variable, the debt ratio, is represented as the ratio of the 10-year average book value of long-term debt obligations to book value of long-term debt plus market value of equity, multiplied by 100 (DEBT), and the natural log of that ratio (LDEBT) . Bradley, Jarrel, and Kim (1984) use these ratios in their study. Obtaining and incorporating the market value of debt would be desirable, but those data are difficult to obtain. Moreover, in some previous studies, the correlation between market and book value of debt is high, thus not much is lost by using book value.

Assumed in the strategic debt model is that assets are used up in the production process and thus lenders in bankruptcy are only able to capture the returns from production of the firm. In reality, however, firms give up not only returns but also any collateralized assets to lenders in bankruptcy. As noted by Jensen and Meckling (1976) as well as Myers (1977), shareholders have an incentive to invest suboptimally to expropriate wealth from the firm's bondholders unless bondholders can collateralize the borrowed funds. If firms cannot collateralize their debt, then lenders require more favorable terms, and firms may choose equity instead.

To obtain more favorable prices for debt, firms can mitigate this moral hazard and bind itself to a less risky project if a larger percentage of their assets can be used as collateral. As collateralizable assets rise, the cost of debt financing falls and the firm takes on more debt.[2]

Myers and Majluf (1984) also suggest that firms may find it advantageous to sell secured debt if the firm's managers have better information about the value of assets than outside investors. Management may refuse to finance positive net present value projects through equity if the incremental firm value to old shareholders is less than new shareholder's claim to existing assets. If management is maximizing existing shares in this way, it prefers issuing debt secured by property with known resale values because issuing equity may be a bad signal to existing shareholders. Thus, if the level of collateralizable assets rises, firms have an increased incentive to use debt to avoid the agency costs borne from asymmetric information.

The proxy for fixed assets is the natural log of the ratio of average gross property, plant, and equipment to average total assets, multiplied by 100 (LFIXED), as used by Friend and Lang (1988), Marsh (1988), and Ferri and Jones (1975). The ratio of average net property, plant, and equipment to average assets is used in some studies as a fixed asset ratio, although in this study these proxies were highly correlated. Titman and Wessels (1988) use the ratio of average inventory plus average gross property, plant and equipment to total assets.

A rise in the volatility of earnings causes the probability of bankruptcy to increase, and the price of debt therefore rises. As debt becomes more costly, firms substitute toward other forms of financing. A negative relationship therefore should exist between risk and firm leverage. Business risk, or the volatility in firm value, is represented here as the natural log of the ratio of standard deviation of operating income before depreciation over the relevant time period to average operating income during the same period (LRISK).

As pointed out by several authors, risk is partially endogenous in models of this type. In the model of strategic debt, returns become more volatile as firms increase debt levels and subsequently deviate further from the output or prices that maximize profit over all states of nature. Although some attempts have been made to screen for exogenous risk, these measures are not used widely. The omission of risk in the regressions left the results relatively unchanged.

Myers' (1984) notion that firms have a "pecking" order in their choice of financing leads to a possible relation between profitability and leverage. Myers argues that the least costly method of financing is retained earnings. Assuming the pool of retained earnings grows as firms become more profitable, internal financing becomes more accessible. As profitability increases, firm leverage falls.[6] Profitability of the firm (LPROFIT) is given as the log of the ratio of average operating income before depreciation to average total assets.

Finally, in a recent study by Showalter (1999), the level of demand and cost uncertainty has been found to be significant factors in debt ratios. As demand uncertainty rises in price competition, firms in concentrated industries may take on more debt to commit to higher prices, inducing rivals to do likewise. As cost uncertainty increases in price competition, firms may use less debt to commit to higher prices and induce rivals to follow. To define the demand uncertainty, first consider the trend regression $Y_t = \beta_o + \beta_1 t + e_t$ for each firm, where Y_t is sales in year t. Demand uncertainty is then the natural log of the ratio of $(u'u)^{1/2}$ from the trend regression to average sales, denoted as LDEM. Similarly, cost uncertainty (LCOS) is the natural log of the ratio of $(u'u)^{1/2}$ from the trend regression $Y_t = \beta_o + \beta_1 t + e_t$, where Y_t is cost of goods sold divided by sales.

Research and development expenditures (RDS) and are defined as the level of R&D over the 10 year period divided by sales, multiplied by 100. The log of RDS, also used in some regressions, is denoted as LRDS. Several studies use this measure as a gauge of R&D intensity.

In the regression to explain R&D expenditures, two additional variables are used: LCONC is the log of the 4-firm concentration ratio of the industry in which the firm resides, and LSIZE is the log of total assets of the firm. Some studies have shown that larger firms and firms in more concentrated industries have accounted for more innovations, and we might expect both to be positive influences on R&D.

B. Data and Methodology

Our methodology consists of two-stage least squares regressions: one equation involves the estimation of

R&D, and the other equation involves the estimation of debt ratios. Recall that R&D and debt are both endogenous variables in the theoretical analysis, thus two-stage least squares is more appropriate than a typical OLS capital structure regression. From the theory, higher debt levels commits a firm to a lower level of R&D spending (stage two in our theoretical analyses above), and firms that invest most heavily in *up-front* R&D are induced to use zero debt, while firms that invest in mainly *flow* R&D are induced to use more debt (stage one above). The two equations to be estimated are of the form $Y_t = \beta_o + \beta_1 X_t + e_t$; in the first equation, RDS is regressed on LDEBT, LCONC, and LSIZE. In the second, DEBT is regressed on RDS, LPROFIT, LRISK, LFIXED, LDEM, and LCOS.

The data is taken from COMPUSTAT Annual Reports, and contains information on 6747 firms that existed in 2000 and had been operating for at least 4 years. The variables were then calculated using the 10-year time period 1991 to 2000. After dropping all observations that had some variables missing, a base set of 2727 firms remained. The variables of interest are measured as firm-specific averages over time to smooth out any measurement errors as well as to minimize the effects of perhaps anomalies in any one particular year. Concentration ratios are taken from 1992 Census of Manufacturers.

C. Results

In the results that follow, debt is a significantly negative influence on R&D expenditures, which supports the stage-two results of both of our theoretical analyses, and R&D is a negative influence on the debt ratio, which supports the stage-one results in the case where R&D expenditures are up-front commitments. That is, for the sample under study, it appears that the costs of up-front R&D investments were more important than flow R&D expenditures.

Table 2 shows summary statistics for all variables used. Tables 3 and 4 show how different industries (defined by 2-digit SIC codes) rank in terms of R&D intensity and debt ratios. The top R&D-intensive industries are paper and allied products, retail trade and security and commodity brokers. Among the highest debt ratios are those in motor freight transportation, amusement and recreational services, and air transportation.

Tables 5 and 6 place firms into debt and concentration categories, and summarize R&D in each category. Table 5 reveals the negative correlation between debt levels and R&D intensity. Firms that rank highest in debt ratio tend to spend less on R&D. Table 6 seems to indicate that R&D is a concave in concentration. As concentration rises from 0 to around 40%, R&D rises, but falls for higher levels of concentration.

Table 7 is the first of the two-stage least squares regressions, where R&D intensity is estimated using as explanatory variables some form of debt ratio (DEBT, LDEBT), LSIZE, and LCONC. In equation (1), RDS is regressed on DEBT, LSIZE, and LCONC. All variables are significant at the .05 level, with DEBT and LSIZE being negative factors, and LCONC being a positive factor. Firms in concentrated industries tend to be most heavily involved in R&D, supporting Schumpeter's traditional hypothesis. However, smaller firms tend to be engaging more in R&D than larger firms, suggesting that perhaps the marginal gains to R&D are bigger among smaller firms. Finally, the more debt intensive industries tend to be less heavily invested in R&D. This result supports the hypothesis above that as debt rises, firms tend to spend less on R&D than if fully equity-financed. Equation (2) shows similar results, where LRDS and LDEBT are substituted for RDS and DEBT.

Table 8 shows the results of the other two-stage least squares regressions, the debt ratio estimation. In these regressions, DEBT (LDEBT in equation (2)) are regressed on RDS (LRDS in equation (2)) and a host of control variables. Note that among the control variables, LRISK, LPROFIT, LFIXED, and LDEM all came in with the correct signs and were significant. LCOS was significant but had the wrong sign. The variables of interest, RDS and LRDS, both were negative and significant, suggesting that firms that tend to use R&D for other reasons also tend to use less debt than other firms. This would suggest that debt carries a strategic disadvantage in the innovation market; from the theory above, debt held a strategic disadvantage when R&D expenditures were made in a fixed, up-front fashion. Thus the data support the up-front, fixed-cost R&D case. Nevertheless, caution must be used when interpreting these results, however, because of two factors. First, higher R&D expenditures may increase the *perceived* volatility of returns, making the cost of borrowing higher and lowering the amount of debt used. To the extent that the LRISK variable fails to capture this volatility (perhaps a new internet company with zero sales and thus zero variation in sales), the negative relationship between debt and R&D could have this alternative explanation. Second, R&D expenditures act as non-debt tax shields; they can be written off in the year expensed. Thus, debt may act as a substitute for R&D (as with investment tax credits or depreciation) in the form of a tax shield.

VI. Summary

Most traditional models of the investigation of R&D spending do not consider that the use of leverage to finance R&D may affect total R&D expenditures in a patent race. We show that debt acts as a commitment to a smaller amount of total R&D spending (debt+equity) than would occur if firms were entirely equity financed. A commitment to lower R&D investment can be strategically beneficial; under a flow-cost model, debt induces a lower rival R&D investment and thus increases expected profit. Firms in this case are partially debt-financed in equilibrium. In a fixed cost model, debt has no strategic value as long as reaction functions are downward-sloping, as must be true in a symmetric equilibrium. Debt in this case induces an increase in rival R&D spending, decreasing the payoff to the leveraged firm. Firms in this case use no strategic debt, and may in fact use "negative" strategic debt levels; that is, in a more general model where debt has other uses, the total debt level is lower when factoring in the strategic effect.

The empirical results support the hypothesis that up-front expenditures on R&D are more important than flow cost expenditures . We find that R&D had a significantly negative effect on debt use for firms in our sample, and firms that used more debt had significantly less R&D expenditures. Both results support the results from the fixed cost case. The second-stage results from the fixed cost model show that firms that use larger debt levels spend less on R&D, while first stage results show that firms choose zero debt. The first stage result of the model is supported by the empirical results because firms that engage in R&D choose to use less debt relative to firms that do not engage in R&D; they seem to recognize that debt causes a strategic disadvantage in the fixed cost case.

Further work in this area may include determining the optimal interest rate-debt level combination that lenders choose in offering funds to firms engaging in R&D. Also, empirical investigations could focus on debt-taking and R&D investment, and how in particular a research firm's financial structure is affected by the time element of investment. Further research might also probe into the question of how a change in market structure affects R&D contribution, and/or how welfare changes with market structure and debt levels. In particular, if the number of competitors increases, do we get the same result as in Lee and Wilde and Loury that equilibrium R&D investment falls for each firm but industry R&D increases? Also, do firms continue to over-invest in R&D spending when debt is an option to finance R&D investment, or might they under-invest? Finally, how does social welfare change when rivalry increases?

Appendix

I. Proof of Lemma 1

The first-order condition (2) implicitly defines equilibrium equity reaction functions $x_i^*=R_i(x_j;b_i,b_j)$ for i=1,2. The slope of each reaction function is derived by totally differentiating (2), producing $\partial R_i/\partial x_j= -P^i_{ij}/P^i_{ii}$. We assumed that $P^i_{ii}<0$, thus the crucial derivative in determining the slope of the reaction functions is P^i_{ij}. Using (2),

$$P^i_{ij} = -2a^{-3}h_j' \int_{\hat{v}}^{\bar{v}} h_i[v-b_i(1+r)][r+h_j]dv + a^{-2}\int_{\hat{v}}^{\bar{v}} h_i'[v-b_i(1+r)]h_j'dv. \tag{20}$$

Rearranging terms, we have in equilibrium

$$\int_{\hat{v}}^{\bar{v}} h_i'[v-b_i(1+r)]\,dv = \frac{a^2}{[r+h_j]}. \tag{21}$$

Substituting (21) into (20) we get

$$P^i_{ij} = \frac{-2h_j'}{[r+h_i+h_j]} + \frac{h_j'}{[r+h_j]} = \frac{h_j'[h_i-r-h_j]}{[r+h_i+h_j][r+h_j]}$$

which is negative if $h_i - h_j < r$. Q.E.D.

II. Proof of Theorem 1

The comparative static effect of an increase in debt on equity contribution can be found by totally differentiating the first-order conditions (2) and using Cramer's Rule to obtain:

$$\partial x_i^*/\partial b_i = (P^j_{jb_i}P^i_{ij} - P^i_{ib_i}P^j_{jj})/B, \tag{22}$$

$$\partial x_j^*/\partial b_i = (P^i_{ib_i}P^j_{ji} - P^i_{ii}P^j_{jb_i})/B \tag{23}$$

where $B = P^i_{ii}P^j_{jj} - P^i_{ij}P^j_{ji} > 0$ by assumption. The individual terms in (22) and (23) are:

$$\text{(a)} \quad P^i_{ib_i} = -2a^{-3}h_i' \int_{\hat{v}}^{\bar{v}} h_i'[v - b_i(1+r)][r+h_j]dv$$

$$+ \; a^{-2}\int_{\hat{v}}^{\bar{v}} [h_i''[v - b_i(1+r)][r+h_j] \; - \; h_i'[r+h_j](1+i)]dv,$$

$$\text{(b)} \quad P^i_{ib_j} = -2a^{-3}h_j' \int_{\hat{v}}^{\bar{v}} h_i'[v - b_i(1+r)][r+h_j]dv \; + \; a^{-2}\int_{\hat{v}}^{\bar{v}} h_i'[v - b_i(1+r)]\, h_j'\, dv,$$

$$\text{(c)} \quad P^i_{ii} = -2a^{-3}h_i' \int_{\hat{v}}^{\bar{v}} h_i'[v - b_i(1+r)][r+h_j]dv \; + \; a^{-2}\int_{\hat{v}}^{\bar{v}} h_i''[v - b_i(1+r)][r+h_j]dv,$$

$$\text{(d)} \quad P^i_{ij} = -2a^{-3}h_j' \int_{\hat{v}}^{\bar{v}} h_i'[v - b_i(1+r)][r+h_j]dv \; + \; a^{-2}\int_{\hat{v}}^{\bar{v}} h_i'[v - b_i(1+r)]\, h_j'\, dv.$$

First note that, upon inspection of (b) and (d) above, $P^i_{ib_j} = P^i_{ij}$ and $P^j_{jb_i} = P^j_{ji}$. Thus, $\partial x^*_j/\partial b_j = P^j_{ji}[P^i_{ib_j} - P^i_{ii}]/B$ and

$$\partial x^*_i/\partial b_i + 1 \; = \; (P^i_{ij}P^j_{jb_i} - P^i_{ib_i}P^j_{jj})/B + (P^i_{ii}P^j_{jj} - P^i_{ij}P^j_{ji})/B$$

$$= \; P^i_{ij}[P^j_{jb_i} - P^j_{ji}]/B + P^j_{jj}[P^i_{ii} - P^i_{ib_i}]/B. \qquad (24)$$

Using $P^i_{ib_j} = P^i_{ij}$ (or equivalently, $P^j_{jb_i} = P^j_{ji}$), the first term in (24) is zero, thus

$$\partial x^*_i/\partial b_i + 1 \; = \; P^j_{jj}[P^i_{ii} - P^i_{ib_i}]/B.$$

From (a) and (c),

$$P^i_{ii} - P^i_{ib_i} = a^{-2}\int_{\hat{v}}^{\bar{v}} h_i'[r + h_j](1+r)dv > 0, \qquad (25)$$

which with B>0 and P^j_{jj}<0 implies $\partial x^*_i/\partial b_i + 1 < 0$, so a rise in debt causes total R&D expenditures to fall. Further, using (24) and with P^j_{ji}<0 and B>0,

$$\partial x^*_j/\partial b_i = P^j_{ji}[P^i_{ib_i} - P^i_{ii}]/B > 0,$$

which shows that a rise in debt by firm i causes firm j to increase its use of equity-financed R&D spending if its reaction function is negatively sloped, or $P^j_{ji} < 0$ (i.e., h_j - h_i < r). Q.E.D.

III. Proof of Theorem 2

Refer to equation (5). The first and second terms of (5) represent the direct effect on equityholders and debtholders, while the third term is the strategic effect and the last term is the cost effect. From the first order-conditions in stage two (equation (5)), we have:

$$a^{-2}\int_{\hat{v}}^{\bar{v}} h_i'[v - b_i(1+r)][r+h_j]\ dv = 1.$$

Evaluated at $b_i = 0$, we have:

$$a^{-2}\int_{\hat{v}}^{\bar{v}} h_i' v[r+h_j]\ dv = 1. \qquad (26)$$

The first term in (5) can be rewritten as:

$$a^{-2}\int_{\hat{v}}^{\bar{v}} h_i' v[r + h_j]\ dv\ \left(\frac{\partial x_i^*}{\partial b_i} + 1\right)$$

which, using (26), collapses to ($\partial x^*_i/\partial b_i$ + 1) and cancels with the cost term in (5). Thus, evaluated at zero debt, (5) retains only its second and third terms:

$$Y^{i}_{b_i}\big|_{b_i=0} = a^{-2}\int_{\underline{v}}^{\hat{v}} [(r+h_j)\frac{\partial h_i}{\partial x_i}(\frac{\partial x_i^*}{\partial b_i}+1)v]\ dv - a^{-2}\int_{\underline{v}}^{\bar{v}} [\frac{\partial h_j}{\partial x_j}\frac{\partial x_j^*}{\partial b_i} h_i v]\ dv.$$

The first term above is zero at $b_i=0$, where $\underline{v}=\hat{v}$ and the integral collapses. The second term above is negative. First, note that $a^{-2}>0$, $v>0$, $h_i>0$, and $\partial h_j/\partial x_j>0$. Then, from Theorem 1, $\partial x^*_j/\partial b_i>0$, thus the second term is negative. Q.E.D.

IV. Proof of Lemma 2

The first-order conditions (8) implicitly define equilibrium equity reaction functions $s_i^* = R_i(s_j;b_i,b_j)$ for i=1,2. The slope of each reaction function is derived by totally differentiating (8), producing $\partial R_i/\partial s_j = -P^i_{ij}/P^i_{ii}$. We assumed that $P^i_{ii}<0$, thus the crucial derivative in determining the slope of the reaction functions is P^i_{ij}. Using (8),

$$P^{i}_{ij} = -2a^{-3}h_j'\int_{\hat{v}}^{\bar{v}} h_i'[r+h_j](v-b_i(1+r))dv + a^{-2}\int_{\hat{v}}^{\bar{v}} h_i'h_j'(v-b_i(1+r))dv$$

$$-a^{-2}h_j' + 2a^{-3}[a-h_i's_i]h_j'. \tag{27}$$

Rearranging first-order condition (8), we have in equilibrium

$$\int_{\hat{v}}^{\bar{v}} h_i'[r+h_j](v-b_i(1+r))dv = a-h_i's_i \tag{28a}$$

$$\Rightarrow \int_{\hat{v}}^{\bar{v}} h_i'(v-b_i(1+r))dv = \frac{a-h_i's_i}{[r+h_j']}. \tag{28b}$$

Substituting (28a) and (28b) into (27), we get

$$P^{i}_{ij} = -2a^{-3}h_j'[a-h_i's_i] + a^{-2}h_j'\frac{[a-h_i's_i]}{[r+h_j]} - a^{-2}h_j' + 2a^{-3}[a-h_i's_i]h_j'. \tag{29}$$

Combining terms and rearranging, we have

$$P_{ij}^{i} = \frac{a^{-2} h_j^{\prime}}{[r + h_j]}[h_i - h_i^{\prime} s_i] \tag{30}$$

which is positive because $h_i' > 0 > h_i''$ (positive but diminishing product) implies that $h_i' < h_i / s_i$. Q.E.D.

V. Proof of Theorem 3.

As before, the comparative static effect of an increase in debt on equity contribution are found by totally differentiating the first-order conditions (8) and using Cramer's Rule to obtain:

$$\partial s_i^*/\partial b_i = (P^j_{jb_i} P^i_{ij} - P^i_{ib_i} P^j_{jj})/B, \tag{31}$$

$$\partial s_j^*/\partial b_i = (P^i_{ib_i} P^j_{ji} - P^i_{ii} P^j_{jb_i})/B \tag{32}$$

where B > 0 by assumption. The individual terms in (31) and (32) are:

$$(a) \qquad P^i_{ib_i} = -2a^{-3}h_i' \int_{\hat{v}}^{\bar{v}} h_i'[r+h_j](v-b_i(1+r))\,dv \;-\; a^{-2}[h_i' - h_i'' s_i]$$

$$+\; a^{-2}\int_{\hat{v}}^{\bar{v}} [r+h_j][h_i''(v-b_i(1+r)) - h_i'(1+i)]\,dv + \;2a^{-3}h_i'[a-h_i's_i]$$

$$(b) \qquad P^i_{ib_j} = -2a^{-3}h_j' \int_{\hat{v}}^{\bar{v}} h_i'[r+h_j](v-b_i(1+r))\,dv \;-\; a^{-2}h_j'$$

$$+\; a^{-2}\int_{\hat{v}}^{\bar{v}} h_i' h_j'(v-b_i(1+r))\,dv \;+\; 2a^{-3}[a-h_i's_i]h_j'$$

$$(c) \qquad P^i_{ii} = -2a^{-3}h_i' \int_{\hat{v}}^{\bar{v}} h_i'[r+h_j](v-b_i(1+r))\,dv \;+\; a^{-2}[h_i'' s_i]$$

$$+\; a^{-2}\int_{\hat{v}}^{\bar{v}} h''(z_i)(v-b_i(1+r))(r+h_j)\,dv \;+\; 2a^{-3}[a-h_i's_i]h_i'$$

$$(d) \qquad P^i_{ij} = -2a^{-3}h_i' \int_{\hat{v}}^{\bar{v}} h_i'[r+h_j](v-b_i(1+r))\,dv \;-\; a^{-2}h_j'$$

$$+\; a^{-2}\int_{\hat{v}}^{\bar{v}} h_i' h_j'(v-b_i(1+r))\,dv \;+\; 2a^{-3}[a-h_i's_i]h_j'$$

The denominators of (31) and (32), are positive from the stability condition B>0. Upon inspection of terms (b) and (d) above, $P^i_{ib_j} = P^i_{ij}$ and $P^j_{jb_i} = P^j_{ji}$. Therefore, $\partial s_j^*/\partial b_j = P^j_{ji}[P^i_{ib_i} - P^i_{ii}]/B$ and

$$\partial s_i^*/\partial b_i + 1 \;=\; (P^i_{ij}P^j_{jb_i} - P^i_{ib_i}P^j_{jj})/B \;+\; (P^i_{ii}P^j_{jj} - P^i_{ij}P^j_{ji})/B$$

$$=\; P^i_{ij}[P^j_{jb_i} - P^j_{ji}]/B \;+\; P^j_{jj}[P^i_{ii} - P^i_{ib_i}]/B\;. \qquad (33)$$

Using $P^j_{jb_i} = P^j_{ji}$, the first term in (33) is zero, thus:

$$\partial s_i^*/\partial b_i + 1 \;=\; P_{jj}^{j}[P_{ii}^{i} - P_{ib_i}^{i}]/B. \tag{34}$$

From (a) and (c),

$$P_{ii}^{i} - P_{ib_i}^{i} \;=\; a^{-2}\int_{\hat{v}}^{\bar{v}} [h_i'(r+h_j)(1+r)dv + h_i']\,dv \;>\; 0. \tag{35}$$

Thus, with $B > 0$ and $P_{jj}^{j} < 0$,

$$\partial s_i^*/\partial b_i + 1 \;=\; P_{jj}^{j}[P_{ii}^{i} - P_{ib_i}^{i}]/B \;<\; 0,$$

which shows that a rise in debt causes total R&D expenditures to fall.

With $P_{ib_i}^{i} < P_{ii}^{i}$, $P_{ji}^{j} < 0$ and $B > 0$, the sign of $\partial s_j^*/\partial b_i$ depends on the value P_{ji}^{j}. As we saw from Lemma 2, equity values are strategic complements, thus $P_{ji}^{j} > 0$ and $\partial s_j^*/\partial b_i < 0$. Q.E.D.

VI. Proof of Theorem 4

Refer to (11). The first term of (11) represents the direct effect of debt, while the second term is the strategic effect and the last two terms are the equity cost savings effect. Evaluated at b_i=0, the first order-conditions in stage two (equation (8)) imply that:

$$\int_{\hat{v}}^{\bar{v}} h_i' v[r+h_j]\,dv \;=\; a - h_i' s_i \tag{36}$$

Using (36), the first term in (11) can be rewritten as:

$$a^{-2}\left(\frac{\partial s_i^*}{\partial b_i} + 1\right)[a - h_i' s_i^* + h_i' s_i^*]$$

which collapses to $(1/a)(\partial x_j^*/\partial b_i)+(1/a)$, producing:

$$Y^i_{b_i}|_{b_i=0} = (\frac{1}{a})(\frac{\partial s_i^*}{\partial b_i}) + \frac{1}{a} + (-a^{-2}) \frac{\partial h_i}{\partial s_j}(\frac{\partial s_j^*}{\partial b_i})[\int_{\underline{v}}^{\bar{v}} h_i v\,dv - s_i^*] - (\frac{1}{a})(\frac{\partial s_i^*}{\partial b_i}) + 1$$

$$= \frac{1}{a} + (-a^{-2}) \frac{\partial h_i}{\partial s_j}(\frac{\partial s_j^*}{\partial b_i})[\int_{\underline{v}}^{\bar{v}} h_i v\,dv - s_i^*].$$

Recalling that $a^{-2}>0$, $\partial h_j/\partial s_j>0$, $\int h_i(v-b_i(1+r)dv>s_i$, and $\partial s^*_i/\partial b_i<0$, the above term is positive; the marginal effect from the first dollar of debt is positive, thus some debt is used in equilibrium. Q.E.D.

VII. Proof of Theorem 5

To evaluate $P^i_{x_c}$ at x_n, we substitute the first-order conditions from the noncooperative case (2).

Rearranging terms and accounting for symmetry, we get in the noncooperative equilibrium

$$[r+2h]^2 = \int_{\hat{v}}^{\bar{v}} h'[v-b_n(1+r)][r+h]\,dv, \tag{37}$$

from which it follows that

$$P^i_{x_c}|_{x_c=x_n, b_c=b_n} = \int_{\hat{v}}^{\bar{v}} \frac{h'[r+2h] - 2h'h - h'[r+h]}{h'[r+h]}\,dv$$

$$= \int_{\hat{v}}^{\bar{v}} \frac{-h'h}{h'[r+h]}\,dv \quad <0. \tag{38}$$

Thus, evaluated at the noncooperative equilibrium, the collusive first-order conditions are negative; a cartel planner chooses less equity per firm than in the noncooperative case.

VIII. Proof of Theorem 6

We evaluate $Y^i_{b_c}$ at the noncooperative equilibrium level of debt by substituting from $Y^i_{b_i}=0$, the condition that defines the unconstrained noncooperative debt level. Using (5), rearranging terms, and accounting for symmetry gives

$$(x_n'+1) = a^{-2}\int_{\underline{v}}^{\bar{v}} [(r+h)vh'(x_n'+1)] - a^{-2}\int_{\underline{v}}^{\bar{v}} [h'x_n'hv]dv,$$

from which

$$Y^i_{b_c}|_{b_c=b_n, x_c=x_n} = -a^{-2}\int_{\underline{v}}^{\bar{v}} hvh'dv < 0. \tag{39}$$

Thus, a cartel planner would choose a lower level of debt for each firm than each firm would choose in competition. Of course, in the noncooperative equilibrium, the amount of debt taken is zero. However, if debt were taken for other reasons in the noncooperative equilibrium, the cartel planner would reduce the level of debt.

IX. Proof of Theorem 7

To evaluate $P^i_{s_c}$ at s_n, we substitute from the noncooperative first-order conditions (8). Referring to (8) and using symmetry,

$$\int_{\hat{v}}^{\bar{v}} h'[v-b_n(1+r)][r+h]\,dv = r+2h-hs_n, \tag{40}$$

from which we get

$$P^i_{s_c}|_{s_c=s_n, b_c=b_n} = h'(r+2h)^{-2}[x_n - \int_{\hat{v}}^{\bar{v}} h(v-b_n(1+r))dv] < 0 \tag{41}$$

because $\int h[v-b(1+r)]dv > s$. Thus, evaluated at the noncooperative equilibrium, the collusive first-order conditions are negative; a cartel planner chooses less equity-financed flow R&D per firm than in the noncooperative case.

X. Proof of Theorem 8.

We evaluate $Y^i_{b_c}$ at the noncooperative equilibrium level of debt by substituting from the noncooperative first-order condition (11). Accounting for symmetry and noting that $a^{-1}s' = a^{-2}x'[r+2h]$ implies

$$a^{-2}s_n'[r+2h] = a^{-2}h'(s_n'+1)\left[\int_{\underline{v}}^{\bar{v}} v(r+h)\,dv + s_n\right] - a^{-2}h's_n'\left[\int_{\underline{v}}^{\bar{v}} hv\,dv - s_n\right].$$

Substituting this and simplifying we get

$$Y^i_{b_c}\big|_{b_c=b_n, s_c=s_n} = a^{-2}h'\left[s_n - \int_{\underline{v}}^{\bar{v}} hv\,dv\right]$$

$$= a^{-2}\int_{\underline{v}}^{\bar{v}} h'hv\,dv + a^{-2}h's_n < 0$$

because the first term is negative given our earlier assumption that s < ∫hvdv, and the last term is also negative since (s'+1)<0 from the proof of Theorem 3. Thus, a cartel planner would choose a lower level of debt for each firm than each firm would choose in competition. Q.E.D.

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Endnotes

1. We take an approach similar to McAndrews and Nakamura (1993). In a competitive lending market, the market value of debt is equal to the risk-free rate (assumed to be zero) plus the expected value of the promised repayment in good states and recovery value in bad states. Suppressing arguments, the market value of debt is:

$$b_i \;=\; a^{-1}\int_{\hat{v}}^{\bar{v}} h(b_i(1+i))\,dv \;+\; a^{-1}\int_{\underline{v}}^{\hat{v}} hv\,dv$$

$$=\; b_i(1+i)\; a^{-1}\int_{\hat{v}}^{\bar{v}} h\,dv \;+\; a^{-1}\int_{\underline{v}}^{\hat{v}} hv\,dv$$

Solving for $b_i(1+r)$, we get the market value of repayment:

$$b_i(1+i) \;=\; \frac{b_i \;-\; a^{-1}\int_{\underline{v}}^{\hat{v}} hv\,dv}{a^{-1}\int_{\hat{v}}^{\bar{v}} h\,dv}$$

Now, suppose that the firm maximizes only equity value in the first stage:

$$P^{i}\,(x_i^*, x_j^*, b_i) \;=\; a^{-1}\int_{\hat{v}}^{\bar{v}} hv\,dv \;-\; b_i(1+i)\; a^{-1}\int_{\hat{v}}^{\bar{v}} hv\,dv \;-\; x_i$$

Substituting the market value of repayment $b_i(1+i)$ into the above equation, we get:

$$P^{i}\,(x_i^*, x_j^*, b_i) \;=\; a^{-1}\int_{\hat{v}}^{\bar{v}} hv\,dv \;-\; \frac{b_i - a^{-1}\int_{\underline{v}}^{\hat{v}} hv\,dv}{a^{-1}\int_{\hat{v}}^{\bar{v}} h\,dv}\; a^{-1}\int_{\hat{v}}^{\bar{v}} h\,dv \;-\; x_i$$

$$=\; a^{-1}\int_{\underline{v}}^{\bar{v}} hv\,dv \;-\; b_i \;-x_i$$

Thus, the firm's maximization of equity value under a competitive debt value is equivalent to the maximization of debt + equity value.

2. We are grateful to Mort Kamien for suggesting this interpretation to us.

3. Follows same logic as the fixed cost case.

4. We could assume the sufficient condition for uniqueness and stability of an equilibrium in this stage, but it is stronger than we need as we are interested only in guaranteeing the existence of an equilibrium with debt. Multiple equilibria with debt would not be a problem, as we do not consider comparative statics properties of this equilibrium. Indeed, it is possible in this case that $Y'_{b_i} > 0$ at F_i for any b_j, so the equilibrium is $(b_i,b_j) = (F_i,F_j)$.

Table 1: Debt Ratios for IPO Firms

Year of IPO	Number of firms	Average Debt as a Percentage of Assets in Previous Year
2001	87	33.41
2000	553	28.83
1999	636	44.78
1998	602	37.79
1997	577	62.61
1996	648	77.21
1995	432	40.76
1994	323	45.75
1993	381	39.94
1992	248	40.45

Table 2. Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
sic	2784	4677.755	1825.361	100	9997
count	2784	8.909	1.52	6	10
assets	2783	2098.088	11551.42	0.082	280971.5
DEBT	2773	24.205	23.184	0	99.531
LDEBT	2628	2.454	1.728	-6.546	44.600
LSIZE	2783	4.762	2.257	-2.501	12.546
LFIXED	2636	-1.759	0.855	-7.706	-0.024
LRISK	1913	-0.191	1.067	-5.336	7.855
SHIELD	2763	0.215	0.180	0	1.020

Table 3: Debt Ratios by Industry

SIC	Industry Description	Observations	mean debt
42	motor freight transportation	1	81.235
79	amusement and recreational services	21	61.228
45	air transportation	1	53.553
72	personal services	1	53.087
70	lodging	10	51.359
22	textile and mill products	6	48.541
21	tobacco products	4	42.25
32	stone, clay, glass and concrete	11	40.481
26	paper & allied products	29	39.08
54	food stores	18	38.205
24	lumber and wood products	6	35.756
30	rubber & miscellaneous products	35	35.171
51	wholesale trade: nondurable goods	39	34.817
58	eating and drinking establishments	69	34.784
37	transportation equipment	74	34.219
53	general merchandise and dept. stores	26	34.155
57	furniture and home furnishings stores	21	32.716
80	health services	56	32.7
34	primary metals and manufacturing	46	31.568
20	food and kindred spirits	36	31.43
59	miscellaneous retail trade	66	30.241
50	durable goods trade	78	30.201
48	multimedia communications	27	29.722
29	petroleum and coal manufacturing	15	29.491
52	building materials & garden supplies	12	28.08
25	furniture and fixtures	18	27.22
55	food stores	11	26.417
39	miscellaneous manufacturing	28	23.036
64	insurance	2	20.423
28	chemicals & allied products	315	19.606
27	printing and publishing	9	19.582
35	industrial machinery & equipment	302	18.765
23	apparel	6	18.639
87	engineering, mgmt, research & related products	40	17.927
36	electronic/electrical equip & components	336	17.487
56	apparel and accessory stores	46	16.318
38	instruments & related products	304	15.85
49	electric, gas and sanitary services	5	14.854

Table 4: R&D Intensity Across Industries

SIC	Industry Description	Observations	mean rd
26	paper & allied products	29	10.453
59	miscellaneous retail trade	66	3.78
62	security & commodity brokers	5	3.147
38	instruments & related products	304	2.457
57	furniture and home furnishings stores	21	1.176
37	transportation equipment	74	0.39
87	engineering, mgmt, research & related products	40	0.365
32	stone, clay, glass and concrete	11	0.325
53	general merchandise and dept. stores	26	0.221
34	primary metals and manufacturing	46	0.215
50	durable goods trade	78	0.202
31	leather products	2	0.16
30	rubber & miscellaneous products	35	0.137
23	apparel	6	0.125
79	amusement and recreational services	21	0.099
27	printing and publishing	9	0.087
78	motion pictures	5	0.087
35	industrial machinery & equipment	302	0.066
48	multimedia communications	27	0.061
39	miscellaneous manufacturing	28	0.058
51	wholesale trade: nondurable goods	39	0.049
80	health services	56	0.042
64	insurance	2	0.022
58	eating and drinking establishments	69	0.018
21	tobacco products	4	0.017
22	textile and mill products	6	0.014
24	lumber and wood products	6	0.013
42	motor freight transportation	1	0.0095
54	food stores	18	0.008
45	air transportation	1	0.0062
72	personal services	1	0.003
70	lodging	10	0.003
49	electric, gas and sanitary services	5	0.003
29	petroleum and coal manufacturing	15	0.0004
36	electronic/electrical equip & components	336	0.0004

Table 5. Descriptive Statistics - Debt Ratios

debt ratio	#Firms	Mean DEBT	Mean RDS
<10	1039	2.993	3.022
10-20	423	14.84	2.245
20-30	374	25.033	1.62
30-40	282	34.931	0.804
40-50	243	44.787	0.307
>50	412	67.08	0.151

Table 6. Descriptive Statistics - Concentration

concentration	#Firms	Mean DEBT	Mean RDS
<10	223	25.193	0.176
10-20	537	33.88	0.241
20-30	609	19.705	1.76
30-40	500	23.224	3.611
40-50	463	17.746	2.255
>50	607	24.586	1.718

Table 7. 2SLS Regression Results: RDS and LRDS as dependent variables (t-statistics in parentheses)

	RDS (1)	LRDS (2)
LDEBT		-.798 (-13.635)*
DEBT	-.0033 (-8.381)*	
LSIZE	.006 (3.016)	.107 (4.362)*
LCONC	.007 (1.289)	.027 (0.378)
constant	0.085 (4.588)*	-2.09 (7.662)*
obs	1700	1223
F	32.12	71.65

*significant at the 0.05 level

Table 8. 2SLS Regression Results: DEBT and LDEBT as dependent variables (t-statistics in parentheses)

	DEBT (1)	LDEBT (2)
LRDS		-.326 (-8.684)*
RDS	-33.044 (-7.343)*	
LPROFIT	-9.546 (-11.674)*	-0.493 (-6.746)*
LRISK	-7.687 (-10.012)*	-.365 (-5.191)*
LFIXED	3.928 (6.33)*	.565 (8.287)*
LDEM	2.402 (9.851)*	.155 (7.245)*
LCOS	2.909 (4.591)*	.133 (2.272)*
constant	9.313 (2.679)*	0.797 (2.49)*
obs	1762	1281
R-squared	0.22	0.29
F	84.29	88.61

*significant at the 0.05 level