Financing and Corporate Growth under Repeated Moral Hazard[1]

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Abstract

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We develop an incomplete contracts model to study the extent to which control rights of different financings affect corporate growth. The model admits a standard hold-up problem under equity financing; insiders may be disincentivized to do R&D because outside investors can use their control rights to expropriate large parts of the returns by hiring more efficient managers in the future. Debt financing may give rise to a double moral hazard problem; both managers and shareholders may divert corporate resources to themselves before debt is serviced. However, in many cases, these phenomena do not occur in equilibrium and control rights are irrelevant. Cross-sectional predictions are derived from those cases where control rights matter. Consistent with the empirical evidence, leverage is inversely related to growth and to profitability.

1 Introduction

There is evidence that financial contracting affects growth. For example, studies by Goldsmith (1969) and Rajan and Zingales (1998) provide evidence that financial development stimulates economy-wide growth.[1] At the corporate level, Lang, Ofek, and Stulz (1996) find that firms with high growth rates have less leverage than slower growing firms. Possible explanations include the ideas that debt reduces overinvestment by reducing the agency costs of free cash flows [Jensen (1986)] and that debt inhibits investments due to the debt overhang problem [Myers (1977)].

In this paper, we study an alternative link between financing and corporate growth. We develop the idea that financial contracts may affect corporate growth through the way they allocate control rights *over time* i.e., between agents who make strategic decisions at one phase in the life of the corporation and those agents who will be in control at a later stage of life of the firm. The agency problem between outside investors and insiders will evolve as growth opportunities appear and disappear and as senior management changes are made. Alternative financial structures may have very different implications for investment decisions confronted by the firm at different points of its history.[2]

Probably the simplest and most wide-spread example of how the allocation of control rights over time arises is the case of the classic start-up firm that begins life with an initial growth opportunity developed by an entrepreneur but which in time gives rise to an opportunity for further growth that would require bringing new techniques *and new managerial expertise* into the firm. It is precisely this case that we analyse in the two-stage growth model we explore in detail in this paper. However, the same sorts of problems will arise repeatedly for mature firms where changing technology and market environment will create growth opportunities that may make the interests of incumbents and investors diverge.

Our model traces a firm from an R&D phase through a capital investment phase and on to a production stage where cash flows are generated. A key feature is that at some point the firm will be confronted by a growth opportunity which would require the replacement of

[1] See Levine (2005) for an overview.

[2] Empirical evidence that the distribution of control rights is an important consideration behind the choice of financing in some cases is provided by Kaplan and Strömberg (2001).

the original insider by new management if the expanded firm is to be operated efficiently. The model thus incorporates two key stages of growth: the initial R&D stage and the entrepreneurial replacement stage. One can view the incumbent manager literally as an entrepreneur whose expertise lies in developing ideas. Alternatively, the 'entrepreneur' may represent a manager whose skills may be outdated and is unable to take the firm to a higher technological level.

To focus on control rights, the model is cast in an incomplete contracts framework along the lines of Bolton and Scharfstein (1990, 1996) and Hart and Moore (1998) where cash flows are noncontractible.[3] Thus, the model incorporates agency costs along the lines of Jensen and Meckling (1976) and Jensen (1986); whoever runs the firm has the ability to divert cash flows to themselves. An important implication is that if the entrepreneur is replaced, he suffers a loss of private benefits and therefore a potential reduction in the return to his R&D efforts.

In a noncontractible cash flows framework, Fluck (1998) has already established an important property of outside equity contracts which give insiders effective control over short-term decisions in the firm. She shows that outside equity financing is only feasible in an infinite (or uncertain) horizon model in the sense that in a finite horizon model the only subgame perfect equilibrium involves insiders stealing all available cash flows every period. In an infinite horizon setting there is a tradeoff for managers between short term gains from retaining current cash flows on the one hand and the long term benefits from continued employment, on the other [see also Myers (2000)]. Thus in an infinite horizon model the equilibrium serves to mitigate the adverse effects for outside investors of ceding control to insiders in an equity contract.

We adopt the basic Fluck/Myers infinite horizon setup, but modify it to allow explicitly for two growth opportunities by introducing the R&D and the entrepreneurial replacement stages. The novel feature of our analysis is the analysis of second stage growth and its link with first stage growth. Our main focus is on whether debt and equity financing impact differently on growth, at either the R&D or the entrepreneurial replacement stages, because of differences in control rights. While equity grants investors unconditional control rights, debt grants them control only in the case of default. This matters because the party with

[3]Zender (1991) develops a model with a mixture of contractible and noncontractible cash flows.

control decides whether or not to replace the entrepreneur.

Under equity financing, there may be a hold-up problem. Specifically, shareholders may be able to use their unconditional control rights to extract rents from the initial R&D efforts of the entrepreneur by replacing him with a more efficient outside manager at a later stage.[4] For this reason, an entrepreneur may prefer debt financing as this allows him to retain control over the replacement decision.[5] This may feed back into his incentive to do R&D. Thus, debt and equity financing *may* impact differently on growth because of differences in control rights. We show that the extent to which there is a hold-up problem under equity financing depends on the equilibrium fraction of cash flows that are paid out following the second stage of growth. At that stage the model is essentially a repeated game and many equilibrium outcomes are possible. The equilibrium that emerges may be a function of what might be broadly considered the quality of corporate governance which may depend upon legal environment or internal organization. If 'corporate governance' in the mature firm is good and pay outs are high, then equity financing may not deter the entrepreneur from undertaking the initial R&D growth phase.

We also identify a potential drawback to debt financing, namely that it may give rise to a double moral hazard problem, where both an outside manager and the entrepreneur may have access to the firm's cash flows before debt is serviced. This turns out to be an issue for projects that are relatively marginal, where yields under entrepreneurial management would not cover the cost of capital. We show that double moral hazard and the hold-up problem never come into play simultaneously.

The hold-up problem under equity financing has been emphasized previously by Burkart, Gromb, and Panunzi (1997). These authors develop a model where increased monitoring by a large shareholder reduces management's scope for consuming private benefits, with the result that managers also put in less effort towards identifying good projects. Burkart et al's main focus is on the relation between ownership concentration and the level of monitoring and managerial effort. With respect to the hold-up problem, our model differs

[4]The hold-up problem has been studied in other contexts by, for example, Goldberg (1976), Klein et al (1978), Grossman and Hart (1986), Hart and Moore (1990), Berkovitch, Israel, and Zender (1998), among others. See Hart (1995) for an overview.

[5]That debt may facilitate entrenchment of the incumbent has been stressed, for example, by Stulz (1988), Harris and Raviv (1988), and Zwiebel (1996).

on two key counts: First, in our model ownership concentration plays no role; shareholders are assumed always to be sufficiently coordinated to make use of their control rights. Second, in our model the hold-up problem is endogenous; it is not necessarily an equilibrium phenomenon. When it is not, the choice of financing tends to be unimportant.[6] When it is, debt is preferred.[7]

The endogeneity of the hold-up problem under equity financing in our model is linked to the endogeneity of the entrepreneur's shareholdings. Since investors only need to break even, if the entrepreneur is replaced by an outside manager and dividends subsequently increase, the entrepreneur's equilibrium equity stake may increase. Higher dividends and an increased equity stake may offset the entrepreneur's loss of private benefits. Thus the future replacement of the entrepreneur may actually increase his incentive to do R&D rather than reduce it.

The main contribution of our approach is to emphasize a dimension of the debt/equity choice that is somewhat different than those emphasized in either static trade-off or pecking order theories. The theme that emerges here is that debt favors effort and growth at relatively early stages of the firm whereas equity facilitates growth at later stages. This is a simplification. Indeed, the model also shows clearly that in many cases the trade-off is not decisive– either debt finance or equity will give rise to the same outcome in equilibrium. Furthermore, we cannot claim that the insight is completely original. At its heart, the trade off in our model turns on the conflict between *ex ante* and *ex post* incentives. A similar conflict is present in Burkart *et al* (1997) as just discussed. It is present also in Myers' (2000) where he views private equity combined with outside equity following an IPO as needed to induce R&D activity. Here we emphasize a point that has not been stressed in past literature. We show that early stage growth is achieved through the simple and natural expedient of debt finance. The implications of this are profound and, we feel, widely observed. As a consequence of choosing a financial structure that favors early stage growth there is a tendency for firms to get stuck on a low trajectory

[6]Strictly, if there is no hold-up problem and the double moral hazard problem is negligible then the financing choice is irrelevant

[7]There is no hold-up problem with long-term debt. Rajan (1992) shows that a hold-up problem can arise under short term debt if the entrepreneur is locked into a relationship with a particular creditor. See also von Thadden (1995).

growth path.

This analysis delivers a number of testable implications for which there is some support in the empirical literature. First, leverage in firms controlled by original owners will tend to be higher than in firms controlled by outside managers. This is because when debt is used to get around the hold-up problem, second stage growth fails to materialize. In particular, in a cross-section we would expect to see a preponderance of relatively highly levered firms that have stagnated after an initial growth spurt. This is consistent with the empirical observation that debt finance dominates among smaller firms.[8]

Second, there is an inverse relation between profitability and leverage. This is consistent with the empirical evidence (Kester (1986), Rajan and Zingales (1995), Fama and French (2002)). This relation occurs in our model because debt is preferred when profitability is relatively low. This contrasts with the usual interpretation that high debt levels stifle profitability.

In addition to these predictions our model suggests that the use of leverage is related to the effectiveness of corporate governance. There are two angles to this point. First, in the basic setup with a static financing strategy, debt has an advantage when corporate governance is at an intermediate level since this is when the hold-up problem is an issue under equity financing. Second, we show that unless agency costs are at their minimum level (corporate governance is at the maximum), efficiency can be improved through a dynamic financing strategy where debt is issued in stages. After an initial financing by debt, there is an LBO, where outside managers borrow capital to buy out the entrepreneur. Done correctly, this achieves the minimum level of agency costs, including the elimination of the hold-up problem with equity and the double moral hazard problem with debt.

The rest of the paper is organized as follows. Section 2 describes the model. Section 3 contains the analysis under equity financing. Section 4 considers debt financing. Section 5 compares debt versus equity and draws out some empirical implications. Section 6 studies the dynamic financing strategy mentioned above and other extensions. For example, we explore different models of formal bankruptcy and find that the thrust of the conclusions from the basic model are robust. Section 7 concludes. An appendix contains proofs not presented in the text.

[8] *Finance for Small Firms – An Eighth Report*, Bank of England, March 2001.

2 The Model

There are three sets of players; an entrepreneur, outside managers, and investors. There are an infinite number of periods, indexed by t. All parameter values are common knowledge and cash flows are noncontractible.

As described in the Introduction the technology involves an R&D stage where an entrepreneur develops an initial growth opportunity, a capital investment stage, and a second-stage growth opportunity when the firm can increase its profitability by implementing a change of management. We implement this parametrically by assuming that at time $t = 0$, the entrepreneur decides whether to develop a product idea by undertaking R&D, at a cost of K, to be financed entirely by the entrepreneur himself. K can be thought of as the value of "effort", a monetary amount, or an opportunity cost. Following R&D, the entrepreneur needs outside funds to make the necessary capital investments, which cost I, to realize the product idea. We assume that neither R&D nor investment take time so that financing and capital investments, if any, also take place at time $t = 0$. If capital investments are made, a cash flow π_1 is produced at time $t = 0$. Every period thereafter a cash flow π_1 is produced as long as the entrepreneur manages the firm. The firm can be liquidated at any date, with the liquidation value being $L \leq I$.

At dates $t \geq 1$ it is possible to replace the incumbent manager with an alternative, outside manager. If an outside managers is put in charge of the firm, a cash flow of $\pi_2 > \pi_1$ is produced. There is an infinitely deep pool of identical outside managers. Outside managers are distinct from the initial investors.

In this formulation, we have made a number of simplifying assumptions for notational convenience that could easily be relaxed. Introducing a delay between the time when R&D costs are sunk and the capital investment is undertaken would simply add an additional discount factor in some formulae. The outcome of the R&D process could be made stochastic with no qualitative change in results. Similarly, the time elapsed between the capital investment and the arrival of the second stage growth opportunity could be increased to some, possibly stochastic, date N. The only important assumption to be maintained is that arrival of the second stage growth opportunity is not affected by the entrepreneur's actions nor by the allocation of the cash flows while the entrepreneur is running the firm. Finally, while we are casting the model in terms of a startup where efforts towards R&D

need to be taken by an entrepreneur, one could adapt the model to apply to a firm that is already up and running under a shareholding incumbent manager. The firm could be producing cash flows of π_0 under the incumbent manager, which would grow to π_1 if he put in an effort of K towards R&D and a further π_2 if the incumbent were replaced. We are essentially analyzing the special case that the current manager owns all shares (before raising capital) and $\pi_0 = 0$. The more general case would add some complexity, but the same basic economic forces would be at work.

Also for simplicity, we assume that managers (including the entrepreneur) do not draw any salary. Their compensation is therefore completely determined by the portion of the cash flows they do not report to investors (i.e. their perk consumption). Managers are assumed to having no money initially so that shareholders cannot require newly engaged managers to pay for the right to extract perks in the future.

Whether or not the entrepreneur is replaced by an outside manager depends on the entrepreneur's actions and those of investors. The set of actions available to investors depend on how the entrepreneur has financed the capital investment. We consider equity and debt financing.

Equity financing

Investors require shares worth I. Denote the corresponding fraction of the shares by $1-\gamma$. So the entrepreneur's fraction is γ. All shares have the same dividend rights. Control is given to investors (the entrepreneur's shares can be viewed as non-voting).[9] After the cash flow π_1 is produced at date 0, the entrepreneur must decide on the initial dividend. Denote this by $y_{10}\pi_1$, where $y_{10} \in [0, 1]$ is the payout ratio. Cash not paid out is consumed by the entrepreneur.

From date 1 onwards, the following stage game takes place until the firm is liquidated (which may be never): Investors have the first move, which is to choose[10]

$$s_t \in \{retain, replace, liquidate\}. \quad (1)$$

That is, investors decide whether to *retain* the incumbent manager (who at first is the entrepreneur), *replace* the incumbent manager and continue with a new manager, or *liq-*

[9] If the entrepreneur has control, equity cannot be raised because of the non-contractibility of cash flows.

[10] Shareholders are assumed to be coordinated. This can be motivated by there being few of them or by shareholders choosing a board of directors that acts in their interest.

uidate the firm. In case of liquidation, the game ends, shareholders receive the liquidation value L, and managers receive nothing.[11] If the firm is not liquidated, the cash flow π_i is produced, where $i = 1$ denotes the entrepreneur and $i = 2$ denotes an outside manager. Next, the manager who is in charge decides the payout ratio, $y_{it} \in [0, 1]$.[12] In other words, the reported cash flow is $y_{it}\pi_i$. Shareholders receive this as a dividend and the manager in charge consumes $(1 - y_{it})\pi_i$ (plus, in the case the entrepreneur, his share of the dividends).

Debt financing

We focus on perpetual debt with a face value of I issued at par and with coupons of d_t, $t = 0, \ldots \infty$. The entrepreneur is the sole shareholder. In an extension in Section 6, we allow for the possibility that the entrepreneur may sell his shares. As long as debt is serviced in full, creditors have no rights to replace the manager or liquidate the firm.

The stage game each period is the same as for equity financing, with the following modifications: After the cash flow is produced, the manager in charge reports a cash flow of $y_{it}\pi_i$ to the entrepreneur (as shareholder) who, in turn, decides whether to service the debt or default. The manager consumes the non-reported portion of the cash flow. After debt has been serviced, the remaining cash flows goes to the entrepreneur. If an outside manager has not been appointed, this sequence of moves collapses to the entrepreneur deciding whether to service the debt. If the entrepreneur defaults, the firm is liquidated, creditors collect L, and shareholders (the entrepreneur) get nothing. Other models of debt are considered in Section 6.

Strategies and Payoffs

Pure strategies are deterministic functions mapping the history of the game into the decision sets described above. Players discount cash flow at the rate r and seek to maximize the discounted value of cash flows that would accrue to them. We focus on subgame perfect Nash equilibria in pure strategies. Since once an outside manager has been appointed the model is a repeated game, we restrict our attention to stationary strategies, $y_{2t} = y_2$ and $s_t = s$ for all t.

First Best

To serve as benchmarks, we write down the first best outcomes at the different stages of

[11] So the entrepreneur would receive γL, since he is also a shareholder.

[12] In equilibrium (see below), outside managers use the same payout ratios. For notational simplicity, we therefore do not distinguish between different outside managers.

the model. First best involves replacing the entrepreneur at date 1, since $\pi_1 < \pi_2$, and investing in R&D and capital when these have positive NPV. Assuming that the present value of the cash flows generated by an outside manager exceeds the liquidation value,

$$\frac{1+r}{r}\pi_2 \geq L, \tag{2}$$

the capital investment has positive NPV if

$$-I + \pi_1 + \frac{\pi_2}{r} \geq 0, \tag{3}$$

and the R&D stage investment has positive positive NPV if

$$-K - I + \pi_1 + \frac{\pi_2}{r} \geq 0. \tag{4}$$

These conditions can be recast in terms of discount rates. (2) implies that if an outside manager is appointed, it is first best to keep the firm alive if

$$r \leq \frac{\pi_2}{L - \pi_2}. \tag{5}$$

The right hand side is the perpetual yield on the project, viewing L as the opportunity cost of keeping the firm alive.

(3) says that it is first best to invest in plant and machinery if

$$r \leq \frac{\pi_2}{I - \pi_1} \tag{6}$$

If the firm cannot be kept alive under an outside manager because moral hazard is too large, it may be run by the entrepreneur. Assuming that the present value of the cash flows generated by the entrepreneur exceeds the liquidation value it is now optimal to make the capital investment if

$$r \leq \phi \equiv \frac{\pi_1}{I - \pi_1}. \tag{7}$$

The parameter ϕ is the yield on the project under the entrepreneur. Corresponding formulas for the R&D stage can be found by replacing I in (6) and (7) by $I + K$.

3 Equity Financing

In this section we analyze equilibria with equity financing. We proceed recursively starting with the subgame where the firm is being run by an outside manager. We then study how the level of managerial moral hazard impacts on the entrepreneurial replacement decision and, in turn, on investors' willingness to provide financing and the entrepreneur's decision to do R&D.

3.1 Managerial Moral Hazard: Subgame where Outside Manager Runs Firm

Our analysis starts at the beginning of a period, where investors decide whether to liquidate the firm or keep it going. The following lemma establishes a necessary condition for going concern equilibria. Define

$$r^* \equiv \frac{\pi_2}{L}. \tag{8}$$

Lemma 1 *Suppose an outside manager runs the firm. A subgame perfect equilibrium in which the firm is maintained as a going concern in perpetuity exists only if* $r \leq r^*$.

The proofs of this and other propositions to follow are given in Appendix 1. The intuition behind this result is that if $r > r^*$ then the proceeds from immediate liquidation of the firm exceed the value of a perpetual payment of π_2 commencing in one period. The latter amount is the maximum possible that investors can hope to earn from a going concern since any outside manager must obtain present and future compensation worth at least π_2 the amount he would obtain by stealing one period's cash flow.

It follows from this lemma that first best cannot always be attained in equilibria. Specifically if $r \in (r^*, \pi_2/(L - \pi_2))$ it is optimal to keep the firm going, but this is not possible in equilibrium.

The following lemma shows that when the feasibility condition in Lemma 1 holds, there will be a range of possible going concern equilibria.

Lemma 2 *Suppose* $r \leq r^*$. *Consider a payout rate* y_2^* *satisfying*

$$\frac{rL}{(1+r)\pi_2} \leq y_2^* \leq \frac{1}{1+r} \tag{9}$$

Then the following is an equilibrium: For every t, *(a) when he is in charge, every manager uses the payout ratio* $y_2 = y_2^*$ *and (b) shareholders play*

$$s = \begin{cases} \textit{retain} & \textit{if } y_2 \geq y_2^* \\ \textit{replace} & \textit{if } y_2 < y_2^*. \end{cases} \tag{10}$$

There is a continuum of these stationary going concern equilibria, indexed by the payout ratio y_2. The range of equilibrium payout ratios, (9), can be understood by looking at the two incentive compatibility constraints of the players.

First, if shareholders believe that they will receive a dividend of $y_2\pi_2$ in every period as long as the firm is maintained as a going concern, they will not liquidate if and only if

$$y_2\pi_2\frac{1+r}{r} \geq L. \tag{11}$$

This can be rearranged to form the left hand side of (9).

Second, if the manager believes that he will be retained for as long as he pays out the fraction y_2, his choice is between receiving a perpetuity of $(1-y_2)\pi_2$, starting this period, or taking out π_2 and then being fired. Thus the manager pays out $y_2\pi_2$ if and only if

$$(1-y_2)\pi_2\frac{1+r}{r} \geq \pi_2. \tag{12}$$

This can be rearranged to form the right hand side of (9).

Investors' incentive compatibility constraint, LHS(9), is increasing in r and imposes a lower bound on y_2. The manager's incentive compatibility constraint, RHS(9), is decreasing in r and imposes an upper bound on y_2. This contrast reflects the conflicting objectives of investors and the manager. Equating the left and right hand sides of (9) confirms that the two incentive compatibility constraints can be simultaneously satisfied if and only if $r \leq r^*$.

Our analysis does not pinpoint a specific equilibrium; there is a range of equilibrium y_2's which support the firm as a going concern. We may think of the particular y_2 that obtains as being influenced by the firm's internal governance [Gompers, Ishii, and Metrick (2003)] and also the quality of shareholders' rights prevailing in the legal environment where the firm operates. The idea is that the more effective is corporate governance, the smaller is the level of managerial moral hazard and the larger is the payout rate. Thus y_2 could be interpreted as an index of the effectiveness of corporate governance.[13] The case that y_2 satisfies the manager's incentive compatibility condition (9) with equality, is the case of maximum corporate governance, or minimum managerial moral hazard.[14]

[13]In a recent paper, Fulghieri and Suominen (2006) postulate a similar connection between governance and cash flow diversion.

[14]The stationary going concern equilibria that we study are natural to focus on since the model at this point is stationary and since outside managers are fundamentally identical. Going concern equilibria with

Finally we note that there is also an equilibrium leading to liquidation. Specifically, if investors always liquidate then a best response for the manager is to pay out nothing, and *vice versa*.

3.2 The Replacement Decision

Next we consider the game at a point where the entrepreneur is in charge and shareholders must decide whether to liquidate, retain the entrepreneur, or replace him with an outside manager. Our discussion focuses on going concern equilibria where the payout rate of outside managers, y_2, satisfies (9). The case that the firm would be liquidated under an outside manager is covered in Theorem 1 below.

If shareholders believe that the entrepreneur will always match the dividends they expect from an outside manager, they will have no incentive to replace the entrepreneur.[15] On the other hand, the entrepreneur has no incentive to pay dividends in excess of what would be paid by an outside manager. So to be retained, the entrepreneur must have a strategy of paying a periodic dividend of

$$y_1\pi_1 = y_2\pi_2. \tag{13}$$

If outside managers' payout ratio is so large that $y_2\pi_2 > \pi_1$, it is impossible for the entrepreneur to match dividends. Shareholders understand this and therefore replace the entrepreneur. In this case, the entrepreneur consumes the entire date 0 cash flow, π_1, and is replaced at date 1.

If the entrepreneur is able to match dividends, stationarity implies that if he prefers to do so once, he prefers to do so every period. On the other hand, if the entrepreneur anticipates being replaced, his best action is to consume all current cash flows. Hence, if $\pi_1 > y_2\pi_2$, the entrepreneur matches dividends if and only if

$$(1-y_1)\pi_1\frac{1+r}{r} + \gamma y_1\pi_1\frac{1+r}{r} \geq \pi_1 + \gamma y_2\frac{\pi_2}{r}, \tag{14}$$

time variant strategies are also possible. However, if there is a going concern equilibrium where outside managers use time variant payout ratios, there is an equilibrium in time invariant strategies which is payoff equivalent. A proof is available upon request.

[15]While one can construct equilibria where the entrepreneur must pay more in dividends than an outsider manager in order to be retained, we do not believe these equilibria are very reasonable.

where γ is the entrepreneur's shareholding. The left hand side of (14) is the present value of cash flows to the entrepreneur if he matches. The right hand side is the current cash flow, π_1, plus the present value of the future equilibrium dividends the entrepreneur collects under an outside manager. By substituting (13) into (14), we get

$$y_2 \leq \frac{\pi_1}{\pi_2[1 + (1 - \gamma)r]}. \tag{15}$$

The entrepreneur matches dividends and is retained if this holds. If the inequality is reversed, the entrepreneur consumes π_1 and is immediately replaced.

This discussion can be summarized as follows. Under equity finance assuming the firm is not liquidated immediately, from date 1 onward there will be a stationary equilibrium which will be one of two types. If y_2 is sufficiently high, i.e., managerial moral hazard is low, then a *managerial equilibrium* will hold, and an outside manager operates the firm. Each period he pays out $y_2\pi_2$ in dividends and consumes $(1 - y_2)\pi_2$ in perks. Otherwise, if managerial moral hazard is high, an *entrepreneurial equilibrium* holds in which the entrepreneur retains control of the firm but pays out a dividend in each period sufficient to match $y_2\pi_2$. In managerial equilibria one condition required for optimality always holds, namely, the entrepreneur is replaced as soon as possible. However, in these equilibria the total payout to investors will be depressed for two reasons: First, the entrepreneur initially diverts π_1 to himself. Second, incentive compatibility implies that the outside manager will divert cash flows to himself with a present value equal to one period's cash flow, π_2. In contrast entrepreneurial equilibria do not achieve first-best optimality because the more efficient outside manager is never put in charge. However, since in period 0 a dividend of $y_2\pi_2$ is paid in an entrepreneurial equilibrium whereas in managerial equilibria it is not, the total value of total payout to investors is greater than would be the case under managerial equilibria. This will work in favor of promoting an initial capital investment. This is an example of the trade-off between *ex ante* and *ex post* optimality mentioned in the introduction. We now develop this issue further by turning to the capital investment and R&D decisions.

3.3 Initial Stage Finance, R&D and the Hold-up Problem

To complete the analysis of equity finance, we now consider the IPO/capital investment decision and then the earlier R&D decision. The two cases to be considered are those when following the IPO a managerial equilibrium would prevail and those that would give rise to an entrepreneurial equilibrium.

In the managerial equilibrium case the entrepreneur does not match dividends, investors replace him at date 1 after which they receive dividends of $y_2\pi_2$ each period. In this case the IPO is feasible if the total value of equity at date 0 is at least as great as the cost of the capital investment,

$$\frac{y_2\pi_2}{r} \geq I \tag{16}$$

In this case the share of the firm retained by the entrepreneur is,

$$\gamma_m = 1 - \frac{rI}{y_2\pi_2}. \tag{17}$$

Turning to the entrepreneur's R&D decision, the total value of the project for him consists of the entire cash flow when he is initially in control plus the value of his share of the dividends once he is replaced. He will undertake R&D when this is at least as great as the costs of doing so,

$$\pi_1 + \gamma_m \frac{y_2\pi_2}{r} \geq K \tag{18}$$

This development shows that even though a firm has an attractive long-term growth opportunity, i.e., $\frac{\pi_2}{\pi_1}$ is large, there are important impediments which potentially stand in the way of ever being able to implement this opportunity. First, as already noted from the previous section the moral hazard involved in employing outside managers ($y_2 < 1$) tends to depress equity values. Second, the loss of dividends π_1 to an insufficiently incentivized entrepreneur at initial stages also depresses equity values. For these two reasons an IPO might fail. However, even if an IPO is feasible, first-stage growth may fail because the combination of early stage perk consumption plus his subsequent dividend payments are insufficient to cover the entrepreneur's R&D costs. For example, consider the case where $K > 0$, $\gamma_m = 0$ and $\pi_1 = 0$. Somewhat more generally good long-term projects will fail at the R&D stage if the entrepreneur is relatively unproductive during the phase of the project when he is in charge and if the share of the firm that he retains is not very large. In short, failure to invest in initial stage growth may occur because later stage growth would give rise to too much extraction of rents by managers at the expense of investors and the entrepreneur.

We now turn to the case where following an IPO an entrepreneurial equilibrium holds. Assuming that an outside manager could be viable (i.e., investors would not liquidate), the entrepreneur must match dividends, $y_2\pi_2$, in every period, starting at date 0. In this case the IPO will be feasible if,

$$y_2\pi_2\frac{1+r}{r} \geq I \tag{19}$$

and, the entrepreneur's shareholding is

$$\gamma_e = 1 - \frac{rI}{y_2\pi_2(1+r)}. \tag{20}$$

These developments allow us to see one of the somewhat surprising implications of this model, namely, that an increase in managerial moral hazard may be attractive for IPO investors. As a result it may be conducive to early stage growth, but this will come at the cost of foregoing later stage growth prospects. The reason is that higher moral hazard leading to lower managerial payout rates may mean that an entrepreneurial equilibrium would arise after an IPO. To see this first recall that from relation (15), all else equal, a reduction in payout rates by potential outside managers will favor entrepreneurial equilibrium. Next, comparing the LHS of (16) with that of (19) we see that for a given y_2 the total value of equity at the IPO stage is greater under entrepreneurial equilibrium than under managerial equilibria for the reason that no dividends are paid in the latter case during the initial phase of entrepreneurial control. As a consequence, starting from a case where y_2 is such that it would give rise to managerial equilibria and an IPO would be infeasible, a reduction in this pay out rate could mean that then an entrepreneurial equilibrium would prevail and an IPO then becomes feasible. But in this case second stage growth never takes place.[16]

Finally, the analysis of the R&D decision is straightforward when it is anticipated that an entrepreneurial equilibrium will prevail following an IPO. For in this case the value of the entrepreneur's perk consumption plus his share of the the dividends paid out will equal the total value of the cash flows produced less the value of dividends to outside investors,

$$\pi_1\frac{1+r}{r} - I \tag{21}$$

So R&D will take place any time this is as at least as great as the cost, K. Stated otherwise, when an IPO followed by entrepreneurial equilibrium is feasible, the only inefficiency that

[16]It should be noted that for given y_2, $\gamma_e > \gamma_m$. As a consequence there will be a small range of y_2 for which both managerial and entrepreneurial equilibria are sustainable post-IPO. In light of their different implications for IPO proceeds, it may that either, neither, or only entrepreneurial equilibria will give rise to a feasible IPO, depending upon the particular configuration of deep parameters, π_1,π_2, r, and I.

occurs is that second stage growth never takes place. There is no inefficiency associated with the R&D decision as such.

This discussion can be summarized in terms of the range of costs of capital, r, for which IPO's will be feasible under managerial or entrepreneurial equilibria. Since negative shareholdings are not possible, (17) means that in a managerial equilibrium, we must have

$$y_2 \geq \frac{rI}{\pi_2}, \tag{22}$$

Combining this with the upper bound in (9) shows that the largest discount rate for which financing can be provided at date 0, r_m^*, satisfies

$$r_m^*(1+r_m^*) \equiv \frac{\pi_2}{I}. \tag{23}$$

In an entrepreneurial equilibrium, (20) implies that we must havef

$$y_2 \geq \frac{rI}{(1+r)\pi_2}. \tag{24}$$

Combining this with the matching condition (15), we get that the threshold discount rate is

$$r_e^* \equiv \pi_1/I. \tag{25}$$

This may be smaller or larger than r_m^*, depending on the relation between π_1 and π_2. However, r_e^* is less than the yield on the project under the entrepreneur, ϕ [see (7)].

Collecting all these developments on equity finance we have (see the appendix for a completion of the proof):

Theorem 1

1. *Suppose that if the entrepreneur is replaced outside managers and shareholders play a going concern equilibrium with a payout ratio of y_2 satisfying (9), as described in Lemma 2. In the subgame that starts with the financing decision at date 0, there are two types of equilibria where equity financing can be raised:*

   (a) In a managerial equilibrium, the entrepreneur pays no dividend at date 0 and is replaced at date 1. The new manager pays a dividend of $y_2\pi_2$ and is retained in perpetuity. Such equilibria exist if and only if (i) $r \leq r_m^*$, and (ii) y_2 also satisfies

$$y_2 \geq \frac{\pi_1}{\pi_2} - \frac{r^2 I}{\pi_2}. \tag{26}$$

(b) *In an entrepreneurial equilibrium, the entrepreneur pays a dividend of* $y_1\pi_1 = y_2\pi_2$ *every period and is retained in perpetuity. Such equilibria exist if and only if (i)* $r \leq r_e^*$*, and (ii)* y_2 *also satisfies*

$$y_2 \leq \frac{\pi_1}{\pi_2} - \frac{r^2 I}{(1+r)\pi_2}. \tag{27}$$

2. *Suppose that the above conditions are not met or that the firm would be liquidated if an outside manager were appointed. There is an equilibrium where financing can be raised if and only if* $r \leq r_e^*$*.*

The theorem shows that underinvestment is more severe than just what managerial moral hazard would suggest. In particular, Part 1 of the theorem shows that there are scenarios where financing cannot be raised even though the entrepreneur is able to match dividends, that is $\pi_1 \geq y_2\pi$, and r is less than the threshold discount rates, r_e^* or r_m^*. In particular, (26) and (27) show that it is not possible to raise financing when the cash flow that would be reported by an outside manager, $y_2\pi_2$, is "slightly" less than the cash flow generated under the entrepreneur, π_1, and the discount rate is sufficiently high.

The source of this problem can be traced back to the matching condition (15), which shows that the entrepreneur optimally chooses not to match dividends in some cases when he is able to. As an example, suppose that $y_2\pi_2 = \pi_1 - \varepsilon$, where $\varepsilon > 0$ is arbitrarily small. In this case, matching dividends would squeeze the entrepreneur's perk consumption towards zero. Hence, he prefers paying no dividends at date 0 and being replaced at date 1 over matching dividends. While replacing the entrepreneur is always first best, when $y_2\pi_2 < \pi_1$ it reduces the total pie available to investors and the entrepreneur and thus also the incentives to invest in capital and R&D. This is the hold-up problem; the entrepreneur would be better off here if investors could commit not to replace him or if outside managers put less pressure on the entrepreneur through having a lower payout rate, y_2.

Theorem 1 also shows that as the cost of capital, r, increases, underinvestment prevails for an increasing range of y_2's. Intuitively, the hold-up problem becomes more severe because the entrepreneur's shareholdings are decreasing in r. Thus, the entrepreneur's preferences become less congruent with those of investors. In other words, as projects become more marginal (NPV closer to zero), the conflict of interest between the entrepreneur and investors grows.

Figure 1 puts the two parts of the theorem together by showing the various constraints that determine the combinations of r and y_2 for which equity financing can be raised in an entrepreneurial or managerial equilibrium. Referring to the figure, the shaded areas show combinations for which financing can be raised and the nonshaded areas show combinations for which financing cannot be raised. Managerial equilibria obtain for high managerial payout ratios, and entrepreneurial equilibria hold for low payout rates. Specifically, the firm can be financed by equity and operate under outside management after second stage growth for combinations of discount rates and payout rates lying below line a and above max[line f, line c]. The firm can be financed by equity and operate under the control of the entrepreneur for payout rates below line e and for discount rates less than r_e^*.[17]

Figure 1 can be used to illustrate how inefficient replacement at date 1 feeds back to a failure to finance the firm at date 0. This inefficiency arises in the non-shaded triangular region which is bounded below by line e, above by c and to the right by r_e^*. In this region, equity financing could be raised if investors could commit not to replace the entrepreneur. But equity investors' unconditional control rights renders such a hands off policy not credible. Thus at date 1, the hold-up problem leads to underinvestment at date 0 for marginal projects (high r) where $y_2\pi_2$ is "slightly" less than π_1.

Finally, if the firm cannot be maintained as a going concern under an outside manager, Theorem 1 (Part 2) shows that it is still possible to raise equity financing, since it may still be possible to run the firm under the entrepreneur. However, there is also a liquidiation equilibrium where the firm could not be maintained as a going concern under either outside

[17] Figure 1 is drawn under the assumption that $L = I$ and the condition that π_2 is so much larger than π_1 that $r_m^* > r_e^*$. Note that $r_m^* > r_e^*$ if and only if $(1 + \pi_1/I)\pi_1/I < \pi_2/I$, that is, if and only if $\pi_2 > \pi_1(1 + \pi_1/I) = \pi_1(1 + r_e^*)$. Figures for $r_e^* \geq r_m^*$ would look similar. As noted in the legend for the figure, lines a and b represent the incentive compatibility constraints of an outside manager to pay out $y_2\pi_2$ per period and of investors not to liquidate, respectively. Hence the "triangle" formed by lines a and b represents the set of y_2's and r's for which the firm can be maintained as a going concern by an outside manager. Lines a and c form a smaller "triangle" representing the set of y_2's and r's for which financing can be raised if the firm will subsequently be run by an outside manager. Line c lies above line b because in a managerial equilibrium, the entrepreneur consumes the entire date 0 cash flow, whereas the outside manager will be paying out $y_2\pi_2$ from period 1 onwards. Additionally, if y_2 is above line b, financing can be raised in an entrepreneurial equilibrium. If y_2 is below line e, the entrepreneur prefers not to relinquish control if investors think that he will not. If y_2 is above line f, the entrepreneur prefers to relinquish control if investors think that he will do so.

managers or the entrepreneur. This illustrates the fragility of equity financing. Essentially, it relies on two-way trust between investors and the entrepreneur. Investors must trust the entrepreneur (or outside managers) to report cash flows that are sufficient to cover the cost of capital; and the entrepreneur (or outside managers) must trust that investors will not replace him or liquidate the firm as long as he reports such cash flows.

4 Debt Financing

Our discussion of the two stage growth model under equity financing revealed that managerial moral hazard can result in inefficiencies in a variety of ways. Very excessive rent extraction by outside managers can discourage any investment, either at early or late stages. More surprisingly we saw that better levels of corporate governance which would make second stage growth options attractive could have the perverse effect of discouraging first stage growth because entrepreneurs would be insufficiently incentivized. In this section we will see that debt financing operates somewhat differently in this environment. The key reason for this is that under debt financing, investors do not have the right to replace the entrepreneur. Thus, investors' incentive compatibility constraint disappears from the analysis. This eliminates the hold-up problem. For this reason, debt finance can be more conducive toward early stage growth, but only at the cost of sometimes sacrificing future growth opportunities.

We focus on equilibria where the firm is kept alive in perpetuity and therefore on perpetual debt contracts. The coupons are determined by the fact that the debt must initially be worth I. Assuming a contractual debt service of d from $t = 0$ onwards, the coupon every period would be

$$d = \frac{Ir}{1+r}. \tag{28}$$

This assumes that the cash flow produced under the initial phase of entrepreneurial control is sufficient to pay this coupon, which need not be the case. Later we will consider the model with a grace period of reduced coupon payments initially. This will prove to be more than a minor technical complication, for it is in this circumstance that a drawback of debt finance can prove to be decisive.

As before, we focus on going concern equilibria where an outside manager, if appointed, uses a time invariant payout ratio y_2 which to be incentive compatible for the outside manager must satisfy,

$$y_2 \leq \frac{1}{1+r}, \tag{29}$$

Again, going concern equilbria may be *managerial* in which case the second stage growth opportunity is realized or *entrepreneurial* in which case it is not. Since contractual debt service is fixed initially and therefore independent of reported cash flows, it is optimal for the entrepreneur to replace himself with an outside manager if the outside manager would report a larger cash flow than what the entrepreneur would generate, i.e.,

$$\text{entrepreneur is replaced iff:} \quad y_2\pi_2 > \pi_1. \tag{30}$$

This contrasts with equity financing, where a managerial equilibrium sometimes obtains when $y_2\pi_2 < \pi_1$ (see Theorem 1).

Assuming (30) holds and an outside manager is replaced this will give rise to a going concern only if it is incentive compatible for the entrepreneur/owner to service the debt. This will be the case if

$$(y_2\pi_2 - d)\frac{1+r}{r} \geq y_2\pi_2. \tag{31}$$

This second incentive compatibility condition is not present under equity finance and is the source of the *double moral hazard problem* alluded to in the *Introduction*. Combining (29) and (31), we get

$$\frac{d(1+r)}{\pi_2} \leq y_2 \leq \frac{1}{1+r}. \tag{32}$$

Substituting for d from (28) this can be rewritten as,

$$\frac{rI}{\pi_2} \leq y_2 \leq \frac{1}{1+r}. \tag{33}$$

Notice that the LHS of this expression is increasing in r and the RHS is decreasing in r. So there is a maximum cost of capital that is compatible with debt supported by a managerial equilibrium. Setting these inequalities to equalities, we find this occurs for r satisfying,

$$r(1+r) = \frac{\pi_2}{I}. \tag{34}$$

i.e., for $r = r_m^*$, the same as the maximum cost of capital compatible with an equity IPO under managerial equilibria [see (23)]. Now, to raise debt financing under managerial equilibria, it must also be the case that before replacing himself (at date 1), the entrepreneur must prefer servicing debt at date 0. Hence,

$$\pi_1 - d + \frac{y_2\pi_2 - d}{r} \geq \pi_1. \tag{35}$$

It can be confirmed that this will hold so long as (28) and (32) hold.

If $y_2\pi_2 < \pi_1$, an entrepreneurial equilibrium is sustainable with a debt coupon set as in (28) only if the entrepreneur is willing to service the debt. This requires,

$$[\pi_1 - d]\frac{1+r}{r} = \left[\pi_1 - \frac{Ir}{1+r}\right]\frac{1+r}{r} \geq \pi_1, \tag{36}$$

since his best alternative at any given time is to consume π_1 and default. Again there will be a maximum cost of capital consistent with a debt financed entrepreneurial equilibrium. Rearranging (36) shows that this requires, $r \leq \frac{\pi_1}{I} = r_e^*$, the same as the maximum cost of capital for which equity financing can be sustained under entrepreneurial equilibrium [see (25)].

If $\pi_1 < \frac{Ir}{1+r}$ it is not feasible to support an entrepreneurial equilibrium with a debt contract. Referring to (7), this inequality can be rearranged as $r > \phi$, i.e., the cost of capital is such that if operated perpetually by the entrepreneur the project has negative NPV. In this case it is also not feasible to support a managerial equilibrium with a debt contract with constant coupon from $t = 0$ onward. For debt to be feasible it will be necessary to introduce a "grace period" with an initial coupon not in excess of π_1. Then once the outside manager is in place the coupon would need to be raised to an amount greater than $\frac{Ir}{1+r}$ so that the initial value of the debt contract is I. It is clear that the more the initial coupon is reduced and the longer the duration of the grace period, the higher is the eventual coupon to be paid in the phase of managerial control. As a consequence, if π_1, π_2 and I are such that a grace period is required, then setting the coupon as $d_0 = \pi_1$ initially and as $d_1 = (I - \pi_1)r$ from $t = 1$ onward, will support the project for the maximum possible cost of capital. Again, this will hold only if the required debt payment, d_1, satisfies incentive compatibility conditions for both the outside manager and the entrepreneur/shareholder. These conditions and the maximum possible cost of capital compatible with a grace period are given in the following theorem which summarizes all our results on debt.

Theorem 2 *Suppose that outside managers use a time invariant payout ratio y_2. There are two types of equilibria where debt financing can be raised.*

1. *In an entrepreneurial equilibrium, the entrepreneur services debt in full every period and is never replaced. Such equilibria exist if and only if (a)* $\pi_1 \geq y_2\pi_2$ *and (b)* $r \leq r_e^*$.

2. *In a managerial equilibrium, the entrepreneur replaces himself at date 1. Debt is serviced every period, including date 0. Such equilibria exist if and only if one of the following two cases is satisfied:*
   Case 1 (No grace period, $r \leq \phi$*): (a)* $y_2\pi_2 > \pi_1$*, (b)* $r \leq r_m^*$*, (c)* $Ir/\pi_2 \leq y_2 \leq 1/(1+r)$.
   Case 2 (Grace period, $r > \phi$*): (a)* $y_2\pi_2 > \pi_1$*, (b)* $r \leq \phi^* \in (\phi, r_m^*)$*, (c)* $\frac{(I-\pi_1)(1+r)r}{\pi_2} \leq y_2 \leq \frac{1}{1+r}$*, where* ϕ^* *is determined by* $\phi^*(1+\phi^*)^2 = \frac{\pi_2}{I-\pi_1}$.

The theorem is illustrated in Figure 2.[18] Managerial equilibria tend to occur for large payout rates and entrepreneurial equilibria tend to occur for small payout rates, just as under equity financing (Figure 1). The figure illustrates the absence of a hold-up problem by the fact that managerial equilibria do not occur when $y_2\pi_2 < \pi_1$. That is, debt is conducive to first stage growth even in the face of moderately high managerial moral hazard problems.

Another advantage to debt is that there is no liquidation equilibrium. Since investors only have conditional control rights, as long as debt is serviced the manager does not need to worry about investors liquidating the firm. Debt obviates the need for two-way trust between investors and the entrepreneur to keep the firm alive. In this sense, debt is a less fragile form of finance than is equity finance.

A disadvantage to debt is that the maximum discount rate for which debt financing can be raised may be less than the threshold discount rate under equity financing, r_m^* (Part 2, case 2). This occurs when operating the firm under the entrepreneur perpetually would be a negative NPV project. It is in this case that the double moral hazard problem of debt proves to be decisive. Intuitively the reason for this is that when a grace period is required, later stage coupons are necessarily above the cost of capital. This results in a reduced threshold discount rate for debt financing.

Finally, turning to the entrepreneur's decision to undertake R&D when subsequently the project would be financed by debt, we note that the benefit of the project for the

[18] Figure 2 is drawn for the case that $r_m^* > \phi$.

entrepreneur is,

$$\pi_1 + \frac{y_2\pi_2}{r} - I \tag{37}$$

in the case of a managerial equilibrium and

$$\pi_1 + \frac{\pi_1}{r} - I \tag{38}$$

for entrepreneurial equilibrium. R&D will be undertaken when these are at least K. It follows then that the net benefits to the entrepreneur will be greater for debt finance than for equity finance in the case that $\pi_1 > y_2\pi_2$ and equity finance either is infeasible or would give rise to managerial equilibrium. Referring to Figure 1, this occurs in the region bounded above by d, below by e and to the left of r_e^*. This further reinforces the effect mentioned previously, that debt favors early stage investment but at the expense of later stage growth. However, for higher managerial payout rates $y_2\pi_2 > \pi_1$ it may not be feasible to finance with debt for reasons of double moral hazard as previously discussed. In such cases, R&D will be undertaken only under equity finance and only when the net benefit of the IPO is sufficient to cover K.

5 Debt versus Equity: Implications and Predictions

The following theorem compares the results on equity finance (Theorem 1 part 1) with debt finance (Theorem 2) assuming outside managers use a time invariant payout rate, y_2, under which the firm can be kept alive.

Theorem 3 *Suppose R&D has been done. Let r and y_2 be such that at least one type of financing can be raised, as described in Theorems 1 (part 1) and 2. Debt and equity financing lead to the same outcomes with respect to investments, production (replacement), and players' payoffs except in the following two cases:*

1. *Debt preferred because it avoids the hold-up problem:*

$$r \leq r_e^* \qquad \text{and} \qquad \frac{\pi_1}{\pi_2} - \frac{Ir^2}{(1+r)\pi_2} < y_2 < \frac{Ir}{\pi_2}. \tag{39}$$

2. *Equity preferred because it avoids double moral hazard:*

$$r > \phi \qquad \text{and} \qquad \frac{Ir}{\pi_2} < y_2 < \min\left\{\frac{1}{1+r}, \frac{(I-\pi_1)r(1+r)}{\pi_2}\right\}. \tag{40}$$

The theorem is illustrated in Figure 3.

Differences between debt and equity arise for two reasons: the hold-up problem under equity financing and the double moral hazard problem under debt financing. The hold-up problem manifests itself in entrepreneurial replacement when from the perspective of investors (including outside shareholders and the entrepreneur) it is inefficient to do so. This happens when $\pi_1 > y_2\pi_2$ and the cost of capital is sufficiently high to make the project "marginal." Intuitively what happens in these cases is a time inconsistency problem. At the financing stage an entrepreneur might may wish to promise to pay out dividends to match a future replacement manager, but under equity financing it is impossible to do so using subgame perfect strategies. LHS(39) is decreasing in r and RHS(39) is increasing in r, showing that the range of y_2's for which there is inefficient replacement is increasing in r. When the hold-up problem bites, debt is preferred. This is indicated by the light and medium shaded (light and darker green) regions in Figure 3. Double moral hazard bites when $r > \phi$, i.e, when the cost of capital is larger than the project's yield under entrepreneurial management. This is indicated by the darkly shaded (blue) region.

Outside of these cases the choice of financing with the associated distribution of control rights is irrelevant in our model. Intuitively, this is because repeated interaction can diminish some of the power bestowed by financial contracts. Under equity financing, as long as investors earn an adequate return on their capital, either as measured by what they could earn from replacing the incumbent or liquidating the firm, investors do not make use of their unconditional control rights. So the incumbent can make equity work like debt, where investors can interfere only if debt is not serviced, by providing investors with an adequate return.

These results are robust if we trace the analysis back to the R&D stage. But, as discussed above, there is now an increase in the set of parameter values for which the hold-up problem may arise. This is indicated by the lightly shaded (light green) region in Figure 3.

We now consider how changes in firm characteristics can impact the choice between debt and equity as indicated by how the critical areas in $(y_2 \times r)$ space vary as underlying parameters π_1, π_2, and others are varied. This will give rise to a number of empirical predictions which we summarize in the form of propositions. Again, demonstrations are given in Appendix 1.

Referring to Figures 1 and 3 the we see that the area where debt is preferred is given by,

$$\frac{I}{\pi_2}\int_0^{r_e^*}\frac{r^2}{1+r}dr \tag{41}$$

Recalling $r_e^* = \frac{\pi_1}{1+r}$ we see the area where debt is preferred is increasing in π_1 and decreasing in π_2. That is,

Proposition 1 *Debt will predominate for firms with modest growth opportunities.*

The precise meaning of 'modest' in this proposition depends upon the equilibrium payout rate that would be applied by an outside manager. Specifically, debt is preferred for π_2 less than $\frac{\pi_1}{y_2}$ but greater than $\frac{\pi_1}{y_2} - \frac{r^2 I}{(1+r)y_2}$.

In Section 1 we argued that our assumption of a one period delay between first and second stage growth opportunities simplified the notation and that the same qualitative results would apply if there were an N period delay. Increasing the delay between the two growth opportunities has an important impact on the quantitative advantage of debt, again as measure by the area in $(y_2 \times r)$ space where debt would be preferred. The reason for this is that increasing this delay increases the length of time that the entrepreneur extracts π_1 from the firm and therefore decreasing the value of equity at the time of the initial growth opportunity. Thus we have,

Proposition 2 *The longer the delay between first stage growth and an anticipated second stage growth the more likely that financing will take the form of debt.*

Since firms' revenues will be observed to grow only if they undertake an initial investment, empirical measures of firm growth will correspond to realizations of the second-stage growth opportunity in our model. In the "hold-up region", only debt financing can be raised, but second stage growth does not materialize. In cross-sections, this pushes debt towards an association with a failure to achieve growth. In the "double moral hazard region", second stage growth is achieved under equity financing, while debt financing cannot be raised. This strengthens the inverse relation between leverage and second stage growth. Thus our model is broadly consistent with the empirical evidence that corporate growth rates are negatively correlated with leverage (Lang, Ofek, Stulz, 1996).

Proposition 3 *There is an inverse relation between leverage and firm growth.*

Our model can also be used to relate leverage and profitability, measured as return on assets as in the empirical literature.[19] Let us identify book assets with investment costs, I,and per period reported return with $y_2\pi_2$.[20] Let us assume that the distribution of (r, y_2) is uniform on the rectangle with lower left corner $(0, 0)$ and upper right corner $(r_m^*, 1)$.

Proposition 4 *There is an inverse relation between leverage and profitability.*

Recently, it has been suggested that this relation can be explained by dynamic tradeoff models [Hovakimiam et al (2001), Hennessy and Whited (2005), Strebulaev (2007)]. We show that it is also consistent with incompleteness in financial contracting. Specifically, the inverse relation between leverage and profitability in Proposition 4 is driven by the cases in the cross-section where managers and investors are unable to overcome contractual incompleteness through dynamic strategies. These are the cases where the hold-up problem and double moral hazard come into play.

In empirical testing of these hypotheses, it would be important to control for factors present in the real world that are omitted from our model. In particular, we have abstracted from cash flow uncertainty which, as Fluck has already pointed out, tends to decrease the attractiveness of debt. We have also abstracted from taxes and bankruptcy costs, the two factors typically emphasized in trade-off models.

[19]See Strebulaev (2007) for references to the empirical literature documenting a robust negative relation between leverage and profitability.

[20]In managerial debt and equity equilibria, the reported return is clearly $y_2\pi_2$. In an entrepreneurial equity equilibrium, the reported return is $y_1\pi_1 = y_2\pi_2$ [since we are working under Theorem 1 (Part 1)]. In an entrepreneurial debt equilibrium, all we can definitely say is that it is at least equal to the coupon which, by (24) and (28), is bounded above by the cash flow in an entrepreneurial equity equilibrium. So as not to create a bias when comparing debt and equity, we assume that reported cash flows in an entrepreneurial debt equilibrium equals this upper bound. Thus, regardless of the financing and the type of equilibrium, the reported return is $y_2\pi_2$. Of course, we get different $y_2\pi_2$'s under managerial and entrepreneurial equilibria.

6 Extensions

6.1 Leveraged Buyout

Our analysis of equity and debt finance has shown that these basic modes of contracting fail to achieve efficient outcomes in many cases because they are unable to overcome entirely agency problems with the result that good growth opportunities may be foregone either at early or later stages of the firm. This inefficiency creates an incentive to design more sophisticated financial structures, adapted to the specific circumstances of the firm, that can do better.

In fact, taking our two-stage growth model quite literally, it is possible to find a relatively simple design that can improve efficiency. Specifically an initial debt issue combined with a subsequent leveraged buy-out of the entrepreneur may achieve the minimal moral hazard bound following second stage growth. Furthermore, full benefit of these efficiency gains would be captured by the entrepreneur who therefore will internalize them in making the R&D and initial investment decisions.

To see this suppose that the firm initially issues debt at date 0 which raises I. Denote the contractual debt service of this debt by d_0^s for $t = 0$ and d_1^s for $t \geq 1$. Then $d_1^s = (I - d_0^s)r$. At date 1, the entrepreneur hires an outside manager and simultaneously exchanges his equity for junior debt and gives all the equity to the new manager. Let d_1^j denote contractual debt service on the debt claim held by the entrepreneur. Minimum moral hazard can be enforced by setting: $d_1^j = \frac{\pi_2}{1+r} - d_1^s$. Thus, the total debt outstanding as of date 1 will be π_2/r. This maximizes cash flows to the entrepreneur, subject to incentive compatibility, and therefore maximizes his incentives to do R&D.

In this manner the LBO achieves an improvement in efficiency by overcoming managerial moral hazard along the lines discussed by Jensen (1989) and Holmstrom & Kaplan (2001). Note that in the context of the two-stage growth model an advantage of the the LBO is that it creates a single layer of agency, thus eliminating double moral hazard.

We fully recognize that achieving such efficiency gains might not be so easy as this makes it out to be. Our model is a stripped down vehicle that captures the notion that growth beyond the start-up phase of the firm may require changes in management which introduce agency problems not present in early stages of the firm's history. Adding realism to the model, e.g., stochastic cash flows and costs of financial distress, would introduce costs of using LBO's that might reduce their attractiveness. Even continuing within our model as formulated it should be noted that our discussion above assumes away contracting frictions that would naturally arise in arranging an LBO. Specifically, it is assumed that the manager who becomes the new sole shareholder of the highly levered firm has no bargaining power whatsoever. In fact, once the entrepreneur has hired the outside manager with a view to doing the LBO he is engaged in a bi-lateral negotiation in which the manager may be able to extract some of the *ex ante* benefits from the arrangement. Furthermore, once the LBO is arranged, the junior debt is held entirely by the entrepreneur, and it may be possible for the manager/shareholder to extract some of the surplus through strategic debt service as discussed in the next subsection. This loss of benefits accruing to the entrepreneur would reduce the incentives to do the early stage investment and R&D.

6.2 Alternative Models of Debt

In models of debt, it is widely recognized that important results may turn on the complexity of the debt structure, for example because of the impact on the ease with which debt can be renegotiated [e.g., Berglöf and von Thadden (1994), Bolton and Scharfstein (1996), and Franks and Nyborg (1996), Diamond (2004)].[21] The bankruptcy code also impacts significantly on debt renegotiations [see, e.g., Bulow and Shoven (1978), Brown (1989), Franks and Torous (1989), Weiss (1990), Bergman and Callen (1991), Franks and Nyborg (1996), Franks, Nyborg, and Torous (1996), Berkovitch, Israel, and Zender (1998).]

Our analysis has implicitly assumed a debt structure that is so complex as to be non-renegotiable and a formal bankruptcy where the firm is automatically liquidated. In this section, we relax these two assumptions. Our objective is to examine the robustness of our results rather than to provide a comprehensive model of debt structure, default, and bankruptcy codes.

We consider two extreme debt structures; complex and simple. Complex debt cannot be renegotiated; default precipitates formal bankruptcy. Simple debt may be renegotiated; default triggers a workout stage, where the players' threat points are determined by what

[21] In practice, complexity can result from having multiple creditors, multiple layers of seniority, and multiple and fragmented collateral.

would happen in formal bankruptcy (see below).

Different models of debt affect equilibrium outcomes only if they affect the players' incentive compatibility constraints. Under debt financing, only the entrepreneur's and managers' constraints enter the analysis, since creditors can take no action while debt is serviced. If debt structure is complex, these constraints may differ if the firm can be kept alive after entering formal bankruptcy or if there are deviations from absolute priority (as in Chapter 11). There would now be an extra term, for example representing priority deviations, on the right hand side of (31) and (35). While this would alter the details of the analysis, it would not affect the thrust of the conclusions.

If debt structure is simple, the entrepreneur's incentive compatibility constraints would depend on his bargaining power. As an example, suppose that formal bankruptcy is liquidation. Upon default, creditors and the entrepreneur (or manager) would enter workout negotiations and share the surplus from keeping the firm alive according to their bargaining powers. If all bargaining power lies with the entrepreneur, the entrepreneur would default for sure at date 1 and creditors would be paid off with shares worth L. Thus debt could not be raised.

The simple debt/maximum bargaining power to the debtor model is used by Fluck (1998), which explains her surprising result that equity dominates debt even though the reverse is true in the finite horizon model that Fluck builds upon.[22] However, if all bargaining power lies with creditors, it is straightforward that we get the same results as in Section 4, since the players' incentive compatibility constraints would be the same. However, for this reason it may be *ex ante* optimal to set up a complex debt structure, a point which has been made by repeatedly in the finite horizon debt literature.

7 Conclusion

In this paper, we have studied the relation between financing and corporate growth that arises because of differences in control rights in alternative capital structures. We have emphasized a dimension of the debt/equity choice that is somewhat different than those emphasized in either static trade-off or pecking order theories. In simple terms, we show

[22]Notably Hart and Moore (1998), Bolton and Scharfstein (1996), Townsend (1978) and Gale and Hellwig (1985).

that debt favors effort and growth at relatively early stages of the firm whereas equity facilitates growth at later stages. These tendencies are not always decisive, and we show that for some combinations of firm growth potential and corporate governance environments, debt or equity finance would give rise to the same outcomes. But in other cases, notably when the second stage growth opportunities represent only a modest potential improvement on first stage productivity, equity may give rise to an important hold-up problem that would give a clear advantage to debt finance and second stage growth will be foregone. In other cases where second stage growth potential is somewhat more significant, debt finance may be infeasible because it would give rise to a second layer of agency, i.e., both managers and shareholders have a potential incentive to divert cash flows away from creditors. The implications of these factors is that debt financed firms may get stuck on a low trajectory growth path. This leads to a number of empirical implications including the negative relation between leverage and both corporate growth and profitability.

To emphasize pure control rights effects, we have kept the model deliberately stripped down. However, the model naturally lends itself to extensions that would allow studying a number of important issues. For example, the repeated interaction feature of the model could be exploited to allow for a series of growth opportunities. This would give rise to a dynamic capital structure theory in an incomplete contracts setting where long-term debt might serve the role of providing sufficient protection for incumbents to undertake investments that in time would lead inevitably to their replacement. Additionally, introducing uncertain cash flows would establish a link to contingent claims valuation of corporate securities. Thus, the model could be adapted to study the dynamic interaction of financing and growth while pricing corporate securities in a setting where dividends and debt service are strategic, as in Anderson and Sundaresan (1996) and Mella-Barral and Perraudin (1997).

Appendix 1

Proof of Lemma 1

Consider an hypothetical equilibrium where the firm is kept alive in perpetuity. Denote the manager who is running the firm at date τ by $M(\tau)$. Let $V_{I\tau}$ and $V_{m\tau}$ be the present value of current and future cash flows under the hypothesized equilibrium for investors and $M(\tau)$, respectively. $V_{I\tau}$ must be at least L, otherwise investors would do better by liquidating the firm. $V_{m\tau}$ must be at least π_2, since the manager has the opportunity to consume the entire date τ cash flow (which is π_2). When the firm is kept alive in perpetuity under outside managers, the present value of the cash flows produced at date τ and in the future is $\pi_2(1+r)/r$. It follows that we must have

$$\frac{\pi_2(1+r)}{r} \geq L + \pi_2,$$

or

$$r \leq \frac{\pi_2}{L} = r^*.$$

This establishes that there is no equilibrium where the firm is kept alive in perpetuity if $r > r^*$. □

Proof of Lemma 2

Next we show that the strategies described in the Lemma [(a) and (b)] constitute a subgame perfect equilibrium, where the firm is kept alive in perpetuity, when y_2 satisfies (9) and $r \leq r^*$. We first show that the strategies constitute Nash equilibrium. Under the proposed equilibrium, the firm is kept alive forever under the same manager whose payoff as of an arbitrary date τ is

$$V_{m\tau} = \frac{(1-y_2)\pi_2(1+r)}{r} \geq \pi_2$$

since $y_2 \leq 1/(1+r)$ by (9). Thus the manager is better off adhering to (a) than not. Since all outside managers use the same strategy, investors are not better off replacing the current manager. Furthermore, investors are better off keeping the manager than liquidating, since $y_2 \geq rL/[(1+r)\pi_2]$ by (9). Given the strategies played by investors and other managers, an outside manager who may potentially be hired could not do better than using the same strategy as the current manager if he (the new manager) were to be hired. This establishes Nash equilibrium.

To establish subgame perfection, note first that since investors suffer no loss in payoff from replacing the current manager, they have a credible threat to replace him. The current manager therefore cannot benefit from paying a lower dividend than $y_2\pi_2$. Second, since there is an infinitely deep pool of alternative managers, the principle of induction establishes that the alternative manager also cannot do better than playing the same strategy as the incumbent once the outside manager is hired; the alternative manager is only placed in charge if the incumbent deviates, moreover, once this happens, the alternative simply becomes the new incumbent and is indistinguishable from the previous manager. Third, since all outside managers use the same strategy, investors cannot gain by replacing the current manager when he pays a dividend of $y_2\pi_2$. This establishes subgame perfection. □

Proof of Theorem 1

Part 1.

Most of the work is already done in the text. To complete the proof, suppose that y_2 satisfies (9) such that the firm is viable as a going concern under an outside manager. Substituting in the expression for γ_m [equation (17)] into (15), we see that there is a managerial equilibrium if $r \leq r_m^*$ and

$$y_2 \geq \frac{\pi_1}{\pi_2} - \frac{r^2 I}{\pi_2}.$$

Substituting in the expression for γ_e [equation (20)] into (15), we see that there is an entrepreneurial equilibrium if $r \leq r_e^*$ and

$$y_2 \leq \frac{\pi_1}{\pi_2} - \frac{r^2 I}{(1+r)\pi_2}.$$

Part 2.

Necessary condition (only if): Consider first the subgame that starts after the capital investment has been made. Since $I \geq L$, we must have $\pi_1(1+r)/r > L$, otherwise the cash flows would not be sufficient to cover the cost of investment. Consider an hypothetical equilibrium where the firm is kept alive forever under the entrepreneur, since this maximizes the total pie to be shared between investors and the entrepreneur. At the largest discount rate for which financing can be raised, we must have $\gamma = 0$. Thus, along the same lines as in the proof of Lemma 1, we must have $r \leq \frac{\pi_1}{L}$. Since $I \geq L$, we can repeat this line of argument to establish that financing can only be raised if $r \leq \frac{\pi_2}{I} = r_e^*$.

Sufficient condition (if):

Consider first the subgame that starts after the capital investment has been made. If $r \leq \frac{\pi_1}{L}$, along the same lines as in the proof of Lemma 2, we have that for any y_1 satisfying

$$\frac{rL}{(1+r)\pi_1} \leq y_1 \leq \frac{1}{1+r} \tag{42}$$

the following is an equilibrium: (a) the entrepreneur uses the payout ratio $y_{1t} = y_1$; (b) shareholders play

$$s_{t+1} = \begin{cases} \text{retain} & \text{if } y_{1t} \geq y_1 \\ \text{liquidate} & \text{if } y_{1t} < y_1. \end{cases} \tag{43}$$

At date 0, since $I \geq L$ it is straightforward that it is equilibrium for investors to provide financing and the entrepreneur to pay out y_1, if $r < r_e^*$. This establishes Part 2 of the theorem. □

Proof of Theorem 2

Part 1: This is established in the text.

Part 2: The case that $r \leq \phi$ is established in the text. So suppose $r > \phi$. As discussed in the text, in this case a grace period is necessary and we set $d_0 = \pi_1$ and $d_1 = (I - \pi_1)r$. As usual the incentive compatibility condition for the manager is $y_2 \leq \frac{1}{1+r}$. The incentive compatibility condition for the entrepreneur/shareholder is as in (31) with d replaced by d_1. Using these two conditions implies that there is a y_2 consistent with both if and only if $r \leq \phi^*$, where ϕ^* is defined by

$$\phi^*(1+\phi^*)^2 = \frac{\pi_2}{I - \pi_1}.$$

By the observation immediately after equation (35), the entrepreneur's incentive compatibility constraint for servicing debt prior to the appointment of the outside manager will also be satisfied since $d_0 < d_1$.

To conclude the proof of *Part 2* we need to verify that $\phi < \phi^* < r_m^*$. By definition, r_m^* is such that $q(r_m^*) = g(r_m^*)$, where $q(r) \equiv 1/(1+r)$ and $g(r) \equiv Ir/\pi_2$. By definition, ϕ^* is such that $q(\phi^*) = h(\phi^*)$, where $h(r) \equiv (I - \pi_1)r(1+r)/\pi_2$.

First, $g(r)$ is strictly increasing and linear and $h(r)$ is strictly increasing and strictly convex. Furthermore, $g(0) = h(0) = 0$ and $g(\phi) = h(\phi)$. This implies that for all $r > \phi$, we have $h(r) > g(r)$.

Second, $q(r)$ is strictly decreasing and $q(\phi) > g(\phi) = h(\phi)$ (since $\phi < r_m^*$). It follows that the point of intersection between $h(r)$ and $q(r)$, at $r = \phi^*$, is larger than ϕ. It also follows that ϕ^* is smaller than the r at which $g(r)$ intersects $q(r)$. In other words, $\phi^* < r_m^*$. □

Proof of Theorem 3

Part 1 (hold-up): From Theorems 1 and 2, we know that only debt financing can be raised if $r \leq r_e^*$ and y_2 is within the stated bounds. In particular, if $y_2 < Ir/\pi_2$ it is impossible to raise equity financing in a managerial equilibrium, and if $y_2 > \pi_1/\pi_2 - Ir/[(1+r)\pi_2$ entrepreneurial equilibria are not possible since the entrepreneur would prefer not to match dividends if his shareholding is γ_e (as given by (20)). Thus if these two conditions are met, equity financing cannot be raised.

Part 2 (Double Moral Hazard): From Theorems 1 and 2, we know that only equity financing can be raised if $r > \phi$ and y_2 is within the stated bounds. In particular, if $r > \phi$, the cost of capital is larger than the yield on the project under the entrepreneur, implying that financing cannot be raised in an entrepreneurial equilibrium and that a grace period is needed under debt financing. When $y_2 > Ir/\pi_2$, equity financing can be raised in a managerial equilibrium provided that the managerial incentive compatibility constraint, $y_2 < 1/(1+r)$, is satisfied. This constraint also needs to be satisfied if debt financing is to be raised in a managerial equilibrium. Finally, if $y_2 < (I - \pi_1)r(1+r)\pi_2$, we showed above that debt financing cannot be raised in a managerial equilibrium. This completes the proof. □

The following will be used in the proofs of the propositions below:

By Theorem 3, for any tuple (r, y_2), debt and equity are outcome equivalent except for a tuple in the two regions specified in the statement of the theorem. Since we assume that debt and equity are equally likely when they are outcome equivalent, any differences between debt and equity with respect to second stage growth are therefore determined on these two regions. Let Regions 1 and 2 be as described in Parts 1 and 2, respectively, in Theorem 3.

Proof of Proposition 2

To see this suppose that the second stage growth opportunity occurs in period N and consider the entrepreneurial replacement decision at date $N-1$. This analysis is identical to that of Section 2. As a consequence, for a range of y_2 and r the entrepreneur will choose to not match dividends and will be replaced. Consider then the decision at $N-2$. If the entrepreneur is not going to match dividends at $N-1$ then he will have no incentive to match dividends one period earlier. Continuing this recursion we see that the value of equity at period 0, the time of the stage 1 growth opportunity is,

$$\frac{y_2\pi_2}{(1+r)^{N-1}r} \tag{44}$$

An IPO will be feasible if and only if this amount is at least as great as I. This feasibility condition can be rearranged as,

$$y_2 \geq \frac{(1+r)^{N-1}rI}{\pi_2} \tag{45}$$

This reduces the range of $y_2 \times r$ where managerial equilibria would be feasible. Notice that if an IPO is feasible then the value of outside equity at $t=0$ is I. The value of outside equity then rises each period of entrepreneurial control at the rate r. So even though in response to the non-payment of dividends the shareholders could liquidate the firm, since $I > L$ it is never a best response to do so.

In contrast, with debt if it is incentive compatible for the entrepreneur to service the debt at period $N-1$ it also will be at $N-2$ and so on. As a consequence, the analysis of debt with N period delay in second stage growth will be identical to that of one period delay given in Section 3. □

Proof of Proposition 3

On Region 1, only debt financing can be raised. Here, $\pi_1 > y_2\pi_2$ and so second stage growth is not achieved. On Region 2, only equity financing can be raised and second stage growth is achieved (here, $r > \phi$ implying that financing cannot be raised in an entrepreneurial equilibrium).[23] Thus, the probability of second stage growth is higher conditional on equity financing than conditional on debt financing. □

Proof of Proposition 4

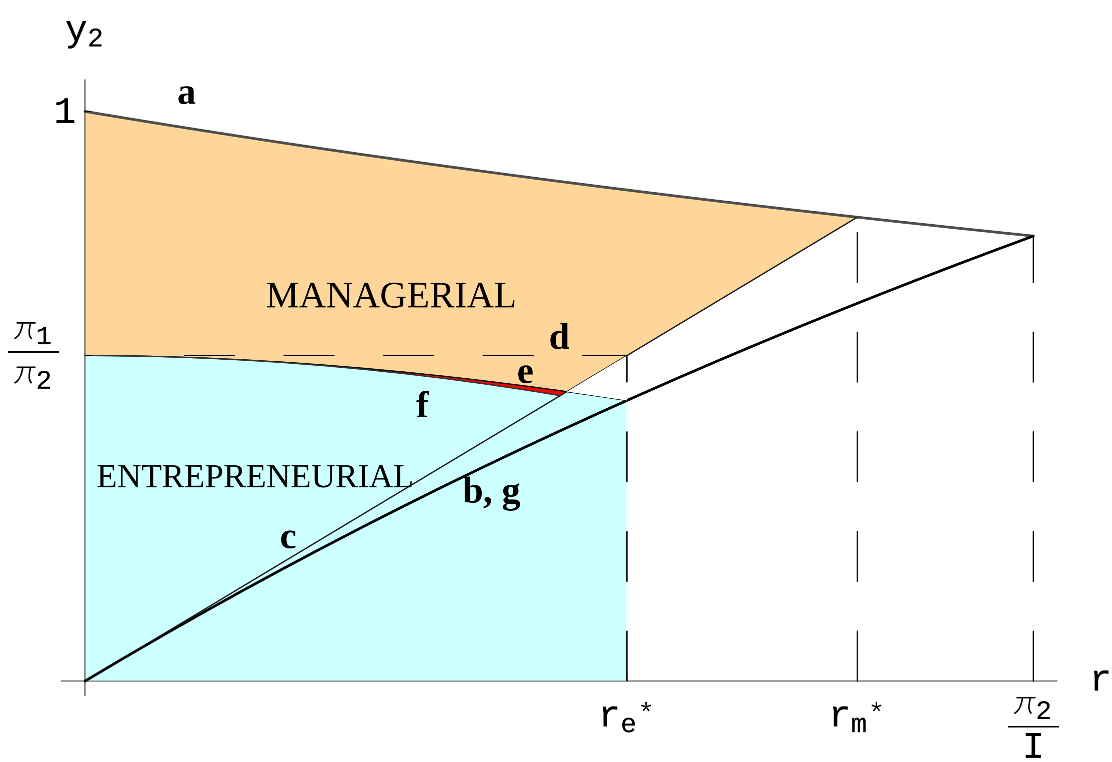
Since I is independent of future profits, the Proposition follows immediately from Proposition 3 and the uniform distribution assumption. □

[23] If $r_m^* \leq r_e^*$, Region 2 is empty.

Appendix 2: Figures

Figure 1: Equilibria under equity financing

This figure summarizes our analysis of the equity contract. The lines represent incentive compatibility and other constraints as described in the legend (see next page). Parameter values are: $I = L = 100$, $\pi_1 = 16$, $\pi_2 = 28$, yielding $r_e^* = .16$, $r_m^* = .2280$, and $\pi_2/I = .28$. The firm can be financed by equity and operate under the entrepreneur for discount rates less than r_e^* and payout rates below line **e**. This area is shaded light (light blue). The firm can be financed by equity and operate under outside management for combinations of discount rates and payout rates lying below **a** and above max[line **f**, line **c**]. This area is shaded medium dark (orange). For combinations of r and y_2 in the area between lines **e** and **f**, shaded dark (red), both managerial and entrepreneurial equilibria are possible. Nonshaded areas represent combinations of y_2 and r for which equity financing is not feasible.



Legend for Figure 1

a Outside manager's incentive compatibility constraint

$$y_2 \leq \frac{1}{1+r}$$

b Investors' incentive compatibility constraint (do not liquidate outside manager)

$$y_2 \geq \frac{Ir}{(1+r)\pi_2}$$

c Financing provided in a managerial equilibrium

$$y_2 \geq \frac{Ir}{\pi_2}$$

d Feasibility of entrepreneur matching dividends of outside manager

$$y_2 \leq \frac{\pi_1}{\pi_2}$$

e Entrepreneur prefers to match dividends if $\gamma = \gamma_e$

$$y_2 \leq \frac{\pi_1}{\pi_2} - \frac{Ir^2}{(1+r)\pi_2}$$

f Entrepreneur prefers not to match dividends if $\gamma = \gamma_m$

$$y_2 \geq \frac{\pi_1}{\pi_2} - \frac{Ir^2}{\pi_2}$$

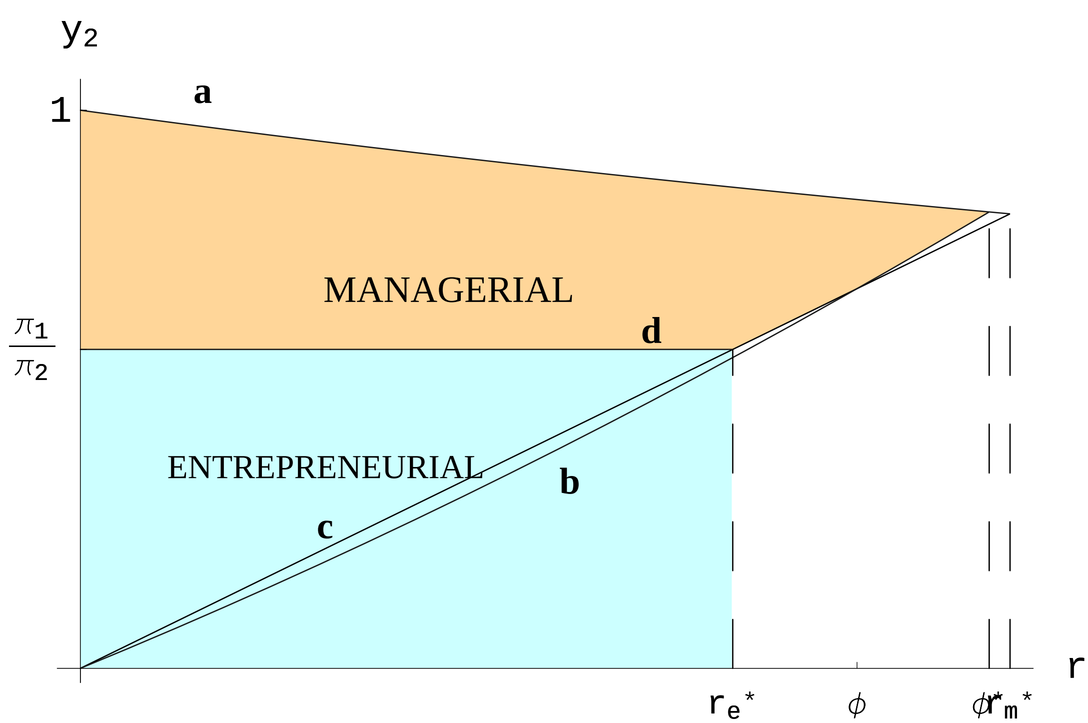
g Financing provided in entrepreneurial equilibrium (assuming firm can be kept alive by outside manager)

$$y_2 \leq \frac{Ir}{(1+r)\pi_2}$$

This uses $y_1\pi_1 = y_2\pi_2$ and is functionally equivalent to constraint **b**.

Figure 2: Equilibria under debt financing

This figure summarizes our analysis of the debt contract. The lines represent incentive compatibility and other constraints as described in the legend (see next page). Parameter values are: $I = L = 100$, $\pi_1 = 16$, $\pi_2 = 28$, yielding $r_e^* = .16$, $r_m^* = .2280$, $\phi = .1905$, and $\phi^* = .2229$. The firm can be financed by debt and operate under the entrepreneur for discount rates less than r_e^* and payout rates below line **d**. This area is shaded light (light blue). The firm can be financed by equity and operate under outside management for combinations of discount rates and payout rates lying below **a** and above max[line **d**, line **c**,line **b**]. This area is shaded medium dark (orange). Nonshaded areas represent combinations of y_2 and r for which equity financing is not feasible.



Legend for Figure 2

a Outside manager's incentive compatibility constraint

$$y_2 \leq \frac{1}{1+r}$$

b Financing provided in a managerial equilibrium with a grace period (and $d_0 = \pi_1$)

$$y_2 \geq \frac{(I - \pi_1)r(1+r)}{\pi_2}$$

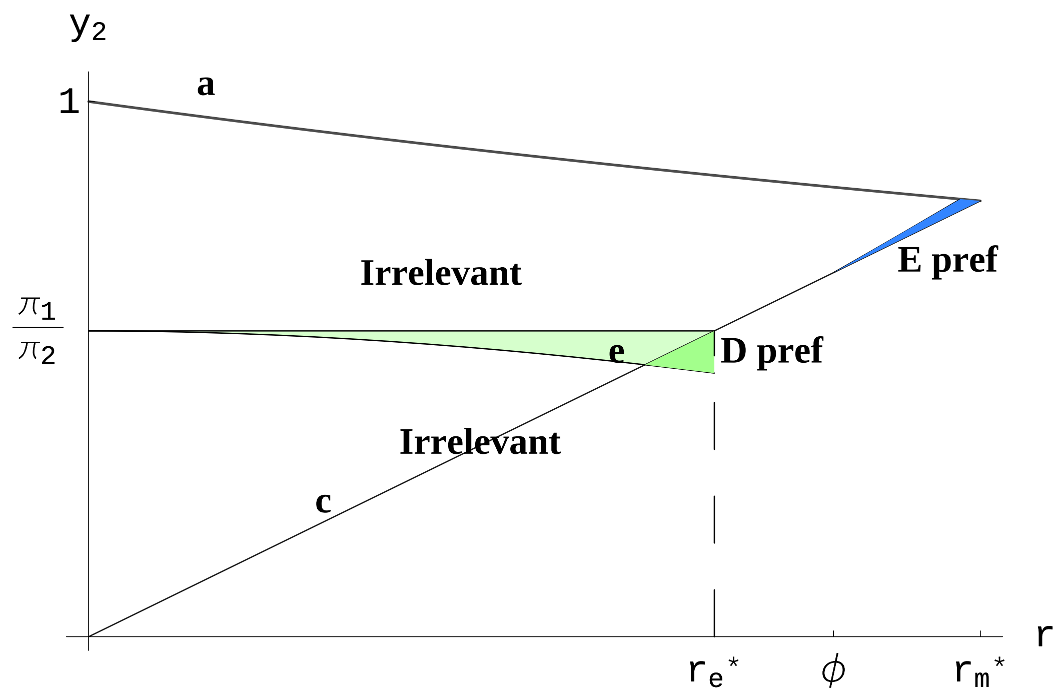
c Financing in a managerial equilibrium without a grace period

$$y_2 \geq \frac{Ir}{\pi_2}$$

d Feasibility of entrepreneur matching dividends of outside manager

$$y_2 \leq \frac{\pi_1}{\pi_2}$$

Figure 3: Comparison of debt versus equity financing



This figure combines Figures 1 and 2 and compares debt versus equity financing. The lines represent incentive compatibility and other constraints as described in the legends of the previous two figures (see particular the legend for Figure 1 for lines **a**, **c**, and **e**). Parameter values are: $I = L = 100$, $\pi_1 = 16$, $\pi_2 = 28$, yielding $r_e^* = .16$, $r_m^* = .2280$, $\phi = .1905$.

In regions marked "irrelevant", debt and equity lead to identical equilibrium payoffs. Debt is preferred in the area shaded medium (green), bordered above by line **c**, below by **e**, and to the right by r_e^*. In this region, equity gives rise to a hold-up problem making equity financing infeasible, as described in the text. Debt is weakly preferred in the region shaded light (light green), bordered above by $y_2 = \pi 1/\pi 2$, below by max[line **e**, line **c**]. In this region, equity financing can be raised but gives rise to inefficient replacement, due to the hold-up problem. Thus, in this region, the incentive to do R&D is reduced under equity financing relative to debt financing. Equity is preferred in the shaded dark (blue), bordered by line **a**, line **c**, and the unlabeled line segment to the left of line **c** (which is a segment of line **b** in Figure 2).

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