

Optimal Financial Contracting: Debt versus Outside Equity

Zsuzsanna Fluck
New York University

This article presents a theory of outside equity based on the control rights and the maturity design of equity. I show that outside equity is a tacit agreement between investors and management supported by the equity-holders' right to dismiss management regardless of performance and by the lack of a prespecified expiration date on equity. As a tacit agreement outside equity is sustainable despite management's potential for manipulating the cash flows and regardless of how costly it is for equityholders to establish a case against managerial wrongdoing. I establish that the only outside equity that investors are willing to hold in equilibrium is that with unlimited life, the very outside equity that corporations issue. Consistent with empirical evidence, this model predicts that debt-equity ratios are higher (lower) in industries with low (high) cash flow variability.

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This article presents a theory of outside equity based on the control rights and the maturity design of equity. I show that outside equity is a tacit agreement between investors and management supported by the equity-holders' right to dismiss management *regardless* of performance and by the lack of a prespecified expiration date on equity. Furthermore, as a tacit agreement, outside equity is sustainable despite management's potential for manipulating or diverting the cash flows and regardless of how costly it is for equity-holders to establish a case against managerial wrongdoing.

The model incorporates outside equity financing, management's potential for diverting cash flows as private benefits, and nonverifiability of managerial performance. Earlier models in the security design literature could incorporate only two of these three features. Models that allow management to divert cash flows as private benefits of control and for costly state verification or nonverifiability of cash flows [e.g., Townsend (1979), Diamond (1984), Gale and Hellwig (1985), Hart and Moore (1989), Bolton and Scharfstein (1990)] are incompatible with outside equity.¹ Security design models that explicitly introduce outside equity financing either assume away the verification problem partially [Chang (1992)] or completely [Aghion and Bolton (1992), Dewatripont and Tirole (1994)] or eliminate management's ability to divert cash flows as private benefits of control in some states of the world [Williams (1989)].²

The innovation in this article is the comprehensive specification of equity. This specification is equivalent to the traditional specification in terms of cash flow claims and ownership and control rights, but complements the traditional specification in terms of a critical but previously disregarded aspect: the maturity of the security.³ In contrast to the literature that (explicitly or implicitly) takes the life of equity and debt claims as equal, this model allows debt and equity to have different maturities. Given the set of theoretically possible financing arrangements with different control rights, cash flow claims, and maturity, it becomes possible to pinpoint the securities that investors are willing to hold.

It turns out that investors would never be willing to hold outside

¹ See Harris and Raviv (1992) for an elaborate discussion.

² For an excellent survey of the most recent literature, including this article, see Duffie and Rahi (1995). Allen (1989), Allen and Winton (1992), and Harris and Raviv (1992) are excellent surveys of the earlier literature.

³ Debt maturity was investigated in Myers (1977), Barnea, Haugen, and Senbet (1980), Flannery (1986), Hart and Moore (1989, 1995), Stulz (1990), Berkovitch and Kim (1991), Diamond (1991, 1993), Gertner and Scharfstein (1991), and Rajan (1992). No investigation has been proposed for the study of the maturity of outside equity, alone or relative to debt maturity.

equity with a prespecified maturity date.⁴ First, equity-holders cannot enforce contracts written on cash flows or earnings of the company because courts cannot verify their realizations. Second, managerial incentive contracts do not work either. When an entrepreneur-manager has the potential to divert cash flows as private benefits, offering him a percentage of these cash flows does not provide any incentive at all [Hart and Moore (1989)]. Even the threat of dismissal fails to discipline management when there is a prespecified expiration date on equity. However, long-term equity financing arrangements that are in the interest of both parties may still be sustainable [Fluck (1993)]. These arrangements do not contract on particular realizations of cash flows, other financial variables, or the completion of a particular transfer of fixed payments. These arrangements are sustainable because both parties have strong incentives to continue their business relationship. Outside equity with unlimited life is such an arrangement. Outside equity with unlimited life is compatible even with nonverifiability of cash flows and with management's ability to divert cash flows as private benefits.

It is *the combination of the control rights and the maturity design of outside equity* that alleviates the moral hazard problem. Debt avoids the verification problem by promising a fixed payment and by control rights⁵ that are contingent on failure to make this fixed payment. Equity avoids the verification problem by giving equity-holders unconditional control rights. By having unconditional control rights, outside equity-holders pose a constant threat of potential dismissal to the entrepreneur-manager. Because outside equity-holders have an unlimited time horizon or, alternatively, lack a prespecified expiration date on their claim, their threat is credible. When outside equity with unlimited life is issued, the entrepreneur-manager faces a threat of dismissal that does not diminish over time, as well as a continuing incentive for honoring outside equity-holders' claims.⁶ The credible threat of dismissal and the incentive for continuation effectively discipline the entrepreneur-manager.

⁴ Limited life equity is the only feasible equity contract in the framework of previous security design models. Limited life equity has been specified as a contract that gives cash flow claims and control rights to equity-holders for T periods. At time T , equity expires, the company is liquidated, and the proceeds from the sale of the assets are distributed among the owners.

⁵ Recent research on control rights of debt includes Harris and Raviv (1989), Hart and Moore (1989, 1994), Aghion and Bolton (1992), Zender (1991), and Zwiebel (1994), and on the role of seniority includes Diamond (1993), Hart and Moore (1995), and Winton (1995).

⁶ If we think in terms of the company's probability of survival, unlimited life is equivalent to a constant rate for the survival of the company over time.

Since my aim is to establish that outside equity is the financing choice of some positive net present value projects, I devote the second part of this article to investigating whether the entrepreneur-manager is willing to issue outside equity with unlimited life. Since the seminal articles of Miller and Modigliani (1958), Jensen and Meckling (1976), and Myers (1977), capital structure⁷ decisions have been extensively studied in the corporate finance literature. This article investigates the entrepreneur's decision whether to seek debt or equity financing in equilibrium. I adopt the standard debt contract of Hart and Moore (1989) into my framework and show that, unlike outside equity, equilibrium debt contracts have a prespecified maturity shorter than the life of the physical assets. Thus my theory implies that investors practice maturity matching: they match the maturity of the optimal debt contract with the life of the physical assets and the maturity of the equity contract with the life of the company's real options. I then characterize projects that can raise debt, projects that can raise outside equity, and those that can raise both. The next step establishes whether an entrepreneur would choose debt, outside equity, or a mix of the two, provided that there is a demand for both. It turns out that in addition to debt, outside equity with unlimited life emerges as the financing choice for positive net present value projects. I found that projects that can raise debt can also raise outside equity but not vice versa. If the cash flows are stable, the entrepreneur-manager issues either debt or outside equity or a mix of the two. If the cash flows are more volatile, the entrepreneur issues outside equity. Despite universal risk neutrality, the *variability of the cash flows* determines the financing choice of the project in my model. The intuition stems from the maturity design of the equilibrium securities: since outside equity has a better technology to spread the moral hazard risk over time (because of its unlimited life), whereas debt concentrates it on the pay-back period (debt has a prespecified expiration date), outside equity can absorb more cash flow risk. This result appears to be consistent with the empirical evidence.⁸

There are two different definitions of nonverifiability of cash flows or costly state verification in the literature. One line of the literature [Townsend (1979), etc.] defines costly state verification as costly information acquisition by investors. This definition is relevant for small privately held companies with severe information asymmetries between investors and management. These companies benefit most from mon-

⁷ Harris and Raviv (1991) and John (1993) are excellent sources for references of this literature.

⁸ The combined evidence broadly supports the view that higher operating risk companies have lower debt ratios [see Friend and Hasbrouck (1988), Friend and Lang (1988), and Titman and Wessels (1988) and the references therein].

itoring and therefore use bank debt and venture capital financing. In the other line of the literature [Hart and Moore (1989, 1994, 1995), etc.] investors and management are equally informed, but investors still face a potentially severe cost associated with establishing their case against management in a court of law. This definition applies to larger companies whose books are frequently audited and whose performance may be followed closely by analysts. These companies typically use publicly traded securities to finance their investment. This article adopts the second approach.

1. The Basic Model

We consider a risk-neutral entrepreneur who seeks financing for his project from risk-neutral investors. Investors and entrepreneurs use the same positive discount factor δ to value future payoffs.

The project yields a periodic operating cash flow $\tilde{v}$. The cash flow, $\tilde{v}$, is an i.i.d. random variable that takes values $v+x > 0$ and $v-x > 0$ with equal probabilities. The project requires an investment outlay of I and involves the operation of an equipment with economic life of two periods.

The project may be repeated over and over again. As long as the project continues, the equipment must be replaced every two periods. The equipment has a positive liquidation value $L_1 < \delta I$ if investors choose to liquidate the project immediately after the investment is sunk and a positive liquidation value $L_2 < L_1$ if investors choose to liquidate immediately following the realization of period 1 cash flows. The subscript refers to the time of the distribution: L_1 is distributed at time 1; L_2 is distributed at time 2. The salvage value of the equipment at the end of its operation is zero. I assume that the operating cash flows of the project always exceed the liquidation value of the equipment, that is, $(1 + \delta)(v - x) \geq L_1$ and $(v - x) \geq L_2$. These latter two assumptions will play a role later in Proposition 7.

The entrepreneur-manager may seek external financing for the timely replacement of the physical assets at the beginning of each cycle or, alternatively, he may set aside funds in the amount of $a = \frac{\delta I}{1+\delta}$, where a solves $I = \sum_{t=0}^1 a(\frac{1}{\delta})^t$, to internally finance the project following the first cycle. I assume that the project can be internally financed following the first cycle, that is, $v - x \geq a$.

This depreciation account enables investors to recoup a larger part of their investment when liquidating the assets. If the manager has retained a in period 1 and the company gets liquidated immediately after the realization of period 1 cash flows, then the liquidation value of the company turns out to be $L_2 + a$, which is assumed to be less than δI . This liquidation value $L_2 + a$ is then distributed at time 2. Similarly, if

Table 1
Notations

v_t	Realized cash flows; either $v + x$ or $v - x$
d_{v+x}, d_{v-x}	Equilibrium dividends offered by the entrepreneur-manager
$\hat{d}_{v+x}, \hat{d}_{v-x}$	Equilibrium dividends offered by the new manager
$\bar{d}_{v+x}, \bar{d}_{v-x}$	Equilibrium dividends offered by the new manager, net of dismissal cost
I	Investment outlay
L_1 or L_2	Liquidation values of the assets
$a = \frac{I}{\sum_{t=0}^1 (\frac{1}{\delta})^t}$	Periodic depreciation allowance

a depreciation allowance a has been set aside in both periods and the company gets liquidated immediately after the realization of period 2 cash flows, then the liquidation of the depreciation account yields I at time 3, the time of its distribution.⁹

Once the investment is sunk, the realizations of period 1 and period 2 cash flows are learned by both parties. Management may divert the cash flows each period. The true realization of the cash flows is assumed to be nonverifiable by a third party; that is, contracts written on cash flows are prohibitively costly to verify in court. Similarly, whether or not the entrepreneur-manager has set aside a depreciation allowance is known to both parties. Management's manipulation of the depreciation account is also nonverifiable unless the company gets liquidated and the depreciation account is foreclosed. As a general principle, only receipts of payments (such as dividends, debt payments, payments associated with asset liquidation) are costlessly verifiable in this model. The true realization of all other financial and accounting variables are assumed to be prohibitively costly to verify.

Finally, the product market is, without loss of generality, a natural monopoly. That is, if the project is liquidated it is profitable for the entrepreneur-manager to restart it to meet demand for the product; conversely if an incumbent runs the project it does not pay for a potential entrant to enter. Our results extend to oligopolistic product markets.

The entrepreneur has two choices: he may seek debt or equity financing from investors.

1.1 The model of outside equity

The entrepreneur-manager may raise I by issuing equity to outside investors. Outside equity-holders have a claim to the cash flows of

⁹ Alternatively, a can be interpreted as the cost at which the equipment may be completely renewed period after period. When the entrepreneur-manager periodically renews the equipment, the liquidation values are, according to this interpretation, constant across periods and equal to L_1 . When the entrepreneur-manager fails to renew the equipment on time, the liquidation values of the assets are, as before, L_1 , L_2 , and 0. Fluck (1997) follows this approach.

the company, $\tilde{v}$, and a right to dismiss and replace management or to liquidate the company *independently* of the realization of cash flows. Equity may carry any possible maturity date or may be issued with unlimited life. For completeness, limited life equity is defined as follows. Investors transfer I to the entrepreneur-manager. In exchange investors receive for T periods (i) a claim to the cash flows of the company and (ii) a right to dismiss the entrepreneur-manager or to liquidate the firm. At time T , the company is liquidated and the proceeds are distributed among the owners. Following liquidation, the entrepreneur-manager may again seek financing to restart the project to meet demand for the product.

Management can divert cash flows as private benefits. As a result, the outside equityholders' claim effectively translates into a claim on cash flows net of depreciation and private benefits of control, which is paid out as dividends, d_{v_t} , where the subscript v_t refers to the current cash flow realization.

The *timing* of the model of outside equity¹⁰ is as follows. At time 0, outside equity-holders invest I in the project. Each period equity-holders simultaneously decide whether to keep or to replace the entrepreneur-manager or to liquidate the firm. Each period, as long as no challenge is initiated, the entrepreneur-manager may choose to set aside the depreciation allowance a and reports the earnings of the project. The reported earnings are then paid out as dividends. As long as no challenge is initiated, outside equity-holders receive d_{v_t} , the dividends the entrepreneur-manager has decided, and the entrepreneur-manager receives $v_t - a_t - d_{v_t}$. In the event of liquidation, the entrepreneur-manager receives no payoff and equity-holders receive the liquidation value of the physical assets. In the event of dismissal, the entrepreneur-manager receives no payoff and outside equity-holders bear the cost associated with replacing the manager. Immediately following a dismissal, new management with identical abilities (i.e., identical cash flows) succeeds the old management. Investors are Bertrand competitors: they are willing to finance a project if they break even.

The set of actions and associated payoffs in the component game are described in the next diagram. The first element of the payoff vector is the payoff to the entrepreneur-manager; the second is the payoff to investors. The third element, whenever applicable, indicates

¹⁰ A similar modeling approach was used in Fluck (1998) for the interaction between entrenched management and dispersed outside equity-holders in an infinite horizon model. Fluck (1998) showed that, in equilibrium, management's willingness to invest in its company and the size of its equity stake are determined by and vary with market factors, such as the real cost of financial capital.

the payoff to the new manager who is replacing the entrepreneur-manager. The notation $\hat{d}_{v_i}$ and $\hat{a}$ refers to decision variables set by the incoming new manager. Note that $d_{v_i}^-$ denotes dividends net of the cost of replacing management.

When the component game is played only once, the unique Nash equilibrium outcome is liquidation since the dividends offered by either manager in any Nash equilibrium would always fall short of the liquidation value of the company. If, however, the financing relationship continues over time, then the equilibria in which management voluntarily limits private benefits of control, pays adequate dividends, and sets aside appropriate depreciation allowance may become supportable by the credible threat of dismissal or liquidation.

1.2 The model of debt

The entrepreneur-manager may also issue debt with various maturities. For modeling debt financing we adopt the standard model of debt from Hart and Moore (1989). For financing a two-period project, this debt contract specifies investors transferring funds I to the entrepreneur upfront in exchange for payments P_t over the life of the debt. Debt-holders are also given the right to liquidate the assets conditional on payments not being met. In contrast to equity-holders who can dismiss management or liquidate the firm regardless of performance, debt-holders' right to liquidate the firm is conditional on the event of a default. As long as debt payments are met, the entrepreneur-manager holds all control rights.

The debt contract expires at maturity if payments are met. In the event of a default at time t , parties have the option to renegotiate. The rules of the renegotiation from Hart and Moore (1989) are as follows. The debtor can make a single take-it-or-leave-it offer. This offer consists of a date t cash payment from the debtor to holders of the debt contracts and a fraction of the assets to be liquidated at date t , the proceeds being transferred to the debt-holders. If debt-holders accept, the new agreement replaces the original. If debt-holders reject, then they have the right to liquidate the assets or to forgive the debt. At this point the debtor can make a cash payment and the assets will be liquidated until either the remaining portion of the debt is paid off or all the assets have been liquidated. Creditors are Bertrand competitors: they finance a project if they break even.

2. Securities That Investors Are Willing to Hold

2.1 Outside equity

Investors hold outside equity only if they are confident that their cash flow claim will be honored in the future. Since cash flows are not veri-

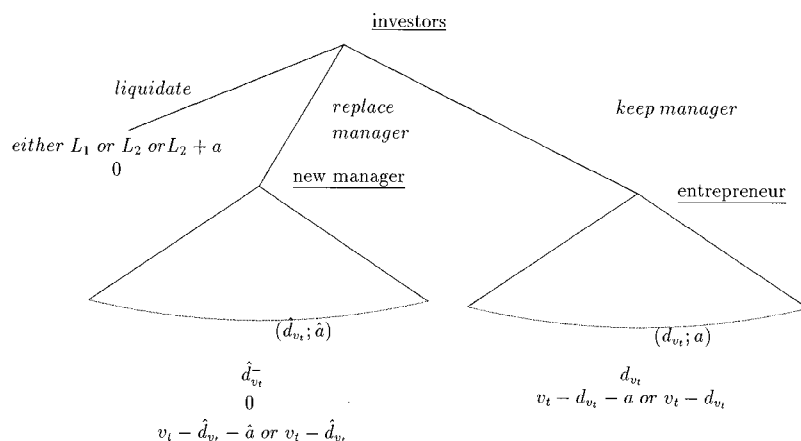


Figure 1
The component game

Investors decide whether to keep or to replace the entrepreneur-manager or to liquidate the firm. If the entrepreneur-manager remains in charge, then he decides on the depreciation allowance a and dividends d . Alternatively, if the entrepreneur-manager is replaced, then he receives no payoff and a new manager takes charge. In the event of a liquidation, the entrepreneur-manager receives no payoff and investors receive the liquidation value of the assets.

fiable, potential outside equity-holders rationally foresee management diverting cash flows as private benefits. The only way outside equity-holders may induce management to voluntarily limit appropriation of private benefits is by credible threats of dismissal. Credible threats of dismissal induce management to voluntarily limit appropriation of private benefits of control so as to retain control over the operation of the assets in the future. Unless outside equity-holders are prepared to exercise it, the threat of dismissal is not credible, however. It is the maturity design of outside equity that gives or takes away the credibility of the dismissal threat.

Suppose that there is a prespecified expiration date on equity. Using backward induction, in the following paragraphs I describe that neither the threat of dismissal nor the threat of liquidation can sustain outside equity financing with a prespecified expiration date. The reader can straightforwardly follow the reasoning in Figure 1.

In the period before equity expires, neither the entrepreneur-manager nor the incoming manager would be willing to pay dividends that match or exceed the liquidation value of the company. Equity-holders would not dismiss the entrepreneur-manager if dismissal is costly; their best response is to liquidate the project. Consequently, in the last period the project is liquidated, the entrepreneur-manager receives no pay, and equity-holders end up with L_2 .

In the second to last period, the entrepreneur-manager knows that the project will be liquidated in the last period and that he will receive no payoff then. Hence he realizes that the second to last period is effectively his last period. Consequently, he acts the same as in the last period. Again, equity-holders would not dismiss the entrepreneur-manager if dismissal is costly; they can only lose by doing so. The incoming manager has no incentive to act any differently in the last period than his predecessor. Consequently, equity-holders' best response in the second to last period is to liquidate the project.

Using backward induction, this argument leads to the unique subgame perfect equilibrium outcome of this dynamic game in which equity-holders liquidate the project in the first period. Consequently, whenever $\delta I \geq L_1$, outside equity with prespecified expiration cannot be supported by threats of dismissal or liquidation.

Proposition 1. *No investor is willing to hold outside equity with a prespecified expiration date.*

Proof. See the Appendix.

As we have seen, neither the threat of liquidation nor the threat of dismissal can support outside equity with a prespecified expiration date. *The threat of liquidation fails* to support outside equity because equity-holders cannot commit *not* to exercise this threat in the last period. *The threat of dismissal fails* to support outside equity when there is a prespecified expiration date because this threat is not credible: investors whose claim has a prespecified expiration date are not prepared to replace unsuitable management when it is time to do so. Only those investors whose claim is of unlimited life can credibly threaten management with dismissal. When deciding whether or not to dismiss management, these investors compare a stream of future corporate earnings that is nondecreasing over time against the one-time cost of dismissing management. The stake of these investors in the company's future is large enough at any point in time to outweigh the cost of replacing unsuitable management.

Proposition 2. *The only outside equity that investors are willing to hold is of unlimited life.*

Proof. See the Appendix.

As Kreps (1990) has pointed out in his discussion of repeated games, an infinite horizon is equivalent to finite but indefinite horizon. Similarly, in the context here, unlimited life represents a *finite but indefinite life* rather than infinite life. A project has a finite but

indefinite life if its real options (growth opportunities) may run out in any period with positive probability. The distinction between finite life with a prespecified expiration date and finite but indefinite life is that in the latter case there is no single prespecified date T , at which the company goes out of business with probability 1.

Investors are willing to hold outside equity with unlimited life if it is incentive compatible (i) for the entrepreneur to pay dividends and to set aside depreciation allowances, and thereby retain future control and (ii) for outside equity-holders not to replace management if equilibrium dividend payments are made. One such (stationary) equilibrium is specified by the strategies σ^I , σ^M below. The equilibrium strategy σ^I for outside equity-holders is not to dismiss the entrepreneur-manager as long as the entrepreneur-manager has paid out equilibrium dividends and set aside sufficient funds for the timely replacement of the physical assets and to dismiss him immediately if he has failed to do so. The equilibrium strategy σ^M for the entrepreneur-manager and for potential new managers is to limit appropriation of private benefits of control so as to pay out equilibrium dividends and to set aside depreciation allowances in the first period and then period after period as long as no deviation has occurred. If a manager finds himself on the job following a deviation from the equilibrium policy then he keeps deviating period after period. It is worthwhile to point out here that if the cost of dismissal is prohibitively large so that equity-holders' long-run gains from enforcing the contract fall short of the potential cost of dismissing management, then outside equity may not be sustainable [as conditions (16)–(18) may fail to hold].

The incentive compatibility conditions associated with these equilibrium strategies (σ^I, σ^M) are presented below. Let $M_{v+x} = v + x - a - d_{v+x}$ and $M_{v-x} = v - x - a - d_{v-x}$ and let us focus on contracts that set $M_{v+x} \geq M_{v-x}$.¹¹ Then it is incentive compatible for the entrepreneur-manager to voluntarily limit private benefits of control and retain future control over the operation of the assets if for every realization of the cash flows he would pay out equilibrium dividends and set aside depreciation and thereby remain in office rather than divert cash flows and face dismissal in the next period.

The first two inequalities that follow represent the managerial incentive conditions when the investment is being made or replaced and when period 1 and period 2 cash flows become known to the

¹¹ This is by no means a restriction. Whenever our equilibrium conditions are satisfied, there is always a contract with the property that $M_{v+x} \geq M_{v-x}$, whereas there does not always exist a contract with the reverse property (consider the case when $v - x = a$). Consequently, contracts with the property $M_{v+x} \geq M_{v-x}$ weakly dominate all other equity contracts in the sense of Gale and Hellwig (1985). This property is only necessary for Inequality (1) to be a sufficient condition for Inequalities (2) and (3).

parties. The left side shows the payoff to the entrepreneur-manager in equilibrium. The right side represents the entrepreneur-manager's payoff if he announces no dividends and/or fails to set aside depreciation payments and is dismissed in the following period. If the left side exceeds the right side for all v_t , then the entrepreneur-manager's control is sustainable.

$$M_{v_t} + \delta M_{v-x} + \frac{\delta^2(M_{v+x} + M_{v-x})}{2(1-\delta)} \geq v_t; \quad (1)$$

$$M_{v_t} + \delta M_{v+x} + \frac{\delta^2(M_{v+x} + M_{v-x})}{2(1-\delta)} \geq v_t. \quad (2)$$

For every v_t , the next inequality represents the managerial incentive condition when the investment is ongoing. Since our model is not stationary,¹² the equity constraints are different when the investment is ongoing and when it is being replaced.

$$M_{v_t} + \frac{\delta(M_{v+x} + M_{v-x})}{2(1-\delta)} \geq v_t. \quad (3)$$

It is straightforward to see that condition (1) is sufficient for conditions (2) and (3) to hold. Consequently, the nonstationarity does not play a role in the equity conditions.

Similarly, it is incentive compatible for outside equity-holders to finance the project ex ante if they at least recover their investment:

$$\frac{\delta(d_{v+x} + d_{v-x})}{2(1-\delta)} \geq I. \quad (4)$$

The condition for the existence of our equilibrium dividend policy places a constraint on the cash flows relative to the investment outlay of the project.

2.2 Debt

It follows from Hart and Moore (1989) that two-period debt contracts cannot be written for the *one-time financing* of our two-period

¹² The nonstationarity of the equity model stems from the same two sources as that of the Hart and Moore (1989) model of debt: (i) as Figure 1 shows, liquidation values are different when the investment is ongoing and when it is being replaced; (ii) the information sets are different when the investment is ongoing and when it is being replaced. Worth noting is that outside equity would also be sustainable if the uncertainty about the cash flows were resolved period by period. In that case conditions (1) and (2) would collapse into condition (3), condition (4) would remain the same, and condition (14) would collapse into condition (15). Similar changes need to be adopted to conditions (16) through (21). The new sufficient conditions would be the equivalent of conditions (3) and (4).

project, since there is no mechanism to enforce payment at the end of the second period. The optimal contract for the *one-time financing* of our two-period project is a one-period debt. The expected payment on this contract must cover the initial investment and has to be sufficient to compensate investors for potential defaults. The entrepreneur-manager may default when realized cash flows are low and he is unable to make the payment. He may also default when current cash flows are high and future cash flows are low. In this case he could pay but would rather default.

Notice that, unlike outside equity, debt with a prespecified expiration date can be supported by the threat of liquidation in equilibrium. This is because *debt leaves ownership in the hands of management* and thereby commits investors not to liquidate the company unless payments have failed.

Let us illustrate the computation of the contractual debt payment for the one-time financing of our two-period project.¹³ Assume that $\delta(v + x) > v - x$. Recall that payments are to be made following the realization of period 1 cash flows when period 2 cash flows are known to both parties. First suppose that cash flows are higher in period 1 than the period 1 value of cash flows in period 2. Then, by threatening with foreclosure, the maximum investors can expect from the entrepreneur-manager is his valuation of the project, that is, the period 1 value of the period 2 cash flows. Consider next the situation wherein period 1 cash flows are lower than the period 1 value of period 2 cash flows. In this case, the entrepreneur-manager is cash flow constrained. The most investors can then guarantee themselves is a cash payment equal to the period 1 cash flows plus some value from liquidating a portion of the assets. The entrepreneur-manager would be willing to transfer the period 1 cash to investors, only if his valuation of the period 2 cash flows following the foreclosure is no less than the period 1 cash flows. Otherwise he would rather make no payment and let investors foreclose all the assets. Consequently, when period 1 cash flows are lower than the period 1 value of period 2 cash flows, the entrepreneur-manager's incentive-compatibility constraint determines the fraction of assets to be liquidated so that cash flows from the remaining assets make him just indifferent between transferring the period 1 cash flows to investors and facing a partial foreclosure or not paying at all and facing full foreclosure. In short, the maximum payment investors can expect from the entrepreneur-manager is the

¹³ The computation of the one-time financing of our two-period project closely follows Hart and Moore (1989). The projects here and there are slightly different, however. Hart and Moore (1989) only considered projects with deterministic cash flows in one period and uncertain cash flows in the other (uncertainty was limited to only one period).

smaller of either the period 1 cash flows or the period 1 value of the period 2 cash flows.

Investors are not willing to write longer-term debt contracts for the financing of the *replacement project* either. When writing a debt contract, investors avoid scheduling any repayment of I at the end of the economic life of the project and beyond. They match the maturity of the debt contract with the *life of the assets* (maturity matching) rather than with the continuation prospect of the project.¹⁴ Debt-holders avoid scheduling payments just before replacement becomes due since this is the very time when the asset has no value if default occurs. Since the entrepreneur-manager *controls the timing* of default, if he chooses to default, he would time his default when debt-holders are in their weakest bargaining position and would then renegotiate with them according to his terms.

To see how the argument works, suppose a payment is scheduled just before replacement becomes due, and the entrepreneur-manager chooses to default on this payment. Then, according to the rules of the game, he has the option to renegotiate. He offers to pay nothing, and the creditors either accept his offer and receive nothing, or liquidate the project and receive nothing. If the project is liquidated it is profitable for the entrepreneur-manager to restart it. Even if holders of this off-equilibrium debt contract commit to never providing financing for this entrepreneur in the future, the availability of another self-enforcing contract (i.e., one-period debt or unlimited life equity) makes it worthwhile for other investors, say finance companies or venture capitalists, to provide financing to the entrepreneur-manager. Holders of one-period debt will still face defaults in some states of the world, even in states where the cash flow constraint is not binding, but they will keep refinancing because they expect to break even. Proposition 3 summarizes this result.

Proposition 3. *The maturity of the equilibrium debt contract is shorter than the economic life of the project.*

Proof. See the Appendix.

Given the repetitive nature of the entrepreneur's project, Proposition 3 implies that all loans are made at the time when replacement becomes due and all debt payments are due at the end of the period immediately following the replacement. That is, the entrepreneur has

¹⁴ Investors match the maturity of the optimal debt contract with the life of the assets so that the longest-term debt they are willing to hold is one period shorter than the economic life of the project. In contrast, they match the maturity of outside equity with the continuation prospects of the project.

to pay back the debt in full in each odd-numbered period. Because of the two-period nature of the project, there is no distinction between long-term and short-term debt. Had the project an economic life of, say, three periods, both one-period and two-period debt contracts would arise as a consequence of Proposition 3.

This result critically depends on the liquidation value being zero at the end of the economic life of the project. *Positive salvage value* at the end of the cycle would give rise to two-period debt contracts in addition to one-period debt contracts in equilibrium. As long as the salvage value is smaller than L_2 , then two-period equilibrium debt contracts will feature a larger payment in the first period than in the second period. Renewable two-period debt may also be written in equilibrium.

However, an important distinction between the equilibrium design of debt and outside equity remains. No equilibrium debt contract extends payments beyond the economic life of the project: outside equity with unlimited life does. Outside equity specifies investors transferring I to the entrepreneur-manager in period 0 in exchange for payments *forever*.

The question naturally arises why outside investors, who are willing to hold outside equity with unlimited life, are *not* willing to hold long-term debt or unlimited life debt.¹⁵ The explanation lies in the different control rights implied by debt and equity. When the project is financed by outside equity, equity-holders have unconditional control rights: the right to terminate the project and the right to dismiss the entrepreneur-manager *independently* of the cash flows or any other financial variables. Having unconditional control rights, outside equity-holders can force the entrepreneur-manager to set aside sufficient depreciation allowances, even though depreciation charges are nonverifiable. The depreciation account makes the equity-holders' bargaining position particularly strong. In contrast, when the project is financed by debt, the entrepreneur-manager has the control rights in all states except default. Since the debt-holders' control rights are conditional on the entrepreneur-manager not making a verifiable payment, debt-holders cannot induce the entrepreneur-manager to set aside depreciation allowances. When the project is financed by

¹⁵ Unlimited life debt is defined as a perpetual bond. Debt-holders transfer I to the entrepreneur-manager in exchange for payments *forever*. The entrepreneur-manager has control rights unless default occurs. In the event of a default the parties may renegotiate. The debtor can make a single take-it-or-leave-it offer. If the creditors accept, the new agreement replaces the original one. If the creditors reject, then they have the right to liquidate the assets or to unilaterally forgive part of the debt. At this point the debtor can make a cash payment and the assets will be liquidated until either the remaining portion of the debt is paid off or all the assets have been liquidated.

debt, it is *not* incentive compatible for the entrepreneur-manager to set aside depreciation charges in equilibrium, so *debt financing induces management to follow a myopic investment strategy*.¹⁶ In the absence of the depreciation account, the value of the assets declines over the life of the equipment and so weakens the debt-holders' bargaining position. Consequently, *debtholders design the equilibrium contract so as to alleviate this debt-induced managerial myopia*: they match the maturity of the debt contract with the life of the assets and schedule declining payments over time.

The intuition behind the maturity-matching result is closely related to that of Myers (1977). In both cases it is recognized that investment policy is the discretionary choice of the manager. The analog of Myers' assumption that the manager's option to invest expires before debt-holders can take over is my assumption that it is the entrepreneur-manager who can restart the project following a liquidation. Notice that debt-holders are limited to liquidate the assets or to forgive the debt in our model. Worth noting is that even if debt-holders could dismiss management, this would only extend the range of feasible contracts by taking on some unlimited life equity aspects in the event of a default [Fluck (1997)]. Similarly, if the entrepreneur-manager were to face extensive delays before restarting his project after a default, or if debt-holders could force him to operate overlapping projects so that leaving the project would mean losing control of another project, then the entrepreneur-manager would be less inclined to default by choice, and longer-term debt contracts might also become supportable.

3. The Capital Structure Decision with Deterministic Cash Flows

The previous section established that investors are willing to hold debt with a maturity of one period and outside equity with unlimited life. The next step is to investigate the entrepreneur's choice of financing.

3.1 Raising debt

Suppose that v , the periodic cash flow of the project, is nonstochastic, that is, $x = 0$. It immediately follows from Hart and Moore (1989) that investors are willing to finance the project by debt only if $\delta^2 v \geq I$,

¹⁶ See Holmström (1982), Narayanan (1985), Stein (1989), Shleifer and Vishny (1990), and Goswami, Noe, and Rebello (1994) for recent research on managerial myopia. Debt can also make managers more focused and less interested in being empire builders as demonstrated by Jensen (1986), Hart and Moore (1995), and Zwiebel (1994).

provided that the liquidation value of the project, L_2 , is less than the funds needed. If there were no moral hazard problem, any project with $\delta v \geq I > \delta^2 v$ could also raise debt with maturity of one period. Because of the moral hazard problem, however, investors cannot enforce any payments at any point in time in excess of the current value of the entrepreneur-manager's expected future payoff at that point in time conditional on the continuation of the project. Since the entrepreneur-manager's valuation of the project is only δv when the repayment becomes due, the maximum investors can expect him to repay is the smaller of $\frac{I}{\delta}$ and δv .

3.2 Raising outside equity

After rewriting conditions (1) and (4) for the deterministic cash flow case, we get $\frac{M_v}{1-\delta} \geq v$ and $\frac{\delta d}{1-\delta} \geq I$, respectively. Using that $M_v = \delta v - d - a$ and solving for d , we obtain

$$\frac{(1-\delta)I}{\delta} \leq d \leq \delta v - a. \quad (5)$$

Then the necessary condition to raise outside equity becomes $\frac{(1-\delta)I}{\delta} \leq \delta v - a$. After substituting $\frac{\delta I}{1+\delta}$ for a , the equity financing condition becomes

$$v \geq \frac{(1-\delta)I}{\delta^2} + \frac{I}{1+\delta}. \quad (6)$$

The comparison of debt and outside equity financing conditions reveals that projects that are unable to raise debt may still raise outside equity.

Proposition 4. *If a project can raise debt financing then it can also raise outside equity financing but not vice versa.*

Proof. See the Appendix.

This result follows because debt is issued only if the smaller of period 1 and period 2 cash flows in present value terms exceed the investment outlay. Holders of the one-period equilibrium debt contract receive a single payment in period 1 and are unable to capture any period 2 cash flows (or those that remain from period 2 cash flows after partial liquidation of the assets following the realization of period 1 cash flows). Because of the unlimited life nature of equity, equity-holders can benefit from both period 1 and period 2 cash flows. Since outside equity can spread the managerial moral hazard risk across periods, whereas debt can not, some projects that fail to raise debt may still issue outside equity.

3.3 Choosing between debt and outside equity

When investors are willing to hold both debt and outside equity, the entrepreneur-manager has the choice of which security to issue for financing the firm. The entrepreneur-manager chooses the type of financing that maximizes his expected payoff. In the case of debt financing, the present value of the entrepreneur-manager's payoff over the long run is

$$\frac{\delta v(1 + \delta) - I}{1 - \delta^2}. \quad (7)$$

When outside equity is issued, the entrepreneur-manager's payoff is computed from condition (5) as

$$(1 - \delta)v \leq M_v \leq v - a - \frac{(1 - \delta)I}{\delta}. \quad (8)$$

Since investors are Bertrand competitors, they are willing to finance the project even if all rents accrue to the manager, that is, if $M_v^* = v - a - \frac{(1 - \delta)I}{\delta}$. Comparing the managerial payoffs when debt or outside equity is issued, we have

$$\frac{\delta v(1 + \delta) - I}{1 - \delta^2} = \frac{\delta M_v^*}{1 - \delta}. \quad (9)$$

Hence the entrepreneur-manager is indifferent between issuing debt and issuing equity when there is demand for both. Consequently, equilibrium returns are equalized across securities. Proposition 5 summarizes the result.

Proposition 5. *Whenever investors are willing to hold both debt and outside equity, then the entrepreneur-manager is indifferent between the two securities. He may as well issue either one or a mix of the two.*

Proof. See the Appendix.

4. The Capital Structure Decision with Stochastic Cash Flows

4.1 Raising debt

In this section I investigate the conditions under which projects with stochastic cash flows can raise debt financing. Since my projects are more complex than those considered by Hart and Moore (1989), I cannot apply their debt-financing constraint directly. Since debt-holders can only assure a payment that is the smaller of (i) the present value

of the future cash flows for the entrepreneur and (ii) the current cash flows plus the maximal amount that can be raised by liquidating assets so that cash flows from the remaining assets make the entrepreneur-manager just indifferent to transferring the current cash flows as a payment, the debt-financing condition will take the following form:

$$F \equiv \delta E \left(\min \left\{ \delta \tilde{v}_2, \max \left\{ \tilde{v}_1, \tilde{v}_1 + \left(1 - \frac{\tilde{v}_1}{\delta \tilde{v}_2} \right) \delta L_2 \right\} \right\} \right) \geq I. \quad (10)$$

To see how the cash flows affect the entrepreneur-manager's access to debt financing I investigate the monotonicity properties of condition (10). After computing the minima for each of the four possible realizations of cash flows and taking the expected value, the investors' payment is obtained:

$$F = \begin{cases} \delta^2 v & \text{if } \delta(v+x) \leq v-x \\ \delta \left[\frac{1}{4}(1+\delta)(v-x) + \frac{1}{2}\delta v \right. \\ \quad \left. + \frac{1}{4} \left(1 - \frac{v-x}{\delta(v+x)} \right) \delta L_2 \right] & \text{otherwise.} \end{cases} \quad (11)$$

Notice that this condition depends on both the first and the second moment of the random cash flow variable. Hence, for fixed v , I , L_2 , and δ , F is decreasing in the standard deviation of the periodic cash flow provided that

$$\frac{(v+x)^2}{vL_2} \geq \frac{2}{(1+\delta)}. \quad (12)$$

The intuition behind the condition is as follows. If the standard deviation of the cash flow is low relative to the discount factor, so that $x \leq \frac{v(1-\delta)}{1+\delta}$, then the present value of the high (as well as the low) realization of the cash flow falls short of the current value of the low realization. If this is the case, then investors expect to receive the smaller of $\frac{I}{\delta}$ and δv when payment becomes due. The project can raise debt if and only if $\delta v \geq \frac{I}{\delta}$.

As the standard deviation of the cash flow increases beyond $\frac{v(1-\delta)}{1+\delta}$, the expected present value of the incentive-compatible payments on debt begins to fall since $\delta(v+x) \geq v-x$ is a sufficient condition for Inequality (12) (see the Appendix). Then the value of x that solves condition (10) for equality $x_d(v, I, L_2, \delta)$ is the cutoff for debt-financing of project (v, I, L_2) . The next proposition summarizes the result. The proof can be derived from the preceeding steps.

Proposition 6. *For given v , I , L_2 , and δ , positive net present value projects with standard deviation exceeding the cutoff level $x_d(v, I, L_2, \delta)$ cannot raise debt financing.*

Note that $x_d(v, I, L_2, \delta)$ depends on L_2 . Hence $x_d(v, I, L_2, \delta)$ would be higher if the option to abandon the project had value for debt-holders in some states of the world, that is, if $L_2 > v - x$. This suggests that firms with high tangible asset value are more likely to raise debt than those with low tangible asset value.

4.2 Raising outside equity

In this section I investigate the conditions under which projects with stochastic cash flows can raise outside equity financing. I show that a project that is unable to raise debt may still be able to raise outside equity. For the purpose of investigating the demand for debt versus outside equity, conditions (1) and (4) can be replaced by a sufficient condition that guarantees the outside equity financing of a stochastic cash flow project in equilibrium.

Lemma 1.

$$\delta v - a - \frac{\delta(1 - \delta)(2 - \delta)}{2 - \delta(2 - \delta)} x \geq \frac{(1 - \delta)I}{\delta} \quad (13)$$

is a sufficient condition for (1) and (4) to hold.

Proof. See the Appendix.

Condition (13) shows that, depending on the riskiness of the cash flows, a project may or may not raise outside equity. As the next proposition states, it all depends on whether the standard deviation of the cash flows exceeds $x_e(v, I, \delta)$, the value of x that solves condition (13), as an equality. The proof is straightforward and is omitted.

Proposition 7. *For given v , I , and δ , positive net present value projects with standard deviations at or below $x_e(v, I, \delta)$ can raise outside equity.*

The next question to investigate is whether a risky project that is turned down for debt financing can still raise outside equity financing. Here I consider only projects whose deterministic cash flow equivalent can raise debt financing. The deterministic cash flow equivalent of a project is a two-period deterministic cash flow project whose cash flow is equal to the expected periodic cash flow of the respective stochastic project. A necessary condition for a risky project to raise financing is that its deterministic cash flow equivalent can secure financing.

Proposition 8. *A risky project that is unable to raise debt may still raise outside equity, provided that $\delta > .7374$.*

Proof. See the Appendix.

Note that even though $\delta > .7374$ is only a sufficient condition (see the Appendix), it includes most reasonable quarterly (or even annual) discount factors. Interestingly enough, whenever $\delta > .7374$, outside equity-holders are willing to bear more risk than debt-holders as measured by the variability of the cash flows. Notice, however, that the risk from variability of cash flows is only part of the risk borne by securityholders. Another component of the risk borne by securityholders is the risk associated with managerial moral hazard. We have shown here that *outside equity can spread this moral hazard risk over time, whereas debt concentrates it on the payback period*. Since outside equity has a better technology for spreading moral hazard risk, *more cash flow risk can be absorbed by outside equity*.

The finding here can also be interpreted as a prediction on the timing of firms' first public equity relative to their first public debt issue, since our key assumptions—costly state verification of managerial wrongdoing in a court of law, and easily accessible information to investors—apply to companies that tend to issue publicly traded securities. Consistent with empirical evidence that companies are four times as large when they have their first public debt issue as when they have their first public equity issue [Carey et al. (1993)], our model predicts that public equity issues are likely to precede firms' first public debt issue.

Worth mentioning is that if the discount factor is very low, then some stochastic cash flow projects may be able to raise debt but not outside equity. The reason is that unlimited life equity is potentially more sensitive to changes in the discount rate than one-period debt. In our particular case, whenever a project is financed by equity, then the entrepreneur-manager must receive high enough expected payoff over the long horizon so as to compensate him not to divert the cash flows in any state. In particular, he must be willing to retain sufficient cash flows for the renewal of the assets even when cash flows are low, when, presumably, his current private benefits are low. In contrast, in the case of debt financing, the entrepreneur-manager does not need to retain funds, and there is at most a one-period lag between the time investors are paid and the time the entrepreneur-manager is paid. Consequently, whenever the discount factor is very low, then a project that cannot raise outside equity may still raise debt.

4.3 Choosing between debt and equity

In the previous section I established that projects that can raise debt can also raise outside equity. When investors are willing to hold both,

the entrepreneur can decide which security to issue. In the context of deterministic cash flow projects we have seen that the entrepreneur-manager is indifferent between debt and equity and may issue one or both as long as he gets all rents from the project. This is not necessarily the case with stochastic cash flow projects. As is seen from condition (11), whenever $\delta(v + x) > v - x$, then debt financing involves inefficient liquidation in equilibrium. Since investors receive I in both debt and equity financing, it is the manager who suffers as a result of liquidation. Hence, whenever $x > \frac{v(1-\delta)}{1+\delta}$, the entrepreneur-manager strictly prefers issuing outside equity to issuing debt. Otherwise he is indifferent between the two and may issue one or both. The next proposition summarizes the result. The proof is straightforward and is omitted.

Proposition 9. *For given v , I , L_2 , δ , and $x > \frac{v(1-\delta)}{1+\delta}$ that satisfy conditions (10) and (13), debt financing involves inefficient liquidation in equilibrium. Hence the entrepreneur-manager will finance these projects by outside equity.*

Consequently, when investors are willing to hold both debt and outside equity, only stable projects with standard deviation $x \leq \frac{v(1-\delta)}{1+\delta}$ will use debt financing. These projects may also use outside equity or a mix of debt and outside equity.¹⁷ Projects with higher cash flow variability $\frac{v(1-\delta)}{1+\delta} < x \leq x_e(v, I, \delta)$ use only outside equity financing. For projects with cash flow variability exceeding $x_e(v, I, \delta)$, neither debt nor outside equity is available. These projects must use other means of financing such as inside equity. Consistent with empirical evidence, this model predicts that debt-equity ratios will be higher in industries where cash flow variability is low relative to industries where cash flow variability is high.

5. Conclusion

This article resolves a long-standing puzzle in the security design literature, namely, that no investor is willing to hold outside equity when management has the ability to divert cash flows as private benefits and when managerial manipulation of cash flows is costly to verify. I have shown here that investors are willing to hold outside equity but with unlimited life only, the very outside equity that corporations issue in practice. In contrast, all debt contracts have prespecified maturity dates in equilibrium. Since unlimited life equity presupposes a

¹⁷ Notice that the constraint $x \leq \frac{v(1-\delta)}{1+\delta}$ depends on δ . Hence the indifference region widens (shrinks) as δ decreases (increases).

project with indefinite growth opportunities, my theory implies that investors practice a particular form of maturity matching: they match the maturity of debt with the life of the physical assets and the maturity of outside equity with the growth prospects of the company.

Furthermore, I have demonstrated that besides debt, outside equity with unlimited life is the financing choice of positive net present value projects. Whenever a project can raise debt, it can also raise outside equity but not vice versa. Depending on the characteristics of their projects, entrepreneurs who cannot raise debt may still raise outside equity. In particular, when cash flows are stable, then the entrepreneur may issue debt, outside equity, or a mix of the two. If cash flow variability is high so that no funds can be raised by issuing debt, investors may still be willing to provide outside equity financing.

This theory also offers interesting insights for other types of securities that firms use, such as preferred stocks and income bonds.¹⁸ Since failure to pay dividends on preferred stock or interest on income bonds cannot force the firm into bankruptcy, preferred stocks and income bonds appear to be incompatible with nonverifiability of cash flows and managerial ability to divert cash flows as private benefits. Interestingly, however, investors would be willing to hold these securities provided that they are issued simultaneously or subsequently with outside common equity of unlimited life. Since preferred stockholders and income bondholders have a higher priority claim, common equity-holders can only satisfy their claim after preferred stockholders and income bondholders have satisfied theirs. Thus preferred stockholders and income bondholders can rely on outside common equity-holders to discipline management. This arrangement is sustainable as long as the preferred stock or income bond issue is small relative to common equity.

A related and important theoretical question is to analyze financing decisions of firms that issue both debt and equity simultaneously or *subsequently*.¹⁹ The first steps in this direction were carried out in Zender (1991). Zender developed debt and *inside equity* as optimal

¹⁸ For an interesting theory of income bonds see Allen and Gale (1992). In a model of adverse selection where the cost of distorting the measurement system is positively correlated with firm type, the authors show that bad firms are more likely to offer securities such as income bonds, whose payments are contingent on earnings. In addition, Allen and Gale establish that the equilibrium where all firms offer a noncontingent contract is universally divine in the sense of Banks and Sobel (1988).

¹⁹ Another related interesting issue is how partnerships and corporations differ in their design of control rights. Subsequent to our work, Myers (1996) contrasts a model of a corporation where stockholders have unconditional control rights with a partnership where a contract limits outside investors' rights for a definite period. Myers finds that even though outsiders realize some gains from having unrestricted control rights, dividends are generally lower in corporations than in partnerships because the costs of a collective action reduce outside stockholders' bargaining power.

instruments in a model where cash flows and control rights were allocated to investors endogenously. Zender addressed the question why residual claimants are assigned control rights while claimants with rights to a fixed cash flow stream are denied direct control over decision making. Zender showed that when investment decisions must be made by a single party, then debt-holders' cash flows are fixed in order to provide the equity-holder with efficient incentives for investment.

Having established the optimality of outside equity with unlimited life in this article, our next challenge is to revisit the optimal financing decisions of firms that have issued outside equity with unlimited life and are beyond their initial financing stage. This problem is beyond the scope of this article and is largely awaiting future research. One paper pursuing this direction is Fluck and Lynch (1997), which focuses on the financing decisions of firms that merge to exploit financial synergies. Fluck and Lynch develop a theory of mergers and divestitures wherein the motivation for mergers stems from the inability of firms to finance marginally profitable, possibly short-horizon projects as stand-alone entities due to agency problems between managers and potential claimholders based on the model developed in this article. A conglomerate merger can be viewed as a technology that allows marginally profitable projects, which investors would otherwise reject, to obtain financing. Their theory is well suited to explain the empirical evidence that diversified firms are less valuable than more focused, stand-alone entities and sheds some new light on the recent spate of mergers between biotechnology and pharmaceutical companies.

Appendix

Proof of Proposition 1. We prove by contradiction that, when outside equity has a prespecified expiration date, neither the threat of liquidation nor the threat of dismissal can induce the entrepreneur-manager to pay out dividends along the path of play in any Nash equilibrium. Suppose that in some Nash equilibrium, the entrepreneur-manager pays dividends at some stages with positive probability. Let T be the last stage at which this is so; that is, there is zero probability of cooperation along the equilibrium path in stages $T + 1, T + 2, \dots, N$, where N is the expiration date on equity. Now examine the incentives of the entrepreneur-manager who is meant to cooperate along the path of play in stage T . He will do no better than zero in the remaining stages by following the equilibrium, since investors will not retain him subsequently along the equilibrium path. By not paying out any dividends in stage T and in every subsequent stage, the entrepreneur-

manager does better immediately than if he follows the equilibrium prescription, and he can do no worse than zero subsequently. Hence the entrepreneur-manager will not cooperate in stage T , and we have a contradiction. We can also reach a contradiction by examining the incentives of investors who are meant to cooperate along the path of play in stage T . ■

Proof of Proposition 2. To establish that a dividend policy is an equilibrium we need to check whether (i) the entrepreneur-manager is willing to pay equilibrium dividends and to set aside depreciation, (ii) investors are willing to finance the project ex ante in exchange for equilibrium dividends, (iii) investors are willing to keep the entrepreneur-manager as long as equilibrium dividends are paid and depreciation is properly set aside, (iv) investors are willing to dismiss the entrepreneur-manager if he failed to pay equilibrium dividends and/or failed to set aside a depreciation account, and (v) the entrepreneur-manager keeps diverting all cash flows after any history of deviation. The corresponding equilibrium conditions follow.

(i) The entrepreneur-manager is willing to pay equilibrium dividends and to set aside depreciation in exchange for staying in office in the future if conditions (1), (2), and (3) hold.

(ii) Investors are willing to finance the project ex ante in exchange for equilibrium dividends if condition (4) is satisfied.

(iii) It is incentive compatible for outside equity-holders not to liquidate the company in periods when the investment is being replaced and when period 1 and period 2 cash flows become known to the parties, as long as equilibrium dividends have been paid out and a depreciation account has been set aside, if for every $v_1 = v - x, v + x$ and $v_2 = v - x, v + x$,

$$d_{v_1} + \delta d_{v_2} + \frac{\delta^2(d_{v+x} + d_{v-x})}{2(1-\delta)} \geq L_1. \quad (14)$$

Similarly, it is incentive compatible for outside equity-holders not to liquidate the company in periods when the investment is ongoing, as long as equilibrium dividends have been paid out and a depreciation account has been set aside, if for every $v_1 = v - x, v + x$ and $v_2 = v - x, v + x$,

$$d_{v_2} + \frac{\delta(d_{v+x} + d_{v-x})}{2(1-\delta)} \geq L_2 + a. \quad (15)$$

It is straightforward to see that condition (4) is sufficient for Inequalities (14) and (15) to hold, provided that $L_1 \leq \delta I$ and $L_2 + a \leq \delta I$.

For the entrepreneur-manager's control to be sustainable, the potential incoming manager needs to have rational beliefs about equity-

holders. This condition assures that equity-holders cannot profit from dismissing the entrepreneur-manager following an equilibrium payout. For this purpose it is sufficient to assume that the new manager pays the same dividends as his predecessor does in equilibrium.

(iv) It is incentive compatible for outside equity-holders to replace the entrepreneur-manager who has failed to comply with the equilibrium in the period when the investment was being replaced and when the parties learned the realization of the period 1 and period 2 cash flows, if for every v_1 and v_2 , taking values $v - x$, $v + x$,

(a) investors are better off repeating the project and replacing the manager than repeating the project and keeping the entrepreneur-manager who would continue to deviate period after period in equilibrium, that is,

$$\hat{d}_{v_2}^- + \frac{\delta(\hat{d}_{v+x} + \hat{d}_{v-x})}{2(1-\delta)} - \frac{a}{\delta} \geq 0; \quad (16)$$

(b) investors are better off repeating the project and replacing the manager than liquidating the project and receiving L_2 (recall that no funds were set aside for depreciation in the prior period), that is,

$$\hat{d}_{v_2}^- + \frac{\delta(\hat{d}_{v+x} + \hat{d}_{v-x})}{2(1-\delta)} - \frac{a}{\delta} \geq L_2; \quad (17)$$

(c) investors are better off repeating the project and replacing the manager than replacing the manager and abandoning the project and thereby receiving the same payment as in a limited life equity contract, that is,

$$\hat{d}_{v_2}^- + \frac{\delta(\hat{d}_{v+x} + \hat{d}_{v-x})}{2(1-\delta)} - \frac{a}{\delta} \geq 0. \quad (18)$$

It is incentive compatible for outside equity-holders to replace the entrepreneur-manager who has failed to comply with the equilibrium in the period when the investment was ongoing, if for every v_1 and v_2 , taking values $v - x$, $v + x$,

(a) investors are better off repeating the project and replacing the manager than not repeating the project and receiving the liquidation value of the project (and the depreciation account) next period:

$$\frac{\delta(\hat{d}_{v+x}^- + \hat{d}_{v-x}^-)}{2(1-\delta)} + \frac{\delta^2(\hat{d}_{v+x} + \hat{d}_{v-x})}{2(1-\delta)} - a \geq a; \quad (19)$$

(b) investors are better off repeating the project and replacing the

manager than reinvesting and liquidating the project, that is,

$$\frac{\delta(\hat{d}_{v+x}^- + \hat{d}_{v-x}^-)}{2(1-\delta)} + \frac{\delta^2(\hat{d}_{v+x} + \hat{d}_{v-x})}{2(1-\delta)} - a \geq -a + \delta L_1; \quad (20)$$

(c) investors are better off repeating the project and replacing the manager than repeating the project and keeping the entrepreneur-manager who would continue deviating period after period in equilibrium, that is,

$$\frac{\delta(\hat{d}_{v+x}^- + \hat{d}_{v-x}^-)}{2(1-\delta)} + \frac{\delta^2(\hat{d}_{v+x} + \hat{d}_{v-x})}{2(1-\delta)} - a \geq -a. \quad (21)$$

(v) Trivially holds. Given that he faces dismissal, it is incentive compatible for the entrepreneur-manager to divert the cash flows following a deviation.

Next we show that condition (4) is sufficient for conditions (16) through (21). Recall that the new manager pays the same dividend as his predecessor and substitute $\hat{d}$ for d in condition (4). First, conditions (19) and (21) trivially hold. Since $I \geq \frac{a}{\delta}$, conditions (16) and (18) obviously hold. Since $I > L_1$, condition (20) also holds. Recall from the basic model that $\delta I > L_2 + a$. Consequently, $I > \frac{L_2}{\delta} + \frac{a}{\delta}$, so condition (17) also holds. ■

Proof of Proposition 3 (by contradiction). Suppose debt holders agree to hold a debt contract with a maturity equal to or longer than the economic life of the project. We prove that the entrepreneur-manager will choose to default on this contract in equilibrium. Let M^∞ denote the present discounted value of the private benefits the entrepreneur-manager can guarantee himself in the future in equilibrium by issuing equity (see the proof of Proposition 2 for the equilibrium conditions).

Consider the entrepreneur-manager's decision whether or not to default at date 2 on a debt contract with maturity $T \geq 2$ issued at date 0. (This decision is relevant as long as the entrepreneur-manager avoided full foreclosure at date 1.) Next we compute the entrepreneur-manager's payoff associated with his date 2 decision whether or not to default.

Decision alternative 1

By defaulting on the debt payment at date 2 and by failing to set aside depreciation allowances at both dates 1 and 2, the entrepreneur-manager can guarantee himself $\tilde{v}_2 + M^\infty$ at date 2. To see that the entrepreneur-manager can keep $\tilde{v}_2$, first recall that in the event of a default on the second payment the entrepreneur-manager can make

a take-it-or-leave-it offer to debt-holders. Debt-holders would be indifferent between accepting the entrepreneur-manager's offer of no payment at all, foreclosing the assets with liquidation value zero, or forgiving the debt. Indeed, the entrepreneur-manager can hold onto $\tilde{v}_2$.

To establish that the entrepreneur-manager can still guarantee himself M^∞ in addition to $\tilde{v}_2$ if the project is liquidated, first recall that (i) it is the entrepreneur-manager who can restart the project following a liquidation; and (ii) investors are willing to finance any project if they expect to break even. Then it remains to show that any project that is profitable enough to pay off an off-equilibrium debt contract with maturity $T \geq 2$ is able to raise outside equity. We proceed in three steps: first, we prove it for debt contracts with maturity $T > 2$, T finite; second, for debt contracts with maturity $T = 2$; and third, for debt contracts with unlimited maturity.

Debt contract 1. Consider first a debt contract with maturity $T > 2$. Such a contract requires that the entrepreneur-manager voluntarily set aside depreciation payments. For a project to raise debt, it is a *necessary condition* that the entrepreneur-manager prefer to comply with the contract rather than run away with the cash flows regardless of consequences (the worst of which in my model is to get zero payment forever):

$$M_{v-x}^0 + \delta M_{v-x}^1 + \sum_{t=2}^{\infty} \delta^t \frac{M_{v-x}^t + M_{v+x}^t}{2} \geq v - x; \quad (22)$$

$$M_{v+x}^0 + \delta M_{v-x}^1 + \sum_{t=2}^{\infty} \delta^t \frac{M_{v-x}^t + M_{v+x}^t}{2} \geq v + x. \quad (23)$$

In the framework of our basic model, consider now the marginal project with respect to this contract, one that is just able to provide the managerial incentive payments [satisfying conditions (22) and (23)], in addition to returning debt-holders' investment and in addition to providing for the internal financing on our off-equilibrium debt contract with maturity $T > 2$. This marginal project would satisfy conditions (22) and (23) for equality and would pay all remaining funds beyond depreciation to investors in periods of self-financing and would pay all funds to investors beyond managerial incentive payments in periods of no internal financing (the last cycle before T). So a necessary condition for this marginal project to raise debt with $T > 2$ is

that there exist (M_{v-x}, M_{v+x}) such that

$$M_{v-x} + \delta M_{v-x} + \delta^2 \frac{M_{v-x} + M_{v+x}}{2(1-\delta)} \geq v - x; \quad (24)$$

$$M_{v+x} + \delta M_{v-x} + \delta^2 \frac{M_{v-x} + M_{v+x}}{2(1-\delta)} \geq v + x. \quad (25)$$

Notice that conditions (24) and (25) are equivalent to condition (1).

A necessary condition for this marginal project to meet debt payments is

$$I \leq \sum_{t=1}^T \delta^t E_{\tilde{v}} P^e(\tilde{v}) + \delta^T I. \quad (26)$$

The first term on the right side is the sum of the payments to investors that can be met in any period [where $P^e(\tilde{v})$ is the actual (possibly renegotiated) payment to investors given cash flow realization $\tilde{v}$ and $E_{\tilde{v}}$ is the expectation operator with respect to $\tilde{v}$]. The second term is the extra payment (the equivalent of the depreciation account) that can be made during the last cycle when the need for internal financing is over.

Reorganizing this condition, we get

$$I \geq \frac{\delta E_{\tilde{v}} P^e(\tilde{v})}{1-\delta}, \quad (27)$$

which will hold as equality for my marginal project. Notice that condition (27) is the equivalent of condition (4).

Consequently, conditions (1) and (4) are necessary to raise any (off-equilibrium) debt with maturity $T > 2$ for the marginal project. Recall from the proof of Proposition 2 that, given the assumptions of our basic model, Inequalities (1) and (4) are also sufficient conditions to raise outside equity. Thus the entrepreneur-manager can always guarantee outside equity financing for his marginal project following a default on a debt contract with maturity $T > 2$. Obviously any project that is more profitable than the marginal project is also able to raise outside equity. Consequently, given the assumptions of the basic model, the entrepreneur-manager can always guarantee outside equity financing following a default on a debt contract with maturity $T > 2$.

Debt contract 2. Consider secondly a debt contract with maturity $T = 2$. Such a contract does not require that the entrepreneur-manager voluntarily set aside depreciation payments. Consider now a marginal project with respect to this contract that satisfies the assumptions of the basic model. This marginal project is defined so that it is just able

to provide the managerial incentive payments in addition to returning debt-holders' investment.

A necessary condition for this marginal project to raise debt with $T = 2$ is that there exists (M_{v-x}, M_{v+x}) such that Equations (24) and (25) are satisfied for at least equality. A necessary condition for this marginal project to meet debt payments is

$$I \leq \delta(1 + \delta)E_{\tilde{v}}P^e(\tilde{v}), \quad (28)$$

where $P^e(v - x) = v - x - M_{v-x}$ and $P^e(v + x) = v + x - M_{v+x}$ for the marginal project.

For the same marginal project to raise outside equity, the entrepreneur-manager must be willing and able to internally finance future projects. Recall from the proof of Proposition 2 that given the assumptions of the basic model, Inequalities (1) and (4) are sufficient conditions to raise outside equity. Because of the need for internal financing in intermediate periods, recall that $d_{v-x} = v - x - a - M_{v-x}$ and $d_{v+x} = v + x - a - M_{v+x}$.

To see whether the marginal project that can raise debt with maturity $T = 2$ can raise outside equity with unlimited life, we need to compare the size of the payments each contract requires over a cycle of the marginal project's life. Since the (minimum) managerial incentive payments are the same no matter what contract is used to finance the marginal project, it is sufficient to compare the payments to investors and those set aside for depreciation purposes under each contract over the same cycle. In the case of the debt contract with maturity $T = 2$, the entrepreneur has to pay back investors I in each cycle, with no internal financing involved. In the case of outside equity with unlimited life the entrepreneur-manager has to come up with $\delta E_{\tilde{v}}d_{\tilde{v}} + \delta^2 E_{\tilde{v}}d_{\tilde{v}}$ in each cycle plus $\delta^2 I$ in depreciation payments in each cycle. Since $E_{\tilde{v}}d_{\tilde{v}}$ solves $\frac{\delta E_{\tilde{v}}d_{\tilde{v}}}{1-\delta} = I$ (recall that investors are willing to finance the project if they break even), we get $\delta E_{\tilde{v}}d_{\tilde{v}} + \delta^2 E_{\tilde{v}}d_{\tilde{v}} = (1 - \delta)I + \delta(1 - \delta)I$. So, in the case of outside equity with unlimited life, the entrepreneur-manager has to come up with $(1 - \delta)I + \delta(1 - \delta)I + \delta^2 I$ in each cycle. This sum is also equal to I .

Consequently, for our marginal project the necessary conditions to raise debt with maturity $T = 2$ are sufficient conditions to raise outside equity, provided that the assumptions of the basic model are met. Thus the entrepreneur-manager can always guarantee outside equity financing for his marginal project following a default on a debt contract with maturity $T = 2$. Obviously, any project satisfying the assumptions of the basic model that is more profitable than this marginal project is also able to raise outside equity. Consequently, given the assumptions of the basic model, the entrepreneur-manager can always

guarantee outside equity financing following a default on a debt contract with maturity $T = 2$.

Debt contract 3. Third, consider a debt contract with unlimited maturity. Such a contract requires that the entrepreneur-manager voluntarily set aside depreciation payments. Consider a marginal project with respect to this contract which satisfies the assumptions of the basic model. This marginal project is defined so that it is just able to provide the managerial incentive payments in addition to returning the investment of holders of this debt contract and in addition to providing for the internal financing of the project.

Following the steps taken in the case of debt contract 1, it is straightforward to show that Inequalities (1) and (4) are necessary conditions to raise any (off-equilibrium) debt with unlimited maturity for the marginal project. Recall from the proof of Proposition 2 that, given the assumptions of the basic model, Inequalities (1) and (4) are also sufficient conditions to raise outside equity. Thus the entrepreneur-manager can always guarantee outside equity financing for his marginal project following a default on a debt contract with unlimited maturity. Obviously any project that is more profitable than the marginal project is also able to raise outside equity. Consequently the entrepreneur-manager can always guarantee outside equity financing following a default on a debt contract with unlimited life.

This establishes that the entrepreneur-manager can guarantee himself M^∞ in addition to $\tilde{v}_2$ if the project is liquidated following a default on payment at date 2. Consequently, by defaulting on the debt payment at date 2 and by failing to set aside depreciation allowances at both dates 1 and 2, the entrepreneur-manager can guarantee himself $\tilde{v}_2 + M^\infty$ at date 2.

Decision alternatives 2, 3, and 4

Similar reasoning establishes that by defaulting on the debt payment at date 2 and by failing to set aside depreciation allowances at date 2 but making it at date 1 (decision alternative 2), or by defaulting on the debt payment at date 2 while setting aside depreciation charges at both dates (decision alternative 3), or by defaulting on the debt payment at date 2 and by failing to set aside depreciation allowances at date 1 but making it at date 2 (decision alternative 4), the entrepreneur-manager can guarantee himself less than by defaulting on the debt payment at date 2 and by failing to set aside depreciation allowances at both dates 1 and 2. In particular, the entrepreneur-manager cannot guarantee himself the full $\tilde{v}_2$ in addition to M^∞ in the former three cases (decision alternatives 2, 3, and 4).

Decision alternatives 5, 6, 7, and 8

Alternatively, by not defaulting on the debt contract at time 2, the entrepreneur-manager can only guarantee himself $\tilde{v}_2 - P_2 + M^\infty$ provided that he has not set aside any depreciation charges at either date (decision alternative 5). Alternatively, by not defaulting on the debt contract at time 2 he can guarantee himself *at most* $\tilde{v}_2 - P_2 + M^\infty$ if he has set aside depreciation charges at date 1 but not at date 2 (decision alternative 6). Similarly, by setting aside depreciation charges at both dates (or at date 2 but not at date 1), the entrepreneur-manager can guarantee himself *at most* $\tilde{v}_2 - P_2 - a + M^\infty$ (decision alternative 7 and 8).

Notice that decision alternative 1 yields higher payoff than any of the other decision alternatives. Consequently, the entrepreneur-manager will default on the debt payment at time 2 and will not set aside any funds for the renewal of the assets, assuming he has avoided full foreclosure at date 1. (Obviously the entrepreneur-manager will fail to make the second payment on the debt contract if he has already faced full foreclosure at date 1.)

Consequently, no debt contract with maturity as long as or longer than the economic life of the project is incentive compatible for the creditors in the first place. ■

Proof of Proposition 4. The debt-financing condition is $v \geq I/\delta^2$. The equity-financing condition takes the form $v \geq \frac{(1-\delta)I}{\delta^2} + \frac{I}{1+\delta}$. Since $I/\delta^2 > \frac{(1-\delta)I}{\delta^2} + \frac{I}{1+\delta}$, a project that can raise equity is not always able to raise debt. ■

Proof of Proposition 5. Since $M_v^* = v - a - (1-\delta)I/\delta$, $\frac{\delta v(1+\delta)-I}{1-\delta^2} = \frac{\delta M_v^*}{1-\delta}$. ■

Proof that $\delta(v+x) \geq v-x$ is a sufficient condition for Inequality (12). To see that $\delta(v+x) \geq v-x$ is a sufficient condition for Inequality (12) let us reorganize it as $\frac{\delta(v+x)}{v-x} \geq 1$, that is, $\delta \geq \frac{(v-x)}{v+x}$ or $1+\delta \geq \frac{2v}{v+x}$. Taking the reciprocal of both sides and multiplying them by 2, we get $\frac{2}{1+\delta} \leq \frac{v+x}{v}$. Multiplying the right side of the latter inequality by $\frac{\delta(v+x)}{v-x}$, a number that is greater than or equal to 1 (see above), preserves the inequality sign and obtains $\frac{2}{1+\delta} \leq \frac{\delta(v+x)^2}{v(v-x)}$. Since $\delta \leq 1$ and $L_2 \leq v-x$, Inequality (12) holds. ■

Proof of Proposition 7. Investors are willing to hold outside equity financing if there exists a pair of dividends (d_{v+x}, d_{v-x}) such that conditions (1) and (4) hold. Rearranging condition (1) and substituting

for v_t , we get

$$2(1 - \delta)(1 + \delta)M_{v-x} + \delta^2(M_{v+x} + M_{v-x}) \geq 2(1 - \delta)(v - x); \quad (29)$$

$$2(1 - \delta)M_{v+x} + 2\delta(1 - \delta)M_{v-x} + \delta^2(M_{v+x} + M_{v-x}) \geq 2(1 - \delta)(v + x), \quad (30)$$

that is,

$$(2 - \delta^2)M_{v-x} + \delta^2M_{v+x} \geq 2(1 - \delta)(v - x), \quad (31)$$

$$(2 - \delta(2 - \delta))M_{v+x} + \delta(2 - \delta)M_{v-x} \geq 2(1 - \delta)(v + x). \quad (32)$$

It is straightforward to see that the fraction of cash flows sufficient to guarantee the cooperation of the entrepreneur-manager in the deterministic cash flow case is no longer sufficient in the stochastic cash flow case. We solve for the entrepreneur-manager's payoff by setting M_{v-x} equal²⁰ to the fraction of cash flows that is sufficient to guarantee the cooperation of the entrepreneur-manager in the deterministic cash flow case (see Section 3.2). By setting $M_{v-x} = (1 - \delta)(v - x)$ and setting condition (32) to equality we get

$$M_{v+x} = (1 - \delta)(v + x) + x \frac{2(1 - \delta)(2\delta - \delta^2)}{(2 - \delta(2 - \delta))}. \quad (33)$$

Then plugging M_{v-x} , M_{v+x} into Inequality (4) we get a sufficient condition for outside equity financing, that is,

$$\delta v - a - \frac{\delta(1 - \delta)(2 - \delta)}{2 - \delta(2 - \delta)}x \geq \frac{(1 - \delta)I}{\delta}. \quad (34)$$

Consequently, positive net present value projects with standard deviation below x_e , the value of x that sets condition (34) to equality, can raise outside equity financing. ■

Proof of Proposition 8. First, rearrange condition (13) and substitute in for a . Outside equity is held by investors whenever

$$\delta^2 v(1 + \delta) - \delta^2 \frac{(1 - \delta^2)(2 - \delta)x}{2 - \delta(2 - \delta)} \geq I. \quad (35)$$

Debt financing is available whenever

$$\delta \left[\frac{1}{4}(1 + \delta)(v - x) + \frac{1}{2}\delta v + \frac{1}{4} \left(1 - \frac{v - x}{\delta(v + x)} \right) \delta L_2 \right] \geq I. \quad (36)$$

²⁰ The resulting payoff pair will be close to the minimum and sufficient for our purpose, that is, to demonstrate that it is easier to raise outside equity than debt.

Recall from the basic model that $L_2 < (v - x)$. Hence the left side of Inequality (36) is bounded from above by $\delta^2(v - \frac{x}{2}) + \frac{1}{4}\delta(v - x)$, which is also bounded from above by the left side of the outside equity financing condition

$$\delta^2 v(1 + \delta) - \frac{\delta^2(1 - \delta^2)(2 - \delta)}{2 - \delta(2 - \delta)}x \geq I \quad (37)$$

for $\delta > .7374$ as shown below. First, for $\delta > \frac{1}{2}$ it is true that $\frac{1}{4}\delta v < \delta^3 v$. Second,

$$-\frac{1}{4}\delta x + \delta^2 \left(v - \frac{x}{2} \right) < \delta^2 v - \frac{\delta^2(1 - \delta^2)(2 - \delta)}{2 - \delta(2 - \delta)}x,$$

that is,

$$-\frac{1}{4} - \frac{\delta}{2} < -\frac{\delta(1 - \delta^2)(2 - \delta)}{2 - \delta(2 - \delta)}.$$

The latter holds for $\delta > .7374$. ■

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