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# Investment “Myopia” and the Internal Organization of Capital Allocation Decisions

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## 1. INTRODUCTION

The principal objective of this paper is to show that a firm’s internal organization of the capital investment decision as well as its capital allocation choices are significantly influenced by the necessity for the firm to raise capital from uninformed investors who reflect their strategic disadvantage in pricing the capital they provide. I focus on moral hazard (a brief discussion in the Appendix shows that the results are unchanged by private information). There is symmetric information prior to contracting, but those who buy claims against the firm’s assets cannot directly and costlessly control the firm’s actions that affect the productivity of these assets. This moral hazard affects asset valuation (see also Ramakrishnan and Thakor).

The fact that informational problems are intricately linked to how firms are internally organized is now widely accepted (see, for example, Holmstrom, 1988, and Williamson, 1967, 1970). Moreover, Holmstrom (1988) and Sah and Stiglitz also make the point that real investment activity is influenced by how investment decisions are internally organized within firms. To this literature the intended contribution of this paper is the observation that information-related frictions can lead value maximizing firms to not adhere

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strictly to the net present value (NPV) rule in project selection and that this causes the internal organization of capital budgeting to be relevant to shareholder welfare.

Recently, there has been much concern over the apparent investment myopia of corporate America. It has been claimed that American managers, in contrast to their Japanese counterparts, are too "short-term" oriented. The implication is that real investment decisions are being distorted due to a "preoccupation" with short-term profits. Substantiating these claims is empirical evidence that is hard to ignore.<sup>1</sup> Further, investment distortions are not limited to a preference for projects that pay off faster. There is strong empirical evidence to suggest that intrafirm capital rationing is pervasive.<sup>2</sup>

What can rationalize these distortions? There is a growing literature that tracks the source of these investment distortions to a divergence in the goals of shareholders (who care only about financial returns) and managers (who care about their current financial payoffs and future payoffs, which will be determined by evolving perceptions of their ability).<sup>3</sup> Narayanan (1985a,b) argues that if managers choose from among projects of equal value to shareholders, they may prefer projects that pay back faster; this is because they enable *early* reputation enhancement, the effects of which linger. However, this does not explain the reliance on the payback criterion in owner-managed

1. For example, there is overwhelming empirical evidence that many firms, regardless of size or sophistication, continue to use the payback criterion as a capital-budgeting tool. The use of this criterion has often been referred to as "myopic" investment decision making. Klammer found that there is no statistically significant relationship between "sophistication" of capital-budgeting technique and firm performance. In fact, the signs of the regression coefficients are "wrong"; better performance seems to go with payback. Fremgren found that firm size does not seem to affect the choice of capital-budgeting technique. Of all the firms surveyed by him, 67% used payback, although only 14 percent as a primary capital-budgeting tool. In a *later* survey by Schall, Sundem, and Geijsbeek, 74 percent of the firms were found to use payback. Gitman and Forrester surveyed large firms (those with assets exceeding \$100 million) for the 1971–76 period and found that 44 percent used payback as a backup capital-budgeting tool. Subsequently, Hendricks compared their 1971–76 findings with 1981 and discovered that the use of payback as a secondary tool had *risen* to 64.8 percent. Gitman and Mercurio conducted a survey on how firms assess project risk in making capital-budgeting decisions. Half the responses came from the 300 largest Fortune 1000 firms and 15 percent from the bottom 300. Payback was found to be the second most important factor in assessing risk, second only to the dollar size of the project.

2. Despite the traditional branding of capital rationing as irrational (see, for example, Van Horne), many firms practice it in interdivisional capital allocation. Brigham and Pettway indicate that 40 percent of the utilities surveyed by them have been subject to capital rationing. Moreover, there is an interesting empirically documented relationship between payback use and intrafirm capital rationing. Pike surveyed the 208 largest industrial firms in the United Kingdom in autumn 1980 and found that firms that ration capital more also emphasize payback more.

3. A theoretical model that rationalizes managerial investment myopia in a shareholder wealth-maximizing framework is given by Stein. It is a private information model in which the manager's myopic investment choice is a signal aimed at gaining an upward revision in the firm's stock price and thwarting a takeover bid.

firms.<sup>4</sup> Hirshleifer and Thakor argue that reputational concerns may induce managers to display conservatism, rejecting riskier, higher-valued projects and accepting safer, lower-valued projects. Scharfstein and Stein explain "herd behavior" by managers who make investment choices that do not deviate from the "norm." Holmstrom and Ricart i Costa justify capital rationing in a model in which managers have initially unknown abilities that are inferred through time from observed cash flow realizations. The optimal managerial wage contract in their model is an option on the value of the manager's human capital. This causes the manager to overinvest, and the owner counterbalances by rationing capital. Holmstrom and Ricart i Costa also suggest that the optimality of rationing in their setting means that the capital budgeting decision must be centralized.<sup>5</sup> This observation is important since centralized capital budgeting is ubiquitous yet its rationale is improperly understood in the context of traditional economic theory.

The feature that distinguishes our model from this literature is that the commonly observed investment practices of payback use, intrafirm capital rationing, and centralized capital budgeting are explained as being value maximizing rather than distortionary. That is, we do not need managers' goals to differ from those of existing shareholders. Whatever distortions there are in this environment stem from the firm's transactions with a less-informed capital market and the fact that the interests of existing shareholders are not necessarily aligned with those of prospective shareholders. *Given* the costs that these transactions impose on the shareholders, investment decisions in this model represent a constrained optimum for the shareholders.<sup>6</sup> The point is that when a firm makes value-maximizing investment

4. Narayanan (1985a) recognizes this limitation. Hakinson surveyed 65 small British firms employing 200 people or less. He found that 68 percent used payback. Since it is reasonable to expect that many of these firms were owner-managed, the evidence suggests payback use in owner-managed firms. Moreover, Narayanan's theory seems to predict a relationship between the use of payback and managerial incentive plans. An empirical study by Statman and Sepe failed to detect such a relationship.

5. In a recent paper, Shah and Thakor rationalize centralized capital budgeting in a private information cum moral hazard setting. They show that, for very large projects, the losses in shareholders' wealth due to the private information of the firm's divisional managers can be reduced by centralizing the capital-budgeting process. However, their theory requires that there be a conflict of interests between managers and current shareholders and is, therefore, not appropriate for firms in which ownership and management are unified.

6. Related to this paper is recent work by Laffont and Tirole on the auctioning of incentive contracts in a multiperiod setting with investments. The similarity of their work to this paper is that in both there is a dynamic investment problem with moral hazard arising from the market unobservability of investment expenditures incurred by the firm. Apart from the fact that their focus is on auctioning contracts to natural monopolies and on corporate control, whereas my focus is on the internal organization of capital budgeting, a key difference is as follows. In Laffont and Tirole, managerial myopia is interpreted as the manager's failure to internalize the effects of investments that are not observed by the market. I interpret this merely as the *source* of moral hazard that drives a wedge between the costs of internal and external financing. I then

decisions, these decisions may be *observationally indistinguishable* in empirical studies from those that rely on the use of the payback criterion and involve intrafirm capital rationing.

The paper's principal findings are summarized below.

1. The preferences for projects that pay back faster, the practice of capital rationing, and the centralizing of capital budgeting are rational in *any* firm that resorts to external financing. Thus, there is unlikely to be any systematic relationship between investment myopia and firm sophistication or size. In other words, large as well as small firms are likely to display a short-term orientation in their real investment choices.
2. A greater use of the payback criterion is likely to be accompanied by more capital rationing within the firm. Projects which pay off more slowly are more likely to be rationed.
3. Both a preference for projects that pay off faster and capital rationing are likely to be more prevalent in firms with centralized capital budgeting.
4. A firm may accumulate liquidity despite having positive NPV projects it could invest in. Consequently, firms may hold liquid assets in excess of normal operating needs.
5. The loss in value added from external financing is proportional to the size of the investments externally financed.
6. A given project need not be valued symmetrically by technologically similar firms. Two firms, identical in all respects except for their initial endowments of retained earnings, may choose different projects from a set of mutually exclusive projects.
7. Payback reliance is likely to be greater in firms that have a higher frequency of new investments to be financed through time.

The rest of the paper is in five sections. In Section 2, the basic intuition underlying the analysis is sketched out. In Section 3, the model is developed. Section 4 contains the analysis that rationalizes a preference for projects that pay back faster under moral hazard. In Section 5, intrafirm capital rationing and centralized capital budgeting are rationalized. Section 6 concludes. All proofs are in the Appendix, which also contains a brief discussion of the results with precontract private information.

## 2. THE BASIC IDEA

Without going into model details, the intuition behind this paper is as follows. Firms often have two types of capital budgeting decisions to make. One

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go on to show that this wedge creates a preference on the part of current shareholders for projects that pay off faster, and I relate this preference to the much-debated investment myopia problem.

decision concerns accepting or rejecting projects available now. The other concerns investment options that will have to be exercised in the future. A rational firm will make its current decisions keeping in mind the characteristics of future options, to the extent that these are known. Further, the value of a project to the firm is *not* independent of *how* the project is financed, i.e., from retained earnings or from externally obtained funds. External funds—whether these are obtained from risky debt or from equity—are more costly.<sup>7</sup> The notion that, due to informational imperfections, external funds are costly relative to internal funds is by now well recognized (see, for instance, Myers and Majluf). In this model, the higher cost of external financing comes from either moral hazard or private information.<sup>8</sup> I focus principally on moral hazard. The firm makes a resource commitment decision that affects the project's payoff. Acting in the best interests of its *existing* shareholders, the firm will optimally choose a lower level of resource commitment when the payoff will be shared with those who do not currently own the

7. There are three possible ways of avoiding the external financing costs that drive our analysis. One way is to avoid equity and take a secured bank loan with sufficient collateral to make the loan riskless to the bank (see Chan and Thakor). This will eliminate moral hazard. This seems unrealistic, however, since the availability of so much collateral means that the firm could perhaps have self-financed by liquidating some of that collateral. Moreover, in practice the bank faces transaction costs in taking possession of and liquidating collateral. This leads to collateral being a dissipative contracting instrument (see Besanko and Thakor), and once again external financing costs more than internal financing. A second is to make sure that all funds needed in excess of rationed earnings are acquired through preemptive rights offerings. This will ensure that there are never any *new* claimants subsequent to the infusion of additional capital. However, this approach will not work if none of the firm's existing shareholders has an unlimited wealth endowment. In this case, for every rights offering to be fully subscribed, shareholders will have to borrow on personal accounts, which is likely to be even more costly for them than having the firm acquire outside funds on its own account. This is because the problems of moral hazard and informational asymmetries are likely to be much deeper for individual credit transactions than for (publicly traded) corporations about which substantial information is already in the public domain. If shareholders are institutions, then we again have the same problem; those investors that they will raise money from to buy the firm's stock are not necessarily current owners of the firm. The point is that a public corporation's ownership is not captive and stagnant. A third possible way is to raise external financing through different packages of financial instruments. However, this will generally not eliminate external financing costs. In the moral hazard case, the only way to eliminate these costs is for the firm to issue riskless (unsecured) debt. But this is never possible in our model. In the precontract private information case, conditions that lead to costless separating equilibria—as, for example, in Brennan and Kraus—must be assumed to not be satisfied. In their model, the existence of a costless "revealing" or "strongly revealing" equilibrium generally requires, for any given set of feasible financing strategies, a restriction on the cross-sectional distribution of firm types. When that restriction is not met, dissipative signaling—with its accompanying deadweight losses—will be employed if the firm needs to raise external funds. The point is that the results derived here will be sustained as long as *some* external financing costs remain. This is because the results do *not* depend on the use of a linear sharing rule such as equity. More complex, nonlinear schemes will generate similar results since they will not, in general, produce the first best outcome.

8. The source of the higher cost is unimportant. For example, in Myers and Majluf, the source of higher external financing costs is private information, whereas in Jensen and Meckling (1976), it is moral hazard.

firm than when all of the payoff goes to existing shareholders. "Outsiders" rationally anticipate this and price the firm's financial claims accordingly, thereby passing along to the firm's existing shareholders the welfare loss connected with the lower resource commitment. Now, given this higher external financing cost, the firm recognizes that its *future* investment opportunities will be worth less if they are not funded from retained earnings. Its ability to finance in the future from retained earnings depends, in turn, on how fast its current projects generate cash flows. A currently available project with a faster payback but a lower economic value than another currently available (mutually exclusive) project may be preferred because it alone permits a future project to be internally financed, and the resulting increase in value (measured in current dollars) of the future project exceeds the loss in value from adopting the lower "stand-alone" value project. Using the same logic, the firm may find it optimal to ration capital to a project now, keep its retained earnings idle for a while and then invest them in a project in the future. This is because the internally financed value of the future project exceeds the sum of the values of the current project (internally financed) and the future project (externally financed). And if the future project is in a division other than the one the current project is in, centralized capital budgeting would dominate a decentralized system because knowledge of the investment opportunities of *both* divisions would be needed to make the optimal decision.

The key to this analysis, then, is that current shareholders are making an appropriable investment that is costly to them, enhances the firm's payoff for them *as well as* new shareholders, and cannot directly be contracted upon. As argued later on (see footnote 16), current shareholders are a distinct group from prospective new shareholders, which leads to a divergence in their interest, creates a wedge between the costs of retained earnings and outside equity, and distorts investment policy. There is considerable empirical evidence to support the notion that external financing is more costly than internal financing (e.g., Masulis and Korwar and Mikkelsen and Partch), although these studies measure announcement effects of equity issues. My model with moral hazard is not equipped to explain announcement effects, but the point is that from both theoretical and empirical standpoints, it is hard to dispute the premise that external equity is generally more costly than retained earnings.

This analysis can be viewed as pointing out some of the significant capital budgeting implications of the difference between *static* and *sequential* decision procedures. This difference was formally explored originally by Weitzman, who cast the problem as one of sequential search for the best alternative from a heterogeneous set of mutually exclusive alternatives. The nature of this problem is such that the *sum* of search costs is paid during search, whereas the *maximum* of the payoffs from the search is collected after

search has been terminated. Consequently, Weitzman finds that the optimal search rule does *not* necessarily involve examining the alternative with the highest stand-alone value *first*. The key in his analysis is to select the optimal search strategy by comparing all possible *sequences* of alternatives from the set of alternatives, rather than by comparing individual alternatives with each other. That is, static and sequential decision rules produce different outcomes. This is similar to the analysis here in which project selection should not be predicated on the stand-alone values of the currently available projects, but rather on the total values generated by combining each of the (mutually exclusive) currently available projects with future options. An important difference, of course, is that exogenous uncertainty suffices for Weitzman's results, but not for the results here. None of the practices I explain can be rationalized without either private information or moral hazard.

Three comments are in order. First, because the practice of rationing capital and the preference for projects that pay back faster in this model are related to the gains from reducing external financing in the immediate future, the explanation is valid for any firm facing the prospect of external financing. That is, owner-managed firms as well as those with a separation of ownership and control are included. Second, intrafirm capital rationing and centralized capital budgeting are explained without invoking any exogenous constraints on the size of the firm's capital budget or assuming any incompetence in the comprehension of overall organizational goals per se on the part of divisional managers. Finally, as mentioned earlier, it is *not* my intention to suggest that any of the practices rationalized in this paper *conflict* with shareholder goals (value maximization). In fact, because shareholder wealth maximization is chosen as the objective function of the firm, every decision rule rationalized here is consistent with value maximization. The objective is to show that when investment myopia or capital rationing is detected in empirical studies, one need *not* conclude that firms are making capital budgeting decisions that do not maximize shareholder wealth. A capital budgeting policy aimed at maximizing aggregate shareholder wealth may well look myopic and involve rationing capital to a project that creates a positive economic surplus for another firm. In this way, the documentation of investment myopia and capital rationing provided by numerous empirical studies can be explained as rational, value-maximizing behavior.

### 3. THE MODEL WITH MORAL HAZARD

Consider a taxless, universally risk-neutral<sup>9</sup> economy in which there is a firm with the option to invest in a single period project requiring an outlay of  $P > 0$ .

9. The risk-neutrality assumption in our context does not compromise generality. One could just as easily work with an equivalent martingale measure, in the Harrison and Kreps sense, and discount payoffs at the riskless rate.



Later extensions will permit multiple projects with two-period payoffs. Assume this firm is all-equity financed. In this model, it makes little difference whether the firm uses risky debt or equity. In the concluding section (see footnote 16), I point out that more complex (nonlinear) packages of external financing instruments will support similar results, so that the analysis does not hinge on the linearity of the payoff sharing rule. At the end of the period, the project yields a random payoff of  $R$ .  $R$  has a distribution function,  $F(R|a)$ , which is conditional on the firm's resource commitment choice  $a \in A$  (where  $A$  is a compact subset of  $\mathcal{R}_+$ , the non-negative real line,  $[0, \infty]$ , for simplicity) and is concentrated on  $[R_1, R_2] \subseteq \mathcal{R}_+$ . Following standard practice in principal-agent models, I assume that  $\partial F/\partial a \leq 0$  (with strict inequality for all  $R$  except the boundaries of the concentration set) and that resource commitment to improving the project's payoff distribution is costly for the firm. Specifically, the cost is  $W(a) > 0$ , where  $W' > 0$ ,  $W'' > 0$  (primes denote derivatives). There are various interpretations of  $W$ . One is that it is a diversion of productive corporate assets—including tangible physical assets, and managerial time—that were owned by *current* shareholders prior to the acquisition of capital from outside investors. Another, somewhat narrower, interpretation is that it is simply the cost of managerial effort expenditure, an effort allocation achieved by shifting attention from projects that were in place prior to the activating of the project for which outside financing is sought. For instance, in preparation for the project in question, management may divert attention from assets in place to preproduct introduction market development and R & D. It is common for firms to seek outside capital for a project when it is time to construct the plant and install equipment. However, project success often hinges on activities such as R & D, test marketing, advertising, and so on, which are conducted *prior* to the acquisition of outside capital. The key is that *new* shareholders do not share the costs associated with these activities.

Consider first the case in which the firm has sufficient internal funds to finance the project. It then chooses an  $a^0 \in A$  that satisfies

$$a^0 \in \operatorname{argmax}_{a \in A} \int_{R_1}^{R_2} R \, dF(R|a) - P[1 + r] - W(a)[1 + r], \quad (1)$$

where  $r \geq 0$  is the single period riskless rate of interest and  $F$  may include mass points. Note that the firm chooses its resource commitment at the beginning of the time period and realizes its payoff at the end of the time period; hence, the compounding of the  $W(\cdot)$  function. Throughout, the term "value" will be used to refer to the net *future* value of a project, i.e., its value at the point in time at which the project's terminal payoff is realized. Since, for comparison purposes, all future values will be standardized along the time dimension, this is the same as computing current net values (NPVs).

Whenever NPVs are used, they will be explicitly identified. In (1) then, the firm is choosing  $a \in A$  to maximize the (internally funded) project's value.

The first-order condition that determines  $a^0$  is

$$\partial E(R|a^0)/\partial a = [1 + r]W'(a^0), \quad (2)$$

where  $E(R|a^0)$  is the expected value of  $R$  conditional on  $a = a^0$ . The value of the project is

$$E(R|a^0) - P[1 + r] - W(a^0)[1 + r], \quad (3)$$

and this is assumed to be strictly positive.<sup>10</sup> Note that our assumption  $\partial F/\partial a < 0$  implies that  $\partial E(R|a)/\partial a > 0$ . We will further assume that  $\partial^2 E(R|a)/\partial a^2 \leq 0$ .

Now suppose the firm has no internal funds currently available.  $P$  must, therefore, be raised externally from the capital market. Let the firm issue additional equity that entitles the buyers of this equity—in the aggregate—to own a fraction  $\alpha \in (0, 1)$  of the firm.<sup>11</sup> At present, the firm's only asset is assumed to be the project in question. Thus,  $\alpha$  represents the fraction of the project's cash flow accruing to those who buy the additional equity. For now, all payoff-relevant parameters are common knowledge, but the firm's choice of  $a \in A$  is ex post unobservable to investors. The project payoff is costlessly observed by all ex post. The firm's objective is to maximize the wealth of its existing shareholders. Thus, even though there is a moral hazard problem between existing shareholders and *new* shareholders, there is no moral hazard between the manager and existing shareholders.<sup>12</sup> This means the optimal resource commitment,  $a^* \in A$ , in this case satisfies

$$a^* \in \operatorname{argmax}_{a \in A} \int_{R_1}^{R_2} [1 - \alpha] R \, dF(R|a) - W(a)[1 + r] \quad (4)$$

subject to

10. Henceforth, I shall only concern myself with projects with strictly positive values when internally funded. Thus, the strict positivity will be assumed to hold even when not explicitly stated.

11. That is, equity financing is always sought by the firm as a whole, and those who buy its shares purchase a claim against its total cash flows. The firm, however, earmarks the externally raised funds for the project in question. The required rate of return on equity in this model is always constant and equal to the riskless rate. This is true for equity issues as well as retained earnings that are invested, since in equilibrium investors who buy the firm's shares earn an expected return equal to the riskless rate. However, the cost to the current shareholders of raising external financing is not invariant to the amount of funds raised. As Lemma 1 shows, the larger this amount, the worse the moral hazard and the greater the value loss to current shareholders.

12. Thus, unlike Narayanan (1985a), there is no moral hazard here that stems from a separation of ownership and control.

$$\int_{R_1}^{R_2} \alpha R \, dF(R|a^*) = P[1 + r]. \quad (5)$$

Note that (5) stipulates competitive pricing of equity in the capital market; equity is priced to make its expected rate of return equal to the riskless rate.

Replacing (4) by the usual first-order representation gives<sup>13</sup>

$$[1 - \alpha] \partial E(R|a^*) / \partial a = [1 + r] W'(a^*). \quad (6)$$

Thus, the value of the project to the firm, in this case, is

$$[1 - \alpha] E(R|a^*) - [1 + r] W(a^*). \quad (7)$$

A simple result is presented below.

*Proposition 1.* The value of the project to the firm is strictly greater if it is internally funded than if it is externally funded.

The intuition is straightforward. Any moral hazard-related welfare loss must be borne by the firm in equilibrium. Thus, project value is higher when this loss can be avoided. This result is used later to establish a preference for projects that pay off faster than others.

#### 4. A SIMPLE EXPLANATION FOR "SHORT-TERM ORIENTATION" WITH MORAL HAZARD

Although it is possible to continue with the general payoff specification of the previous section, the analysis is eased by some simplifying assumptions. Suppose the project payoff is  $R > P$  with probability (w.p.)  $a$  and 0 w.p.  $1 - a$ , where  $a \in A \equiv [0, 1]$ . Moreover, let  $W(a) = ka_2$ , where  $k$  is a real-valued, positive number.

It is easy to check that

$$a^0 = R\{2k[1 + r]\}^{-1} \wedge 1,$$

where  $\wedge$  is the "min" operator. By imposing the parametric restriction

$$R \leq 2k[1 + r], \quad (R1)$$

13. To ensure the validity of the first-order condition approach, we assume that for any  $a, a', a'' \in A$  and  $\lambda \in [0, 1]$  such that  $W(a) = \lambda W(a') + (1 - \lambda) W(a'')$ , we have  $F(\hat{R}|a) \leq \lambda F(\hat{R}|a') + (1 - \lambda) F(\hat{R}|a'')$ . This will ensure that the cumulative distribution function condition of Grossman and Hart holds.

we can write

$$a^0 = R\{2k[1 + r]\}^{-1}, \quad (8)$$

and the project's value with internal financing as

$$R^2\{4k[1 + r]\}^{-1} - P[1 + r]. \quad (9)$$

Similarly,

$$a^* = [1 - \alpha]R\{2k[1 + r]\}^{-1}. \quad (10)$$

Using (5), we can write the determining equation for  $\alpha$  as

$$\alpha a^* R = P[1 + r]. \quad (11)$$

Substituting for  $a^*$  from (10) into (11) and solving the resulting equation gives us

$$\alpha = [1/2] \pm [[1/4] - 2kP[1 + r]^2 R^{-2}]^{1/2}, \quad (12)$$

which satisfies the feasibility restriction on  $\alpha$  regardless of which solution is adopted. Of course, we need the restriction

$$R^2 \geq 8kP[1 + r]^2 \quad (R2)$$

to guarantee that  $\alpha$  is a real number.<sup>14</sup> The value of the project with external financing is

$$R^2[1 - \alpha^2]\{4k[1 + r]\}^{-1} - P[1 + r], \quad (13)$$

where  $\alpha$  is given by (12). Since project value is monotonically declining in  $\alpha$ , the Pareto efficient solution for  $\alpha$  is

$$\alpha = [1/2] - [[1/4] - 2kP[1 + r]^2 R^{-2}]^{1/2}. \quad (12')$$

Henceforth, the smaller value of  $\alpha$  will always be picked as the equilibrium solution.

The loss in value due to external financing is obtained by subtracting (13) from (9), and is  $\alpha^2 R^2\{4k[1 + r]\}^{-1}$ . Substituting for  $\alpha$  from (12'), we can write the value loss as

14.  $(R - 1)$  and  $(R - 2)$  jointly imply that  $4k^2[1 + r]^2 \geq R^2 \geq 8kP[1 + r]^2$ , which means  $k \geq 2P$ .

$$\{[1/2] - [[1/4] - 2kP[1 + r]^2R^{-2}]^{1/2}\}^2 R^2 \{4k[1 + r]\}^{-1}. \quad (14)$$

A direct comparative static result is given below.

*Lemma 1.* The loss in project value due to external financing is strictly increasing in  $P$ .

To examine the payback issue, suppose the firm has a choice between two mutually exclusive projects at the initial point in time,  $t = 1$ . The firm currently has just enough internal funds available to fund either project. Each project requires an investment of  $P$  at  $t = 1$ . Project X yields no payoff at  $t = 2$  (the end of the first period) but yields  $R_X > 0$  w.p.  $a$  and 0 w.p.  $1 - a$  at  $t = 3$  (the end of the second period). Call this the "slow" project. Project Y yields its only payoff of  $R_Y > 0$  w.p.  $a$  and 0 w.p.  $1 - a$  at  $t = 2$ . Call this the "fast" project. If internally funded, project X has a higher value than project Y. Thus, the textbook recommendation would be for the firm to adopt project X.

Assume now that the firm will have available at  $t = 2$  another project. This project, called Z, will need an investment of  $P$  at  $t = 2$  and will produce a payoff of  $R_Z > 0$  w.p.  $a$  and 0 w.p.  $1 - a$  at  $t = 3$ . This project has a positive value even if it is externally financed. Further, project Z is technologically unrelated to projects X and Y. That is, there is no (synergistic) correlation between the payoff from project X or Y and that from project Z, other than through the possible impact of an observed payoff realization at  $t = 2$  (related to project Y) on the resource commitment chosen for project Z. Moreover, it is optimal to invest in project Z regardless of the firm's investment decision at  $t = 1$ , since this project has a positive value no matter where the funds to finance it originate from. Thus, the accept-reject decision for project Z is independent of the firm's initial investment decision. This means each of the three projects can be justifiably viewed as a *distinct* project. There are no "tie-ins" that would suggest looking at either projects X and Z or projects Y and Z as a single "mega" project.

If the firm opts for project X, it will surely need to raise external funds for project Z at  $t = 2$ . As mentioned earlier, the equity issued by the firm will entitle its buyers in the aggregate to a fraction  $\alpha$  of the *total* payoff accruing to the firm from both projects X and Z. It makes no difference whether the additional equity issued at  $t = 2$  represents a claim only against the project it finances or against the whole firm. Thus, I adopt the more natural assumption that incrementally issued financial instruments are claims against the entire portfolio of firm assets.

The firm's resource commitment decision, made at  $t = 1$ , involves choosing a pair  $\{a_X^*, a_Z^*\} \in [0, 1] \times [0, 1]$  such that

$$\{a_X^*, a_Y^*\} \in \operatorname{argmax} \left\{ \begin{array}{l} a_X a_Z [R_X + R_Z][1 - \alpha] + a_X [1 - a_Z] R_X [1 - \alpha] \\ + [1 - a_X] a_Z R_Z [1 - \alpha] - k a_X^2 [1 + r]^2 \\ - k a_Z^2 [1 + r] - P[1 + r]^2 \end{array} \right\} \quad (15)$$

subject to

$$\alpha a_X^* a_Z^* [R_X + R_Z] + \alpha a_X^* [1 - a_Z^*] R_X + \alpha [1 - a_X^*] a_Z^* R_Z = P[1 + r], \quad (16)$$

where  $a_X^*$  and  $a_Z^*$  are the optimal choices for projects X and Z, respectively.

Were the firm to opt for project Y, it would reduce the likelihood of resorting to external financing at  $t = 2$ . In the state in which the payoff from project Y is  $R_Y$  at  $t = 2$ , project Z can be completely internally funded.<sup>15</sup> In the other state, additional equity must be issued to finance project Z. At  $t = 1$  then, the firm's choice of resource commitment to project Y,  $a_Y^*$ , is obtained by solving the following dynamic programming problem

$$a_Y^* \in \operatorname{argmax}_{a_Y \in [0,1]} \{a_Y \{R_Y[1 + r] + V^o(Z)\} + [1 - a_Y][V^*(Z)] - \Gamma\}, \quad (17)$$

where  $\Gamma \equiv k a_Y^2 [1 + r]^2 - P[1 + r]^2$ ,

$$V^o(Z) = a_Z^o R_Z - k [a_Z^o]^2 [1 + r] - P[1 + r], \quad (18)$$

$$V^*(Z) = \hat{a}_Z^* R_Z [1 - \hat{\alpha}] - k [\hat{a}_Z^*]^2 [1 + r], \quad (19)$$

$$a_Z^o \in \operatorname{argmax}_{a_Z \in [0,1]} \{a_Z R_Z - k a_Z^2 [1 + r] - P[1 + r]\}, \quad (20)$$

$$\hat{a}_Z^* \in \operatorname{argmax}_{a_Z \in [0,1]} \{a_Z R_Z [1 - \hat{\alpha}] - k a_Z^2 [1 + r]\} \quad (21)$$

subject to

$$\hat{\alpha} \hat{a}_Z^* R_Z = P[1 + r]. \quad (22)$$

In words, the firm is choosing  $a_Y^*$  at  $t = 1$  to maximize the value of project Y at  $t = 1$ , taking as given its optimal resource commitment choice for project Z in each state of nature at  $t = 2$ . If project Y yields  $R_Y$  at  $t = 2$ , then project Z is internally funded and has a value of  $V^o(Z)$ . Otherwise, project Z must be externally funded and has a value of  $V^*(Z)$ . With these preliminaries, the central result of this section can be stated.

15. Since all projects under consideration have strictly positive values when internally funded, we have  $R_Y > P$ . This permits complete internal financing.

*Proposition 2.* Given a choice between two mutually exclusive projects X and Y, a firm with sufficient internal funds to invest in either project may choose the lower-valued fast project (project Y) if there is an investment opportunity (project Z) that will become available in the future. This is despite the fact that project Z is technologically unrelated to either project X or project Y and would have a positive value even if it were entirely externally funded.

This proposition makes a number of points. First, investment myopia (or apparent use of the payback criterion) may be rational for current shareholders. A project which yields "early" cash flows may be preferred to one which yields "late" cash flows even though the latter has a higher value. The intuition is that the gain in value from adopting the slow project is more than offset by the loss in value on a *future* investment option that must be externally financed because the slow project does not yield its cash flows early enough to permit internal financing. Thus, it would be perfectly rational for a firm to appear myopic and choose the fast project to jointly optimize its current choice of project and its intertemporal incidence of external financing costs. A word of clarification, though. Project X has a higher value than project Y only when each project is evaluated *separately* (static decision rule), not in conjunction with project Z. Clearly, the reason why the firm picks project Y is that the selection maximizes the *total* value of its present and future investment opportunities (sequential decision rule), i.e., the combined value of projects Y and Z exceeds the combined values of projects X and Z.<sup>16</sup>

A second implication of the proposition is that the accept-reject decision on a project depends on the firm's *future* investment opportunities, including those that have *no* technological or market bearing on the project in question. The model predicts that a firm with numerous profitable investment opportunities that are expected to become available in the near future is more likely to currently sacrifice higher-valued projects in preference for lower-valued projects that pay off relatively quickly. That is, we have a predicted relationship between payback use and the firm's frequency of new capital financing.

A third implication—that also flies in the face of conventional wisdom—is that a given project will *not* be valued symmetrically by all firms, despite all payoff-pertinent information about the project being common knowledge. A firm with sufficient retained earnings to cover the required investment will value the project higher than will a firm that must use external funds. In fact,

16. The significance of this finding lies in the assumed absence of any technological synergy between project Z and either project X or project Y. Moreover, it also implies that simple value additivity does not hold in this setting. Note that the apparent "short-term" orientation here actually stems from a deep concern with the future consequences of current investment choices.

the project may have positive value if internally financed and negative value if externally financed. Consequently, it will be accepted by one firm and rejected by the other.

Based on the above analysis, I do *not* wish to suggest that firms will *always* be "short-term" oriented. It is certainly possible to construct examples in which slower payback projects are preferred. The point of this analysis is simply that, *everything else remaining the same*, a faster payback project will be preferred if the firm has a future demand for investment funds.

## 5. CAPITAL RATIONING AND CENTRALIZED CAPITAL BUDGETING

Now suppose there is a multidivisional conglomerate faced with capital allocation requests from its divisions. For simplicity, suppose there are two divisions. They are completely unrelated to each other; their technologies are distinct, and they operate in different product and factor input markets. Thus, each division can assess the optimality of a given investment for *that* division without any knowledge of the operational details or investment profile of the other division. I seek answers to two closely linked questions. First, would the firm ever *deny capital to a project with positive value if internally funded even though the firm currently has sufficient internal funds available and these funds would be kept idle if the project is not funded?* This is the capital-rationing issue. Second, making its capital-budgeting decisions contingent on an examination of the current and future investment opportunities of *both* divisions, could the firm do better than it would if it decentralized its budgeting process and instructed each division to invest only in positive-value projects? This is the issue of whether a centralized budgeting system can dominate a decentralized system.

To answer these questions, suppose the firm currently has  $P$  dollars of retained earnings. Its two divisions are X and Y (the same letters will be used to designate the projects the two divisions have). Division X has a project requiring an investment of  $P$  at  $t = 1$  and yielding a payoff of  $R_X$  w.p.  $a_X$  and a payoff of 0 w.p.  $1 - a_X$  at  $t = 3$ . Division Y has a project requiring an investment of  $P$  at  $t = 2$  and yielding a payoff of  $R_Y$  w.p.  $a_Y$  and 0 w.p.  $1 - a_Y$  at  $t = 3$ . Both projects have positive value if internally funded and these projects are *not* mutually exclusive. Moreover, if the firm uses up its retained earnings to fund project X internally at  $t = 1$ , the externally funded value of project Y will be positive.

To create a simple distinction between centralized decision making and divisional decision making, suppose that neither division knows the other division's investment profile but the firm (top management) knows the investment profiles of both its divisions. This seems to be a reasonable way to



draw the line between centralized and decentralized budgeting. Proponents of centralized capital budgeting have argued that its advantage inheres in the greater information available to top management than to a divisional manager. While it is very plausible that top management knows more about the firm *as a whole* than a divisional manager does, the counterargument has been that the additional information about *other* divisions that the divisional manager lacks is *not* an impediment to his making *intradivisional* capital allocation decisions. The question about the optimality of centralized budgeting then simply reduces to asking whether division X could have done better knowing something about division Y and vice versa. The next proposition provides an answer.

*Proposition 3.* The firm may deny capital to project X, keep its retained earnings idly invested in a zero value asset (the riskless asset) for a period, and then invest it in project Y. Thus, the firm gains by making a (centralized) capital-budgeting decision that takes the investment opportunities of *both* divisions into account.

This proposition has striking implications. First, capital needed for investment in a positive-value project may be rationed despite its ready availability in the form of retained earnings. This rationalizes the empirically documented practice of capital rationing. It may also explain the puzzling behavior by many successful firms of holding cash and marketable securities well in excess of operating liquidity needs (see Fruhan). Further, a firm whose investment opportunity set presents it with a greater frequency of new investments to be financed is more likely to hold higher levels of liquidity. The reason for doing so would be to minimize the incidence of rationing. Thus, we have a prediction about the cross-sectional relationship between a firm's investment opportunity set and its working capital management practices. Second, centralized capital budgeting makes sense for our firm because the optimal decision in a regime with price decentralization would have been to use the currently available retained earnings to invest in project X and then fund project Y externally. The manager of each division would have (correctly) documented investment in a positive-value project. But, as the proposition indicates, this may be the wrong decision for the firm. Third, project X here is rejected because it does not yield its cash flows fast enough. Were it able to produce cash flows faster, it may have been accepted since its payoff in the good state would have supplied sufficient retained earnings to finance project Y. That is, the project's acceptance likelihood would have been enhanced even if we had held its value *fixed*. This brings out a relationship between a project's payoff pattern and its likelihood of being rationed: *projects with slower paybacks are more likely to be rationed*. This has previously not been theoretically established. There is

empirical evidence that capital rationing appears more widespread in firms that rely on the payback criterion as a capital-budgeting tool. Note also that this analysis implies that capital rationing and investment myopia are more likely to be encountered in firms that use centralized capital budgeting.

The intuition here is similar to that underlying Proposition 2. Even though project X has positive value, it forces the firm to raise capital externally in order to fund project Y one period hence. Loosely speaking, the decline in the value of project Y, due to the excess cost of external funds over retained earnings, exceeds the value of project X. Hence, it is optimal to sacrifice project X in order to preserve the firm's ability to finance project Y through retained earnings.

It is worth noting that the capital rationing described here exists despite the absence of any externally imposed market constraints on the size of the firm's capital budget. There are no preset limits on external financing which are independent of the profitability of proposed investments. The rationing here concerns the problem managers face in the allocation of resources to capital projects [such rationing is discussed in Lorie and Savage and Weingartner (1963)], rather than that of the firm or its owners facing an exogenous market constraint on capital expenditure. Thus, the extensive criticisms of the capital rationing literature in Weingartner (1977) do not apply here.

Thus far, the source of inefficiency has been moral hazard. It can be shown, however, that similar results can be obtained with private information. To see this, suppose that the firm's manager—who continues to act in current shareholders' best interest—knows more about its currently available investment opportunities than does the capital market. Further, suppose that investors will incur a screening cost  $K > 0$  (see Stiglitz) to become as informed as the manager when the firm seeks external financing.<sup>17</sup> In equilibrium these costs must be borne *ex ante* by the firm. In the Appendix, I show that a preference for faster payback projects can be established in this setting also.

## 6. CONCLUSION

The central theme of this paper is that real investment activity is influenced by how capital allocation decisions are organized within firms (centralization versus decentralization), and this internal organization is affected by the costs firms face in dealing with a less-informed capital market.<sup>18</sup> Hence, in a

17. Relaxing this assumption to make  $K$  an increasing function of the amount of external financing raised does little to alter the results.

18. Although raising capital exclusively through preemptive rights offerings may not be feasible, the theory presented here asserts that existing shareholders would be made better off if it were. The empirical evidence of Bhagat is supportive of this. He finds that the removal of preemptive rights provisions from corporate charters has a negative effect on shareholder wealth.

constrained optimum for the *shareholders*, firms may appear to use the payback criterion in project selection, practice intrafirm capital rationing despite facing no explicit quantity constraints on external capital, and centralize their capital-budgeting decisions.

These investment policy prescriptions coincide with the investment myopia and excessive conservatism of American managers that has recently been the focus of much debate. The existing literature suggests that these practices may be privately optimal for managers but not for shareholders. While not providing absolution to self-serving managers, the analysis here shifts the focus from the managerial labor market to the capital market as the driving force behind these practices. Thus, much of what we observe *may* persist even if ownership and control of firms were unified. Undoubtedly, though, performance evaluation and ability assessment concerns of privately informed managers will distort investment choices away from the constrained optimum for shareholders identified here and further exacerbate intrafirm capital rationing and the apparent preference for faster payback projects.

## APPENDIX

*Proof of Proposition 1.* We can write (7) as

$$E(R|a^*) - \int_{R_1}^{R_2} \alpha R \, dF(R|a^*) - [1 + r] W(a^*). \quad (A1)$$

Substituting (5) in (A1) gives the value of the project with external financing as

$$E(R|a^*) - P[1 + r] - [1 + r] W(a^*). \quad (A2)$$

Since  $\partial E(R|a)/\partial a > 0$  and  $\partial^2 E(R|a)/\partial a^2 \leq 0$ , the function  $E(R|a) - P[1 + r] - [1 + r] W(a)$  is strictly concave in  $a$  and strictly increasing in  $a^0$  for all  $a < a^0$ , where  $a^0$  is the point of stationarity of the function. Since  $a^* < a^0$ , we thus have

$$\begin{aligned} E(R|a^*) - P[1 + r] - [1 + r] W(a^*) \\ < E(R|a^0) - P[1 + r] - [1 + r] W(a^0). \end{aligned} \quad \text{Q.E.D.}$$

*Proof of Lemma 1.* Immediate upon partially differentiating (14) with respect to  $P$ . Q.E.D.

*Proof of Proposition 2.* The firm's maximization program in (15) and (16) can be simplified and written as

$$(a_X^*, a_Z^*) \in \operatorname{argmax} \{a_X R_X [1 - \alpha] + a_Z R_Z [1 - \alpha] - k a_X^2 [1 + r]^2 - k a_Z^2 [1 + r] - P[1 + r]^2\} \quad (\text{A3})$$

subject to

$$\alpha a_X^* R_X + \alpha a_Z^* R_Z = P[1 + r]. \quad (\text{A4})$$

The first-order conditions for  $a_X^*$  and  $a_Z^*$  now yield the solutions

$$a_X^* = R_X [1 - \alpha] \{2k[1 + r]^2\}^{-1}, \quad (\text{A5})$$

$$a_Z^* = R_Z [1 - \alpha] \{2k[1 + r]\}^{-1}. \quad (\text{A6})$$

Substituting (A4), (A5), and (A6) in (A3) and simplifying, we get the following value for the investment portfolio consisting of projects X and Z

$$R_X^2 [1 - \alpha^2] \{4k[1 + r]^2\}^{-1} + R_Z^2 [1 - \alpha^2] \{4k[1 + r]\}^{-1} - P[1 + r][2 + r], \quad (\text{A7})$$

where

$$\alpha = [1/2] - \{[1/4] - 2kP[1 + r]^3 [R_X^2 + R_Z^2 [1 + r]]^{-1}\}^{1/2}. \quad (\text{A8})$$

Next, we must solve the dynamic programming problem in (17)–(22). Following the usual process of backward induction, we first solve (21) and (22). The solution is

$$\hat{a}_Z^* = R_Z [1 - \hat{\alpha}] \{2k[1 + r]\}^{-1}, \quad (\text{A9})$$

$$\hat{\alpha} = [1/2] - \{[1/4] - 2kP[1 + r]^2 [R_Z]^{-2}\}^{1/2}. \quad (\text{A10})$$

Substituting (A9) in (19) provides

$$V^*(Z) = R_Z^2 [1 - \hat{\alpha}^2] \{4k[1 + r]\}^{-1} - P[1 + r], \quad (\text{A11})$$

with  $\hat{\alpha}$  given by (A10).

Solving (20) now gives us

$$a_Z^o = R_Z \{2k[1 + r]\}^{-1}. \quad (\text{A12})$$

Substituting (A12) in (18) yields

$$V^o(Z) = R_Z^2 \{4k[1 + r]\}^{-1} - P[1 + r]. \quad (\text{A13})$$

We can now solve (17). Substituting (A11) and (A13) in (17) and simplify-

ing gives us the objective function, and the first-order condition for  $a_Y^*$  with this objective function now gives us

$$a_Y^* = \{4kR_Y[1+r]^2 + \hat{\alpha}^2 R_Z^2\} \{8k^2[1+r]^3\}^{-1}, \quad (\text{A14})$$

where  $\hat{\alpha}$  is given by (A10). The total value of the firm's investment portfolio consisting of projects Y and Z is now obtained by substituting (A15) in the objective function. This gives

$$a_Y^* \{R_Y[1+r] + R_Z^2[4k[1+r]]^{-1}\} + [1 - a_Y^*] R_Z^2 [1 - \hat{\alpha}^2] \{4k[1+r]\}^{-1} - k[a_Y^*]^2 [1+r]^2 - P[1+r][2+r]. \quad (\text{A15})$$

Now, the value of project X, when internally financed, exceeds the value of project Y, when internally financed. That is, we must have

$$R_X^2 \{4k[1+r]^2\}^{-1} - P[1+r]^2 > R_Y^2 \{4k\}^{-1} - P[1+r]^2,$$

which implies the parametric restriction

$$R_X^2 > R_Y^2 [1+r]^2. \quad (\text{R3})$$

Thus, there are the following parametric restrictions on the model:

$$\begin{aligned} R_X &\leq 2k[1+r]^2, & (\text{R1}') \\ R_Y &\leq 2k[1+r], & (\text{R1}'') \\ R_Z &\leq 2k[1+r], & (\text{R1}''') \\ R_X^2 + R_Z^2[1+r] &\geq 8kP[1+r]^3, & (\text{R2}') \\ R_Z^2 &\geq 8kP[1+r]^2, & (\text{R2}'') \end{aligned}$$

and (R3). Note that (R1'), (R1''), and (R1''') guarantee that the feasibility restrictions on the optimal resource commitments for all projects are satisfied. (R2') ensures that  $\alpha$  is a real number, and (R2'') ensures that  $\hat{\alpha}$  is a real number. It is easy to see that, given (R2''), it is unnecessary to have (R2').

We want to establish that the set of exogenous parameters

$$\Omega \equiv \left\{ \{R_X, R_Y, R_Z, r, k, P\} \in \mathcal{R}_+^6 \mid \begin{array}{l} (\text{R1}'), (\text{R1}''), (\text{R1}'''), (\text{R2}'') \text{ and} \\ (\text{R3}) \text{ hold, and } (\text{A15}) > (\text{A7}) \end{array} \right\}$$

is nonempty.

Now for (A15) to exceed (A7), we need

$$\begin{aligned} &[4kr_Y\{1+r\}^2 + \hat{\alpha}^2 R_Z^2]^2 [64k^3\{1+r\}^4]^{-1} - R_Z^2 \hat{\alpha}^2 [4k\{1+r\}]^{-1} \\ &> R_X^2 \{4k[1+r]^2\}^{-1} - \hat{\alpha}^2 [R_X^2 + R_Z^2[1+r]][4k\{1+r\}^2]^{-1}, \end{aligned} \quad (\text{A16})$$

which is obtained by using (A14) and simplifying. It is easy to check now that the following set of exogenous parameter values constitute an element of  $\Omega$ :  $r = 0.01$ ,  $k = 0.5$ ,  $R_X = 0.8928437$ ,  $R_Y = 0.884$ ,  $R_Z = 1.01$ , and  $P = 0.25$ . Thus, the set  $\Omega$  is nonempty. Q.E.D.

*Proof of Proposition 3.* The firm has three options: (1) use its currently available retained earnings to invest in project X at  $t = 1$  and do nothing at  $t = 2$ , (2) use its retained earnings to invest in project X at  $t = 1$  and acquire external funds to invest in project Y at  $t = 2$ , and (3) keep its retained earnings idle until  $t = 2$  by rejecting project X at  $t = 1$  and then use the retained earnings at  $t = 2$  to invest in project Y.

With option (1), the value of the firm's investment portfolio is

$$R_X^2\{4k[1 + r]^2\}^{-1} - P[1 + r]^2. \quad (\text{A17})$$

With option (2), the firm solves the following problem,

$$\{a_X^*, a_Y^*\} \in \operatorname{argmax} \{a_X R_X[1 - \alpha] + a_Y R_Y[1 - \alpha] - ka_X^2[1 + r]^2 - ka_Y^2[1 + r] - P[1 + r]^2\} \quad (\text{A18})$$

subject to

$$\alpha a_X^* R_X + \alpha a_Y^* R_Y = P[1 + r]. \quad (\text{A19})$$

Thus,

$$a_X^* = R_X[1 - \alpha]\{2k[1 + r]^2\}^{-1}, \quad (\text{A20})$$

$$a_Y^* = R_Y[1 - \alpha]\{2k[1 + r]\}^{-1}, \quad (\text{A21})$$

and the value of the firm's investment portfolio is

$$R_X^2[1 - \alpha^2]\{4k[1 + r]^2\}^{-1} + R_Y^2[1 - \alpha^2]\{4k[1 + r]\}^{-1} - P[1 + r][2 + r], \quad (\text{A22})$$

where

$$\alpha = [1/2] - \{[1/4] - 2kP[1 + r]^3\{R_X^2 + R_Y^2[1 + r]\}^{-1}\}^{1/2}. \quad (\text{A23})$$

Finally, with option (3), the value of the firm's investment portfolio is

$$R_Y^2\{4k[1 + r]\}^{-1} - P[1 + r]. \quad (\text{A24})$$

I shall assume that  $R_Y > R_X$ , so that investing in only project Y is better than investing in only project X.

The implied parametric restrictions on the model are

$$4k[1 + r]^2 \geq R_X^2 > 4kP[1 + r]^4, \quad (R4)$$

$$4k[1 + r] \geq R_Y^2 > 4kP[1 + r]^3, \quad (R5)$$

$$R_X^2 + R_Y^2[1 + r] \geq 8kP[1 + r]^3, \quad (R6)$$

$$R_Y > R_X. \quad (R7)$$

(R4) guarantees that  $a_X^* \leq 1$  and that the (internally funded) value of project X is positive. (R5) guarantees the same for project Y. And (R6) guarantees that  $\alpha$  is real. We can now combine (R4), (R5), and (R7) to write

$$4k[1 + r] \geq R_Y^2 > R_X^2 > 4kP[1 + r]^4. \quad (R4')$$

Given (R4'), it is obvious that (R6) is redundant.

We now want to establish that there are feasible parameter values for which (A24) exceeds (A22). With some algebra, we can see that this is equivalent to showing that

$$\alpha^2 R_Y^2 \{4k[1 + r]\}^{-1} > [1 - \alpha^2] R_X^2 \{4k[1 + r]^2\}^{-1} - P[1 + r]^2. \quad (A25)$$

Thus, there should be a nonempty set of exogenous parameter values such that (A25) and (R4') are satisfied. An element of that set is  $r = 0$ ,  $R_X^2 = 4.1kP$ ,  $R_Y^2 = 11.9kP$ ,  $P = 1/3$ ,  $k > 0$ . Thus, we are done. Q.E.D.

#### REPLICATION OF PAYBACK RESULT UNDER PRIVATE INFORMATION

Suppose a firm has a choice between two mutually exclusive projects A and B at  $t = 1$ . The firm currently has  $\$P$  of internal funds. Each project requires an investment of  $\$P$ . Project A yields no cash flow at  $t = 2$ ; at  $t = 3$ , it yields a cash flow of  $R$  w.p.  $p_A$  and zero w.p.  $1 - p_A$ . Project B yields a cash flow of  $R$  w.p.  $p_B$  and zero w.p.  $1 - p_B$  at  $t = 2$ ; it yields no cash flow at  $t = 3$ . Project A has a higher value than project B (with internal financing for both), i.e.,

$$p_A R - P[1 + r]^2 > p_B R[1 + r] - P[1 + r]^2,$$

which means

$$R[p_A - p_B\{1 + r\}] > 0. \quad (A26)$$

At  $t = 2$ , the firm will have the option to invest in project C, which requires an investment of  $\$P$  and yields a cash flow of  $R$  w.p.  $p_C$  and zero w.p.  $1 - p_C$  at  $t = 3$ .

Although corporate insiders know the probability distribution of the cash

flow of project C, outsiders do not. They will discover it by expending a screening cost of  $K$ . In order to ensure that investing at time zero in either project A or B dominates the strategy of saving the currently available liquidity to avoid screening costs for project C w.p. one at  $t = 2$ , assume that

$$p_B R - P[1 + r] > K[1 + r]. \quad (\text{A27})$$

Although (A27) is sufficient, it is stronger than what is needed. Moreover, to ensure *interim efficiency* in the external financing of project C, assume

$$p_C R - P[1 + r] > K[1 + r]. \quad (\text{A28})$$

That is, if the firm finds itself in the state in which the first period project cash flow is zero, it should still view investing in project C with complete external financing as optimal. The following analog of Proposition 2 can be proved now.

*Proposition 2'.* Suppose

$$p_B K[1 + r] > R[p_A - p_B\{1 + r\}]. \quad (\text{A29})$$

Then, the firm will reject the (slower payback) project A and invest in the (faster payback) project B at  $t = 1$  and then invest in C at  $t = 2$  regardless of whether it requires external funding or not.

*Proof:* Suppose project A is funded internally, project B is rejected and project C is funded. The total value of this investment strategy to the firm is

$$\frac{2p_A p_C R[1 - \alpha] + p_A[1 - p_C]R[1 - \alpha] + [1 - p_A]p_C R[1 - \alpha]}{P[1 + r]^2}, \quad (\text{A30})$$

where  $\alpha$  is determined by

$$\frac{2\alpha p_A p_C R + \alpha p_A R[1 - p_C] + \alpha[1 - p_A]p_C R}{-K[1 + r]} = P[1 + r]. \quad (\text{A31})$$

Substituting (A31) in (A30) yields

$$\frac{2p_A p_C R + p_A[1 - p_C]R + [1 - p_A]p_C R - P[1 + r]^2}{-[P + K][1 + r]}. \quad (\text{A32})$$

Now consider the option of rejecting project A, investing in project B, and then funding project C. The total value of this strategy to the firm is



$$p_B[\{R - P\}\{1 + r\} + p_C R] + [1 - p_B][p_C R\{1 - \alpha\}] - P[1 + r]^2, \quad (\text{A33})$$

where

$$\alpha p_C R = [P + K][1 + r]. \quad (\text{A34})$$

Substituting (A34) in (A33) yields

$$p_B[R - P][1 + r] + p_B p_C R + [1 - p_B][p_C R - \{P + K\}\{1 + r\}] - P[1 + r]^2. \quad (\text{A35})$$

Comparing (A32) and (A35), we need the expression in (A35) to exceed that in (A32). A little algebra shows that this is true as long as (A29) holds. Q. E. D.

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