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Internal versus External Financing: An Optimal Contracting Approach*

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Abstract

We study optimal financial contracting for centralized and decentralized firms. Under centralized contracting, headquarters raises funds on behalf of multiple projects. Under decentralized contracting, each project raises funds separately on the external capital market. The benefit of centralization is that headquarters can use excess liquidity from high cash-flow projects to buy continuation rights for low cash-flow projects. The cost is that headquarters may pool cash flows from several projects and self-finance follow-up investments without having to return to the capital market. Absent any capital market discipline, it is more difficult to force headquarters to make repayments, which tightens financing constraints ex ante. Cross-sectionally, our model implies that conglomerates should have a lower average productivity than stand-alone firms.

BEGINNING WITH FAZZARI, HUBBARD, AND PETERSEN (1988), several studies document that the investment behavior of firms is affected by financing constraints.[1] In this paper, we explore the relation between financing constraints and organizational structure. Specifically, we ask whether centralized firms where headquarters raises funds on behalf of multiple projects face tighter or looser financing constraints than stand-alone firms.

The internal capital markets literature provides some hints on the role of organizational structure for financing constraints. There, headquarters either adds or destroys value, for example, by engaging in winner-picking (Stein (1997)),

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[1] See Hubbard (1998) for an overview of the literature.

redeploying assets across divisions (Gertner, Scharfstein, and Stein (1994)), or weakening managerial incentives (Stein (2002)). Naturally, these activities will affect the return to capital and hence also the firm's financing constraint. As none of these papers adopts an optimal contracting approach, the precise nature and magnitude of the effect remains unclear, however. On the other hand, optimal contracting models, while deriving financing constraints and the associated underinvestment problem from first principles, typically consider an entrepreneurial firm where the entrepreneur raises funds for a single project. In this setting, questions of organizational structure and multiple projects cannot be addressed.

This paper adopts an optimal contracting approach to examine the role of headquarters for financing constraints, thus tying together internal and external capital markets. We compare optimal contracting between (a) outside investors and individual project managers ("decentralized borrowing"), and (b) outside investors and headquarters, who borrows on behalf of multiple projects and subsequently allocates the funds to the various projects on the firm's internal capital market ("centralized borrowing"). The term "borrowing" refers to the fact that in our setting, like in related multiperiod settings by Bolton and Scharfstein (1990), Hart and Moore (1998), and DeMarzo and Fishman (2000), the optimal contract is a debt contract. Financing constraints arise endogenously in our model as we assume that part of the project cash flow is nonverifiable. The problem is then to provide the firm (i.e., the project manager or headquarters) with incentives to pay out funds rather than to divert them.

The benefit of centralization is that financial contracts with centralized firms are more efficient. To make the firm reveal its true cash flow, investors must offer it a bribe. In a two-period model like ours, bribes can come in two forms. Either the firm makes a lower repayment in the *first period*, or it is offered a higher continuation benefit. The continuation benefit is the expected rent captured by the firm in the *second period* if the financing relationship is continued. Under centralized borrowing, a greater fraction of the bribe comes in the form of continuation benefits, which is efficient as it involves undertaking positive NPV second-period investments that would have not been undertaken otherwise. Effectively, headquarters uses excess liquidity from high-cash-flow projects to buy continuation rights for low-cash-flow projects. This allows headquarters to make greater repayments, which eases financing constraints ex ante.

The cost of centralization is that headquarters can accumulate internal funds by pooling cash flows from different projects and self-finance second-period investments without returning to the capital market. Absent any capital market discipline, however, it is more difficult for investors to force the firm to pay out funds, which tightens financing constraints. This last point is reminiscent of Jensen (1986), where the problem is also that firms can undertake investments without revisiting the capital market. Our model adopts an ex ante perspective: Anticipating that a free cash-flow problem might arise, investors are reluctant to provide financing in the first place.

Based on these costs and benefits of centralization, we trace out the boundaries of the firm. Ceteris paribus, centralization is optimal for projects with a low expected return, or productivity, while decentralization is optimal for projects with a high expected return. Cross-sectionally, this implies that conglomerates should have a lower average productivity than stand-alone firms. Our model provides testable implications linking financing constraints to operating productivity, the degree of firm diversification, and the composition of a firm's investment portfolio.

An important question is to what extent the value created in an internal capital market will eventually be shared with investors. Our paper suggests that the same ability that allows headquarters to create value, namely, the ability to pool cash flows, also protects it from fully relinquishing these gains to investors. As the centralized firm might not need the investors for follow-up financing, the investors' ability to extract some of the gains created in an internal capital market is limited. Taking into account this conflict, we provide conditions under which conglomeration is optimal. We believe this is a central contribution of the paper, and a possible answer to the question why the value created in an internal capital market might not be fully passed on to investors.

Several papers have analyzed the costs and benefits of internal capital markets, notably Gertner et al. (1994), Stein (1997), Rajan, Servaes, and Zingales (2000), and Scharfstein and Stein (2000). None of these papers addresses the issue examined here, namely, contracting between headquarters and outside investors, and the implications of this for the optimality of conglomerates. In terms of empirical predictions, a key feature of our model is the relation between productivity or operating performance and the mode of incorporation. None of the above papers studies this relation. Moreover, some of these papers make predictions relating divisional investment to the divisions' investment opportunities. In our model, opportunities are the same across divisions, which is an assumption we make to abstract from winner-picking effects. Instead, our model makes predictions relating divisional investment to past division cash flows.

Berkovitch, Israel, and Tolkowsky (2000) and Matsusaka and Nanda (2002) also explore the relation between internal capital markets and firm boundaries. In the paper by Berkovitch et al., headquarters has unlimited funds, which implies financing constraints do not matter. Matsusaka and Nanda assume that external finance entails a deadweight loss that is equally great for conglomerates and stand-alone firms. This assumption is precisely what we question in our paper. Finally, we are not the first to note that cash-flow pooling can affect agency problems between the firm and investors. Papers in this genre include, for example, Diamond (1984), Li and Li (1996), and Fluck and Lynch (1999). Unlike these papers, cash-flow pooling in our paper has both endogenous costs and benefits.

The rest of the paper is organized as follows. Section I derives the costs and benefits of centralization in an optimal contracting framework. Section II discusses robustness issues. Section III presents various extensions of the basic model. Section IV summarizes the empirical implications and compares them to the evidence. Section V concludes. All proofs are in the Appendix.

I. Centralized versus Decentralized Borrowing

A. The Model

The model is a multiperiod contracting model with partially nonverifiable cash flows in the spirit of Bolton and Scharfstein (1990), DeMarzo and Fishman (2000), Gertner et al. (1994), and Hart and Moore (1998). For the same reason as in these models, the optimal contract in our model is a debt contract. Anticipating this result, we use the term "borrowing" to denote the act of raising external finance. While the basic formulation here follows Bolton and Scharfstein, none of the results in this paper depend on the specifics of their model. In Section II.C, we show that the same trade-off also obtains in a Hart–Moore type framework.

Suppose a project lasts for two periods. In each period, it requires an investment outlay $I>0$ and yields an end-of-period cash flow $\pi_l<I$ with probability $p>0$ and $\pi_h>I$ with probability $1-p$, where $\pi_h>\pi_l$. Cash flows are uncorrelated across periods. Instead of assuming that a project lasts for two periods, we could equally imagine two separate, but technologically identical (sub)projects that are carried out one after the other. The expected per-period cash flow net of investment costs is strictly positive, that is, $\overline{\pi}:=p\pi_l+(1-p)\pi_h>I$.

Suppose a firm has two such two-period projects. For the moment, we shall assume that cash flows are uncorrelated across projects. In Section III.A, we relax this assumption. As the firm has no funds, it must raise funds from outside investors. For convenience, we assume there is a single investor who makes a take-it-or-leave-it offer to the firm. While the assumption that there is a single investor may seem unrealistic, it is inconsequential for our results. The only reason for making this assumption is that it simplifies the contracting problem. See Section II.E and footnote 3 for a discussion of this issue.

The firm's founder can choose between two organizational structures, which differ in their assignment of projects to managers. Under *centralized borrowing*, a single manager called *headquarters* is in charge of both projects. Under *decentralized borrowing*, a separate *project manager* is in charge of each project. We use the standard assumption that agents in charge of projects maximize the cash proceeds from projects under their control, for instance, because they derive private benefits that are proportional to these proceeds. As projects require no monitoring or managerial effort, but only capital, the question is therefore whether the founder should form one firm where headquarters borrows on behalf of both projects or two separate firms that borrow independently on the external capital market. While the problem is framed as an organizational design problem, it could be equally framed as a divestiture problem where a conglomerate contemplates spinning off one of its divisions. The model and results would be the same.

Neither cash flows nor investment decisions are verifiable, which implies contracts can only condition on payments to and from the investor as well as public messages. The assumption that cash flows are nonverifiable is standard and captures the notion that outsiders such as courts frequently have less information than the parties to a contract. Since we adopt a message-game approach, it actually makes no difference whether cash flows and investment decisions are observable but nonverifiable, or whether they can be observed by project managers and headquarters but not by investors. We can therefore equally assume that project managers and headquarters have private information about cash flows and investment decisions. The assumption that investment decisions are nonverifiable simplifies the analysis, but is not needed. In Section II.C we show that the same kind of trade-off obtains in a setting where investment decisions are verifiable. Finally, even though courts cannot observe actual cash flows, it is commonly known that the lowest possible cash flow is π_l. Hence, we can equally assume that a fraction π_l of the cash flow is verifiable and only the difference $\pi_h - \pi_l$ is nonverifiable.

Under both centralized and decentralized borrowing, the partial nonverifiability of cash flows creates an incentive problem between the firm and the investor. Under centralized borrowing, the problem is to provide headquarters with incentives to pay out funds. Under decentralized borrowing, the problem is to provide individual project managers with incentives to pay out funds. Under centralized borrowing, there are two subcases, depending on whether a high-cash-flow firm can partly self-finance second-period investment or not. We shall label these subcases "self-financing" and "no self-financing," respectively.

B. Decentralized Borrowing

The model of decentralized borrowing is adapted from Bolton and Scharfstein (1990). Under decentralized borrowing, each of the two project managers borrows separately on the external capital market. As the contracting problem is the same for each manager, we will henceforth speak of *the* manager and *the* project. The standard way to deal with nonverifiability of cash flows is to adopt a message-game approach. In the present context, this means that after the cash flow is realized, the manager makes a publicly verifiable announcement stating that the cash flow is either low or high. The sequence of events is as follows:

- Date 0: The investor pays I and the manager (optimally) invests.
- Date 1: The manager announces that the first-period cash flow is $\hat{s} \in \{l, h\}$. Based on this announcement, the manager makes a first repayment $R^1(\hat{s})$, and the investor finances second-period investment, that is, he pays I a second time, with probability $\beta(\hat{s})$. If the manager receives I, he again (optimally) invests.
- Date 2: Based on the date 1 announcement, the manager makes a second repayment $R^2(\hat{s})$.

Two comments are in order. Like most financial contracting models, we allow for probabilistic (re)financing schemes to permit nontrivial solutions. If the continuation probability can be either zero or one, the qualitative results are the same but the benefits from centralization are smaller. Second, while it is theoretically possible to have the manager also announce the second-period cash flow (in case he receives funding at date 1), this is pointless as he will always claim that the second-period cash flow is low. By contrast, it is possible to induce the manager to truthfully reveal the first-period cash flow by threatening him not to provide second-period financing. An implicit assumption herein is that, if the manager of a high-cash-flow firm claims that the cash flow is low, he cannot use the remaining cash to self-finance second-period investment. If he could, the investor's threat to terminate funding would be empty and financing would break down completely. Formally, the assumption is

ASSUMPTION 1: $\pi_h - \pi_l < I$.

Recall that the investor can always extract π_l. An immediate implication of Assumption 1 is that $\pi_l > 0$, or else the assumption that $\pi_h > I$ is violated. The investor solves the following maximization problem:

$$\max_{\beta(s),\, R^1(s),\, R^2(s)} -I + p[R^1(l) + \beta(l)(R^2(l) - I)] + (1-p)[R^1(h) + \beta(h)(R^2(h) - I)]$$

s.t.

$$r(s) - R^1(s) + \beta(s)[\bar{\pi} - R^2(s)] \geq r(s) - R^1(\hat{s}) + \beta(\hat{s})[\bar{\pi} - R^2(\hat{s})] \text{ for all } s,\ \hat{s} \in \{l,\ h\}, \tag{1}$$

$$R^1(s) \leq r(s) \text{ for all } s \in \{l,\ h\},$$

and

$$R^2(s) \leq r(s) - R^1(s) + \pi_l \text{ for all } s \in \{l,\ h\}, \tag{2}$$

where $r(l) := \pi_l$ and $r(h) := \pi_h$.

The first constraint is the manager's incentive compatibility (or truth-telling) constraint. The remaining two constraints are limited liability constraints. The first states that the first-period repayment must not exceed the first-period cash flow, while the second states that the total repayment must not exceed the sum of first- and second-period cash flows. Whenever (1) and (2) are satisfied, the manager's individual rationality constraint is also satisfied, which is why it can be omitted.

From Bolton and Scharfstein (1990), we know that the solution to this problem is $\beta(l) = 0$, $\beta(h) = 1$, $R^1(l) = R^2(h) = \pi_l$, and $R^1(h) = \bar{\pi}$. If the manager announces that the first-period cash flow is high, he receives second-period financing for sure. If he announces that the cash flow is low, he receives no second-period financing.

The optimal contract involves two types of inefficiencies. First, with probability p, the second-period investment is not undertaken. Despite this inefficiency, however, there will be no renegotiation on the equilibrium path as the maximum which the investor can assure in the second period is $\pi_l < I$. Second, if we insert the optimal contract in the investor's objective function and solve for the value of I at which he breaks even, we have that the investor invests at date 0 if and only if

$$I \leq \overline{\pi} - \frac{\overline{\pi} - \pi_l}{2 - p}. \tag{3}$$

Projects that cost less than $\overline{\pi}$ but more than the right-hand side in (3) receive no funding at date 0 even though they have a strictly positive NPV. In other words, the firm is financially constrained.

C. Centralized Borrowing: No Self-Financing

Under centralized borrowing, headquarters borrows against the combined cash flow of the two projects. The relevant cash flow is therefore $r(l,l) := 2\pi_l$ with probability p^2, $r(l,h) := \pi_l + \pi_h$ with probability $2p(1-p)$, and $r(h,h) := 2\pi_h$ with probability $(1-p)^2$. The sequence of events is the same as under decentralized borrowing.

As a contract now encompasses two projects, the potential contracting space becomes richer. In particular, the investor may use separate refinancing probabilities $\beta_1(\hat{s})$ and $\beta_2(\hat{s})$ for each of the two second-period investments, which implies he will end up refinancing either zero, one, or two projects. It can be shown, however, that any such contract is equivalent to a contract where the investor uses a common refinancing probability $\beta(\hat{s})$ for both second-period investments.[2] Without loss of generality, we can thus assume that the investor pays $2I$ with probability $\beta(\hat{s})$ at date 1.

We finally need to specify what the firm's self-financing possibilities are if a firm with two high cash flows falsely claims that its cash flows are low. Given Assumption 1, there are only two possibilities: (a) $2(\pi_h - \pi_l) < I$, in which case the firm cannot self-finance at all, and (b) $2I > 2(\pi_h - \pi_l) > I$, in which case a firm with two high cash flows can make one, but only one, second-period investment without returning to the capital market. If a high cash-flow firm could self-finance both second-period projects, Assumption 1 would be violated, that is, the investor's threat would be empty and financing would break down.

In our model, centralization has costs and benefits. We derive the basic tradeoff in two steps. We first consider the case where self-financing is not possible. In this case, centralization has only benefits. We then introduce the possibility that a high cash-flow firm can self-finance one second-period investment with internal cash. In this case, the benefits derived earlier are still there, but there are also costs.

Consider first the case where the firm cannot self-finance second-period investment. Formally, we have the assumption that self-financing is not possible.

ASSUMPTION 2: $2(\pi_h - \pi_l) < I$.

In what follows, we assume that Assumptions 1 and 2 hold.

[2] A proof of this statement is contained in a previous working paper version of this paper (Inderst and Müller (2000)). The proof is available from the authors upon request.

The problem under centralized borrowing is to provide headquarters with incentives to reveal the true cash flow. Denote the set of possible cash flows by $S := \{(l,l), (l,h), (h,h)\}$. The investor maximizes

$$\begin{aligned}\max_{\beta(s),\, R^1(s),\, R^2(s)} & -2I + p^2[R^1(l,\ l) + \beta(l,\ l)(R^2(l,\ l) - 2I)] \\ & + 2p(1-p)[R^1(h,\ l) + \beta(h,\ l)(R^2(h,\ l) - 2I)] \\ & + (1-p)^2[R^1(h,\ h) + \beta(h,\ h)(R^2(h,\ h) - 2I)]\end{aligned} \tag{4}$$

s.t.

$$\begin{aligned} & r(s) - R^1(s) + \beta(s)[2\bar{\pi} - R^2(s)] \\ & \quad \geq r(s) - R^1(\hat{s}) + \beta(\hat{s})[2\bar{\pi} - R^2(\hat{s})] \text{ for all } s,\ \hat{s} \in S,\end{aligned} \tag{5}$$

$$R^1(s) \leq r(s) \text{ for all } s \in S. \tag{6}$$

and

$$R^2(s) \leq r(s) - R^1(s) + 2\pi_l \text{ for all } s \in S. \tag{7}$$

The individual rationality constraint can be again omitted as it is implied by the stronger limited liability constraints (6) and (7).

The optimal contract is derived in the Appendix in the proof of Proposition 1. In the low- and high-cash-flow states, the optimal contract is the same as under decentralized borrowing, except that all payments are multiplied by two. We thus have $\beta(l,l) = 0$, $R^1(l,l) = 2\pi_l$, $\beta(h,h) = 1$, $R^1(h,\ h) = 2\bar{\pi}$, and $R^2(h,h) = 2\pi_l$. If both first-period cash flows are low, the firm obtains no second-period financing, while if both first-period cash flows are high, the firm obtains second-period financing for sure. In the intermediate case where one cash flow is low and the other is high, the optimal contract is either identical to that of the high-cash-flow firm (if $p \geq 1/2$), or it has $\beta(h,l) = 1/[2(1-p)] > 1/2$, $R^1(h,l) = \pi_h + \pi_l$, and $R^2(h,l) = 2\pi_l$ (if $p \leq 1/2$). This case distinction is due to the fact that if $p \geq 1/2$ the limited liability constraint (7) is slack. By contrast, if $p < 1/2$ the constraint binds, which implies that the investor can extract the maximum possible date 1 repayment.

The only cash-flow state where centralization makes a difference is thus the intermediate state where one cash flow is low and the other is high. In this state, the refinancing probability is strictly greater than one-half. By contrast, the average refinancing probability under decentralized borrowing is $[\beta(h)+\beta(l)]/2 = 1/2$. We can therefore conclude that the first type of inefficiency, namely, that efficient second-period investments are not undertaken, is less severe if borrowing is centralized.

If we insert the optimal contract in the investor's objective function (4) and solve for the value of I at which he breaks even, we obtain that the investor invests at date 0 if and only if

$$I \leq \bar{\pi} - \frac{\bar{\pi} - \pi_l}{2 - p + p^2} \tag{8}$$

if $p \leq 1/2$, and

$$I \leq \bar{\pi} - \frac{\bar{\pi} - \pi_l}{2 - p^2} \tag{9}$$

if $p \geq 1/2$. Comparing (8) to (9) with the corresponding value under decentralized borrowing, (3), we have that the second type of inefficiency, namely, that positive NPV projects are not financed at date 0, is also less severe under centralized borrowing. This holds for any value of p. The following proposition summarizes these results.

PROPOSITION 1: *If Assumptions 1 and 2 hold, centralized borrowing is optimal for all p. That is, it is optimal to have headquarters borrow on behalf of both projects and subsequently allocate the funds on the firm's internal capital market rather than have each project borrow separately on the external capital market.*

The superiority of centralization vis-à-vis decentralization is *not* based on a superior allocation of funds to projects inside the firm. At date 1, the two projects are identical in every respect. Hence, there is no scope for winner picking. Rather, the superiority of centralization derives from the fact that incentives for revealing the true date 1 cash flow can be provided more efficiently.

The argument why centralized borrowing is optimal proceeds in two steps. If both projects have a high cash flow, the optimal repayment and refinancing probability under centralized and decentralized borrowing are identical. Similarly, if both projects have a low cash flow, the optimal contracts under centralized and decentralized borrowing are the same. In what follows, we can thus focus on the intermediate cash-flow state where one project has a high and the other has a low cash flow. To facilitate the exposition, we first derive some preliminary results. Incentive compatibility requires that a firm with two high cash flows or one high and one low cash flow has no incentive to mimic a firm with two low cash flows. To make mimicking a low-cash-flow firm as costly as possible, the investor sets $\beta(l) = 0$ and $R^1(l) = \pi_l$ (under decentralized borrowing) and $\beta(l,l) = 0$ and $R^1(l,l) = 2\pi_l$ (under centralized borrowing). Moreover, it is evidently optimal to set $R^2(h) = \pi_l$ and $R^2(h,l) = R^2(h,h) = 2\pi_l$, which means the firm must pay out its entire verifiable date 2 cash flow.

Under decentralized borrowing, one firm has a high and the other has a low cash flow. Consider the high-cash-flow firm's incentive compatibility constraint:

$$\underbrace{\pi_h - R^1(h)}_{\text{first-period rent}} + \underbrace{\beta(h)[\bar{\pi} - \pi_l]}_{\text{continuation benefit}} \geq \pi_h - \pi_l. \tag{10}$$

The right-hand side depicts the payoff from mimicking the low-cash-flow firm. Accordingly, to induce the high-cash-flow firm to reveal its cash flow, the investor must leave the firm a rent of $\pi_h - \pi_l$ if it announces h. (This rent is called *information rent.*) The investor can provide this rent in two ways: (a) he can demand a lower date 1 repayment $R^1(h)$, or (b) he can grant the firm a higher continuation benefit $\beta(h)[\overline{\pi} - \pi_l]$ by increasing the continuation probability $\beta(h)$. Consider the cost to the investor under either option. Reducing the date 1 repayment is a zero-sum transaction, that is, a dollar left in the firm's pocket is a dollar less in the investor's pocket. By contrast, granting the firm a continuation benefit of $\beta(h)[\overline{\pi} - \pi_l]$ costs the investor only $\beta(h)$ $[I - \pi_l]$, which is less than $\beta(h)[\overline{\pi} - \pi_l]$. The difference $\beta(h)[\overline{\pi} - I]$ is the (expected) efficiency gain from second-period investment. As the investor makes the contract offer, he can siphon off this efficiency gain. The solution is thus to provide as much rent as possible in the form of continuation benefits.[3] As the maximum continuation benefit under decentralized borrowing is $\overline{\pi} - \pi_l$, the remainder $\pi_h - \overline{\pi}$ must come in the form of first-period rent, that is, in the form of a lower date 1 repayment.

Consider now the intermediate-cash-flow firm under centralized borrowing. As we show in the Appendix in the proof of Proposition 1, it suffices to consider the incentive constraint ensuring that the intermediate-cash-flow firm has no incentive to mimic the low-cash-flow firm:

$$\underbrace{\pi_h + \pi_l - R^1(h,\ l)}_{\text{first-period rent}} + \underbrace{\beta(h,\ l)2[\bar{\pi} - \pi_l]}_{\text{continuation benefit}} \geq \pi_h - \pi_l. \tag{11}$$

The information rent that must be granted in the intermediate-cash-flow state is again $\pi_h - \pi_l$. Unlike above, however, the investor can now provide a continuation benefit of up to $2[\overline{\pi} - \pi_l]$. The continuation benefit actually provided is either $2[\overline{\pi} - \pi_l]$ (if $p \geq 1/2$) or $\pi_h - \pi_l$ (if $p < 1/2$), which is both strictly greater than the corresponding value $\overline{\pi} - \pi_l$ under decentralized borrowing. This is what constitutes the *fundamental advantage of centralized over decentralized borrowing.* While the total information rent is the same under centralized and decentralized borrowing, its composition is different. Under decentralized borrowing, the continuation decision concerns a single project, which means that a relatively large fraction of the rent must come in the form of first-period rent. By contrast, under centralized borrowing the continuation decision concerns two projects, which means that most (if $p \geq 1/2$), or even all (if $p < 1/2$) of the information rent can be provided in the form of continuation benefits. This is efficient, as it involves undertaking positive NPV investments that would have not been undertaken otherwise. Our result that centralization improves contract efficiency is robust in

[3] If the firm made the contract offer, *it* could siphon off the efficiency gain. Hence regardless of who makes the contract offer, he or she will want to provide as much information rent as possible in the form of continuation benefits. This is important, as it underscores the fact that the following argument (viz., that centralization is superior as it offers more scope for providing rents in the form of continuation benefits) applies irrespective of who makes the contract offer. In particular, this means that the argument also holds under a competitive credit market.

various ways. It holds if the state space is continuous (Section II.A), if investments are divisible (Sec. II.B), if credit markets are competitive (footnote 3 and Sec. II.E), and if cash flows are correlated (Sec. III.A).

Another way to view the trade-off between first- and second-period rents is in terms of *financial slack*. Any nonverifiable date 1 cash flow retained in the firm represents unused liquidity: Efficiency could be improved by trading it in for continuation rights. Consider the high-cash-flow firm under decentralized borrowing. After paying out $\overline{\pi}$, the high-cash-flow firm has remaining liquidity of $\pi_h - \overline{\pi}$. If the high-cash-flow firm were to share this liquidity with the low-cash-flow firm, the latter could trade it in for continuation rights. But as each firm cares only about its own continuation decision, this does not happen.[4]

Under centralized borrowing, this externality problem does not arise. As headquarters adopts a firm-wide perspective, it does not care which of the two projects produces the cash flow. Effectively, headquarters uses liquidity produced by the high-cash-flow project to buy continuation rights for the low-cash-flow project. (This also explains why the benefits of centralization arise only in the intermediate-cash-flow state.) Note that a financial intermediary, such as, for example, a bank, cannot do this as it does not have direct access to the firms' cash flow. Much like the investor under decentralized borrowing, a bank would have to provide the high-cash-flow firm with incentives to disgorge cash.

Finally, consider again the inequality in Assumption 2 and replace 2 by n, which implies that even n projects cannot provide sufficient cash to finance a single second-period investment. Replacing 2 by n, we obtain $n(\pi_h - \pi_l) < I$. If n becomes sufficiently large, this inequality can no longer be satisfied. In other words, the more projects there are under one roof, the more likely it is that the firm can finance at least one second-period investment without returning to the capital market. Therefore, let us next consider the case where (partial) self-financing is possible.

D. Centralized Borrowing: Self-Financing

In the context of this model, self-financing means that if both date 1 cash flows are high, headquarters can use its *nonverifiable* cash flow of $2(\pi_h - \pi_l)$ and finance one second-period investment without having to return to the capital market. We replace Assumption 2 by Assumption 3.

ASSUMPTION 3: $2I > 2(\pi_h - \pi_l) \geq I$.

In what follows, we assume that Assumptions 1 and 3 hold.

The fact that a high-cash-flow firm can partly self-finance second-period investment tightens the firm's incentive compatibility constraint. In the absence of self-

[4] What if the two firms write an insurance contract at date 0? Due to the nonverifiability of cash flows, the high-cash-flow firm *must* earn an information rent of $\pi_h - \pi_l$. If the insurance contract were to oblige the high-cash-flow firm to share this rent with the low-cash-flow firm, the former would not reveal its true cash flow in the first place. Hence any incentive compatible contract between the two firms must lead to exactly the same allocation as here.

financing, the payoff from mimicking a low-cash-flow firm is $2(\pi_h - \pi_l)$. By contrast, if the firm can self-finance second-period investment, the payoff from mimicking a low-cash-flow firm (and subsequently reinvesting the retained cash) is $2(\pi_h - \pi_l) + \overline{\pi} - I$. To induce the high-cash-flow firm not to mimic a low-cash-flow firm the investor must now additionally compensate the firm for the forgone profit of $\overline{\pi} - I$, that is, he must pay the firm a higher information rent. The general idea is that, by pooling cash flows from several projects, centralized firms may accumulate internal funds and make follow-up investments without having to return to the capital market. This weakens the investors' threat to withhold future financing, which in turn tightens financing constraints at date 0.

If we solve the investor's expected profit for the value of I at which he breaks even, we have that the investor invests at date 0 if and only if

$$I \leq \overline{\pi} - \frac{\overline{\pi} - \pi_l}{1 + p + \frac{(1-p)^2}{2}}, \tag{12}$$

if $p \leq 1/2$, and

$$I \leq \overline{\pi} - \frac{\overline{\pi} - \pi_l}{1 + 2p(1-p) + \frac{(1-p)^2}{2}} \tag{13}$$

if $p \geq 1/2$. Comparing (12) to (13) with the corresponding value under decentralized borrowing, (3), we obtain the following result.

PROPOSITION 2: *If Assumptions 1 and 3 hold, centralized borrowing where headquarters borrows on behalf of both projects is optimal if* $p \geq \sqrt{2} - 1$. *By contrast, if* $p \leq \sqrt{2} - 1$ *it is optimal to have each project borrow separately on the external capital market.*

Self-financing makes it more costly for the investor to induce the firm to reveal its true cash flow, which is captured by the additional "bribe," or information rent, $\overline{\pi} - I$ in the high-cash-flow state. The cost of centralization thus depends on the distribution of cash flows in two ways. First, the probability of the high-cash-flow state is decreasing in p. Second, the "bribe" $\overline{\pi} - I$ is also decreasing in p. Proposition 2 shows that if p is sufficiently small, that is, if the projects' productivity is sufficiently high, the costs of centralization outweigh the benefits. To relax financing constraints, the firm should decentralize, or what is equivalent, disintegrate. As a single-project firm does not generate enough cash to self-finance second-period investment, it must necessarily revisit the capital market. Hence, decentralization acts as a commitment vis-à-vis investors to stay on a tight leash.[5] The notion that firms may benefit from committing to a policy of revisiting the

[5] If both first-period cash flows are high, the two firms have a strong incentive to remerge at date 1. To commit not to merge again, the firms may write a covenant into their debt contract restricting merger activity. Such covenants are common. For instance, Smith and Warner (1979) find that 39.1 percent of the public debt issues in their sample include covenants restricting merger activity.

capital market is not new and has been used as an explanation, for example, for why firms pay dividends (Easterbrook (1984)) or issue debt (Jensen (1986)). In showing that a firm's organizational structure may act as a commitment to revisit the capital market, our argument complements these arguments.

The investor cannot legally prevent the firm from self-financing as both cash flows and investment decisions are nonverifiable. While the assumption that investment decisions are nonverifiable may be realistic in some cases, in particular if the firm consists of a complex bundle of investments where it is difficult for outsiders to ascertain whether the *i*-th investment has been undertaken or not, it may be less realistic in other cases. In Section II.C, we show that the assumption that investment decisions are nonverifiable is not needed if the parties can renegotiate after default.

Proposition 2 admits an alternative interpretation, which goes beyond the issue of financing constraints. It applies to situations where managers can withhold cash from both investors *and* the firm's owner(s). This may be because managers are better informed or ownership is dispersed, implying that the owners, while having formal control rights, have insufficient incentives to enforce their claims. Under this scenario, the firm's owners are in the same boat as the investor: Unless management can be incentivized to pay out cash, neither the investor nor the owners will see any of it. The optimal contract underlying Proposition 2 is also optimal in this setting as it maximizes the cash flow extracted by outsiders. The p-threshold characterizing the firm boundaries also remains optimal.

II. Discussion

A. Continuous Cash-Flow Distribution

The argument that one project does not generate enough cash to allow self-financing but two projects do is evidently independent of the cash-flow distribution. This is not so obvious with regard to the benefits of centralization, that is, the argument that financial contracts with centralized firms are more efficient.

Suppose cash flows are continuously distributed with support $[\pi_l,\pi_h]$. Consider first the case where borrowing is decentralized. It can be shown that the optimal contract is $\beta(\pi)=1$ and $R^1(\pi)=\overline{\pi}$ if $\pi\geq\overline{\pi}$, and $\beta(\pi)=(\pi-\pi_l)/(\overline{\pi}-\pi_l)$ and $R^1(\pi)=\pi$ if $\pi<\overline{\pi}$ (e.g., Bolton and Scharfstein (1990) and DeMarzo and Fishman (2000)). The optimal contract thus resembles a standard debt contract with face value $\overline{\pi}$ and liquidation probability $1-\beta(\pi)$. Consider next centralized borrowing. The firm's "type" is fully characterized by the sum $\omega:=\pi_1+\pi_2$, where π_1 and π_2 are the two first-period cash flows. Again, it can be shown that the optimal contract is $\beta(\omega)=1$ and $R^1(\omega)=2\overline{\pi}$ if $\omega\geq 2\overline{\pi}$, and $\beta(\omega)=(\omega-2\pi_l)/2(\overline{\pi}-\pi_l)$ and $R^1(\omega)=\omega$ if $\omega<2\overline{\pi}$. Hence, the optimal contract is again a standard debt contract, now with face value $2\overline{\pi}$ and liquidation probability $1-\beta(\omega)$.

Consider the above optimal contracts. If either $\pi_1\leq\overline{\pi}$ and $\pi_2\leq\overline{\pi}$ or if $\pi_1\geq\overline{\pi}$ and $\pi_2\geq\overline{\pi}$, that is, if either both cash flows are low or high, the refinancing probability under centralized borrowing is identical to the average refinancing probability under decentralized borrowing, $[\beta(\pi_1)+\beta(\pi_2)]/2$. In all other (i.e., intermediate) cash-flow states, the refinancing probability is strictly greater under centralized borrowing. The intuition for why centralized borrowing is superior is the same as in the basic model: In intermediate-cash-flow states, headquarters can use excess liquidity from low-cash-flow projects to buy continuation rights for high-cash-flow projects. In high- and low-cash-flow states, such cross-subsidies are either not necessary or not possible, respectively. By contrast, under decentralized borrowing, cross-subsidies never occur. Accordingly, the first type of inefficiency, namely, that efficient second-period investments are not undertaken, is strictly lower under centralized borrowing.

We can again solve for the value of I at which the investor breaks even. Again, we find that the second type of inefficiency, namely, that positive NPV projects are not financed at date 0, is less severe under centralized borrowing if and only if the expected refinancing probability under centralized borrowing is higher. By the above argument, this is the case if and only if

$$\Pr(\pi_i < \overline{\pi} | \pi_j \geq \overline{\pi}) > 0 \text{ for } i \neq j, \tag{14}$$

that is, if there is a nonzero probability that one cash flow is below and the other is above the mean. Proposition 1 thus extends to arbitrary continuous cash-flow distributions satisfying (14). If (14) does not hold, the organizational structure is irrelevant. Condition (14) holds, for instance, if the joint distribution of π_1,π_2 has full support. Conversely, if π_1 and π_2 are perfectly positively correlated, (14) does not hold. Since both distributions have the same mean, the probability that one cash flow is below the mean and the other is above the mean is then zero.

B. Indivisibility of Investments

What is the role of investment indivisibilities in this model? In particular, suppose at date 1 the firm could invest a fraction $\alpha \leq 1$ of I in a project technology with constant returns to scale. Would this affect our results? We address this question in three parts, pertaining to the role of indivisibilities for (a) the threat to withhold financing ("termination threat"), (b) the benefits of centralization, and (c) the costs of centralization.

B.1. Termination Threat

Consider, for instance, the benchmark model of decentralized borrowing. There, the incentives for a high-cash-flow firm to repay $\overline{\pi}$ instead of π_l are that in return the investor finances second-period investment. Investment indivisibilities are *not* essential in providing these incentives. What is essential is that the firm cannot capture all, or most, of the second-period efficiency gains by self-financing the investment. Suppose the high-cash-flow firm can use its nonverifiable cash flow of $\pi_h - \pi_l$ to finance a fraction $\alpha := (\pi_h - \pi_l)/I$ of the second-period investment. With constant returns to scale, the expected return on this investment is $\alpha\overline{\pi}$. By the same logic as in Section I.D ("self-financing"), the investor must then grant the high-cash-flow firm an *additional* information rent of $\alpha(\overline{\pi} - I)$ to preserve incentive compatibility. Solving the investor's expected profit for the value of I at which he breaks even, we have that the investor invests at date 0 if and only if

$$I \leq \overline{\pi} - \frac{\overline{\pi} - \pi_l}{(1-p)(1-\alpha)+1}. \tag{15}$$

If $\alpha = 0$, (15) coincides with the corresponding threshold in the basic model, (3). By inspection, the right-hand side in (15) is strictly decreasing in α, positive for low α, and negative for high α. If α is high, the firm can realize most of the second-period efficiency gains without borrowing additional funds from the investor. In this case, the investor's threat to withhold financing at date 1 is ineffective, and financing at date 0 breaks down. By contrast, if α is low, the firm can only realize a small fraction of the efficiency gains by itself. In this case, the incentives to make a high repayment and turn to the investor for additional funding are strong, and date 0 financing becomes feasible. Moreover, the lower α, the greater is the right-hand side in (15), and the looser is the firm's date 0 financing constraint. Hence, the effectiveness of the threat to withhold future financing does not depend on investment indivisibilities. What is key, however, is that the firm cannot exploit all, or most, of the efficiency gains through self-financing.

B.2. Benefits of Centralization

In Section I.C ("no self-financing"), we elucidated the benefits of cash-flow pooling by comparing the incentive compatibility constraint of the high cash-flow firm under decentralized borrowing, (10), with that of the intermediate cash-flow firm under centralized borrowing, (11). Consider again these two incentive constraints, now assuming that the firm can use its nonverifiable cash flow to invest in a project technology with constant returns to scale. The two incentive constraints become

$$\underbrace{\pi_h - R^1(h)}_{\text{first-period rent}} + \underbrace{\beta(h)[\overline{\pi} - \pi_l]}_{\text{continuation benefit}} \geq \pi_h - \pi_l + \alpha(\overline{\pi} - I) \tag{16}$$

and

$$\underbrace{\pi_h + \pi_l - R^1(h,\ l)}_{\text{first-period rent}} + \underbrace{\beta(h,\ l)2[\overline{\pi} - \pi_l]}_{\text{continuation benefit}} \geq \pi_h - \pi_l + \alpha(\overline{\pi} - I), \tag{17}$$

respectively. The high-cash-flow firm under decentralized borrowing and the intermediate-cash-flow firm under centralized borrowing have the same nonverifiable cash flow, $\pi_h - \pi_l$. Hence, both firms can invest the same fraction α and, by the argument in (a), earn the same additional information rent $\alpha(\overline{\pi} - I)$. The benefits of cash-flow pooling thus remain unchanged: Both firms continue to earn the same total information rent (right-hand side in (16) and (17)), but under centralized borrowing, a greater fraction of this rent can be provided in the form of continuation benefits.

B.3. Costs of Centralization

In Section I.C ("self-financing"), the costs of centralization were that in the high-cash-flow state, the centralized firm can extract a higher information rent than the two decentralized firms together. These costs do not arise if the firm can invest a fraction α of I in a project technology with *constant* returns to scale at date 1. Note that in all three cash-flow states the centralized firm and the two stand-alone firms together have the same nonverifiable cash flow, namely, $2(\pi_h - \pi_l)$ (high-cash-flow state), $\pi_h - \pi_l$ (intermediate-cash-flow state), and zero (low-cash-flow state). By the argument in (B.2), the information rent collected by the centralized firm is therefore the same as that collected by the two decentralized firms together in each of the three cash-flow states.

For centralization to be costly in our model, it is essential that in the high-cash-flow state the centralized firm, after investing its nonverifiable cash flow of $2(\pi_h - \pi_l)$, earns a higher second-period return than the two decentralized firms together after investing $\pi_h - \pi_l$ each. This is true if and only if the project technology exhibits *increasing* returns to scale. The fixed-cost technology in Section I is not the sole, but a practically very important example of this technology class.

C. Nonverifiability of Investment Decisions

In Section I.D, the nonverifiability of investment decisions allowed the firm to self-finance second-period investment without interference by the investor provided it had enough (nonverifiable) cash flow. The investor cannot simply add a clause in the contract stating that the firm cannot invest unless it makes a sufficiently high repayment. As investment decisions are nonverifiable, the only way for the investor to get the firm to make a high repayment is to pay it a higher bribe, that is, information rent. We argued earlier that the assumption that investment decisions are nonverifiable may be realistic in some cases, but less realistic in others. We shall now relax this assumption, instead assuming that the parties can renegotiate after default. The basic insight remains the same: Centralization is costly because the centralized firm can realize a higher payoff in the renegotiation than two decentralized firms together. Consequently, the investor must offer the centralized firm a higher bribe to prevent default.

Our model of renegotiation is adapted from Hart and Moore (1998). In this setting, if the firm defaults, the investor seizes the asset underlying the project. To bring their story in line with our model, we assume that the asset value corresponds to the verifiable cash-flow component π_l. The investor then has the choice between selling the asset on the market or renegotiating ownership. If the investor sells the asset on the market, he receives π_l. If he sells the asset back to the firm, he receives P, which is the price obtained in the renegotiation. If the asset is sold back to the firm, it may be used for another period, where it generates a nonverifiable return of $\pi_l + \Delta$. At the end of the second period, the asset's liquidation value is zero. We shall assume that $\Delta > 0$, that is, the asset is worth more to the firm than to the market, which implies that date 1 liquidation is inefficient. As Hart and Moore point out, however, the firm may not have enough cash to compensate the investor for not liquidating the asset.

Consider the high-cash-flow state, and suppose that $2(\pi_h - \pi_l) > \pi_l > (\pi_h - \pi_l)$, where the first inequality follows from Assumption 3. In this case, neither of the two stand-alone firms has sufficient cash to buy back the asset. However, the centralized firm—after earning $2\pi_h$ but claiming that it has only $2\pi_l$—has the necessary cash, which means there is scope for renegotiation. Depending on the distribution of bargaining powers and the firm's liquidity, the outcome of the renegotiation is that the centralized firm makes an additional net gain of $\pi_l + \Delta - P \geq 0$.[6] In a renegotiation-proof contract, the investor must therefore pay the centralized firm a higher information rent than the two decentralized firms together. Even though investment decisions are verifiable (the use of the asset in the second period is observable) and the investor can prevent the firm from continuing by liquidiating the asset, we have again that centralization lowers the investor's profit in the high-cash-flow state, which is all we need for Proposition 2 to hold.

D. Renegotiation

While the optimal contract under both centralized and decentralized borrowing entails inefficiencies, there will be no renegotiation on the equilibrium path, as the maximum which the investor can assure in the second period is $\pi_l < I$. As the discussion in the preceding subsection suggests, the situation is different if the high-cash-flow firm falsely claims that its cash flow is low (i.e., off the equilibrium path). Consider, for instance, the high-cash-flow firm under decentralized borrowing. Upon claiming that its cash flow is low, the firm pays out π_l, which implies its remaining (i.e., nonverifiable) cash flow is $\pi_h - \pi_l$. While this is not enough to self-finance second-period investment, the firm could renegotiate and ask the investor for additional funds of $I - (\pi_h - \pi_l) < \pi_l$. As the investor can assure a date 2 repayment of π_l, he will provide these funds. A similar reasoning holds for the high- and intermediate-cash-flow firms under centralized borrowing. In a renegotiation-proof contract, the investor would therefore have to pay all but the lowest cash-flow firms an additional information rent. Besides, however, nothing changes. In particular, as long as the investor has sufficient bargaining power in the renegotiation, the costs and benefits of centralization are the same as in the commitment case.[7]

E. Competitive Credit Markets

Introducing competitive credit markets mitigates the underinvestment problem but does not eliminate it. For instance, the refinancing probability of the low-cash-flow firm under decentralized borrowing is then no longer zero but strictly between zero and one. The fact that $\beta(l) = 0$ facilitated many of our results. If

[6] The inequality may be strict even if the investor has all the bargaining power in the renegotiation. For instance, suppose $2(\pi_h - \pi_l) = \pi_l + \Delta/2$. In this case, the investor can extract, at most, half of the surplus, since $\pi_l + \Delta/2$ is the most that headquarters can pay.

[7] If the firm has all the bargaining power, the investor's payoff from each project is $-I + \pi_l < 0$. Hence, financing breaks down completely, much like when there is only a single period.

$\beta(l) > 0$, these results will be more complex, but their qualitative nature remains the same. In particular, both the underinvestment problem and the basic trade-off analyzed here remain the same. One minor change is that the contract between the firm and the investor must be augmented by a seniority provision (both under centralized and decentralized borrowing). To see this, suppose the high-cash-flow firm under decentralized borrowing defaults and approaches a new investor. As the firm needs only $I - (\pi_h - \pi_l) < \pi_l$ to finance second-period investment, the new investor is willing to help out. But this means that the original investor will make a loss. A seniority provision stating that the firm cannot make a repayment to a new investor unless it has fully settled its debt with the original investor avoids this problem. Since payments to and from investors are verifiable, such a seniority provision is enforceable.

III. Which Projects Should Be Pooled?

In this section, we examine the decision to pool projects from various angles. The empirical implications following from this are discussed in Section IV.

A. Correlation

We now relax our assumption that cash flows in any given period are uncorrelated. We do, however, retain the assumption that cash flows are serially uncorrelated. Denote the correlation coefficient by ρ. While the optimal contract under both self-financing and "no self-financing" remains unchanged, allowing for correlation alters the probabilities of the three cash-flow states and therefore the investor's expected payoff. (Intuitively, the optimal contract remains unchanged, as incentive compatibility and limited liability are both ex post constraints that do not depend on the ex ante probabilities.) The new probabilities are $p[1-(1-\rho)(1-p)]$ for the low-cash-flow state, $2(1-\rho)p(1-p)$ for the intermediate-cash-flow state, and $(1-p)[1-p(1-\rho)]$ for the high-cash-flow state. A derivation of these probabilities can be found in the proof of Proposition 3 in the Appendix.

If self-financing is not possible, the result is evident. As centralization has benefits but no costs, centralized borrowing is optimal except if $\rho = 1$. If $\rho = 1$, the probability of the intermediate-cash-flow state is zero. But the intermediate-cash-flow state is the only cash-flow state where centralized and decentralized borrowing differ. If self-financing is possible, the result is more complex.

PROPOSITION 3: *Suppose Assumptions 1 and 3 hold. Decentralized borrowing is optimal if $\rho \geq 2/3$ while centralized borrowing is optimal if $\rho \leq -1/2$. If $\rho \in (-1/2, 2/3)$, there exists a strictly increasing function $\overline{p}(\rho)$ such that decentralized borrowing is optimal if $p \leq \overline{p}(\rho)$ and centralized borrowing is optimal if $p \geq \overline{p}(\rho)$.*

If $\rho \to 1$, the probability of the intermediate-cash-flow state goes to zero while the probability of the high-cash-flow state remains positive. Hence centralization has costs but no benefits. Conversely, if $\rho \to -1$ the probability of the high-cash-flow state goes to zero while the probability of the intermediate-cash-flow state approaches one.[8] Hence, centralization has benefits but no costs. For intermediate values of ρ, we have the same picture as before: While neither organizational form dominates the other, there exists a critical value $\overline{p}(\rho)$ such that centralized borrowing is optimal if $p \geq \overline{p}(\rho)$ and decentralized borrowing is optimal if $p \leq \overline{p}(\rho)$. When $\rho = 0$, this critical value equals $\overline{p}(0) = \sqrt{2} - 1$, which coincides with the result in Proposition 2.

B. High versus Low Future Profitability

Is conglomeration more beneficial in industries where expected future profits are low or high? To answer this question, we introduce separate probabilities—and hence profitabilities—for each period. Denote the probability of the low cash flow in period t by p_t and the corresponding expected cash flow by $\overline{\pi}_t$. While we no longer assume that the two periods are the same, we retain the assumption that the two projects are identical. Heterogeneous project bundles are considered below. We have the following result.

PROPOSITION 4: *Suppose Assumptions 1 and 3 hold. If $p_2 \leq 1/2$ centralized borrowing is optimal if and only if $p_1 \geq (1 - p_2)/(1 + p_2)$. By contrast, if $p_2 \geq 1/2$, centralized borrowing is optimal if and only if $p_1 \geq 1/3$.*

If the first-period profitability is sufficiently high, centralized borrowing is never optimal. For all other values of p_1, there exists a critical p_2-value such that decentralized borrowing is optimal if p_2 is below that value and centralized borrowing is optimal if p_2 is above that value. Intuitively, if the follow-up investment is unattractive, the incentives to engage in self-financing are small, which implies that centralized firms can be disciplined at a relatively low cost. In this case, the benefits of centralization outweigh the costs. By contrast, if the follow-up investment is attractive, the incentives to engage in self-financing—and thus the information rent that must be granted to the high-cash-flow firm—are high. In this case, the costs of centralization outweigh the benefits.

C. Cash-Flow Balancing

The termination threat is based on an intertemporal exchange: The firm exchanges first-period cash flow (thereby giving up first-period rents) for second-period continuation rights. The termination threat is thus most effective if there is a balance between first-period cash flow and continuation rights. If the continuation value is high but the first-period cash flow is low the firm can only buy a small fraction of the continuation rights. Similarly, if the first-period cash flow is high but the continuation value is low the firm is only willing to give up a fraction

[8] Due to the two-point distribution, not all (ρ, p)-combinations are feasible. In particular, if $\rho = -1$, the only feasible p-value is $p = 1/2$, which explains why the probability of the high-cash-flow state goes to zero as $\rho \to -1$. The set of feasible (ρ, p)-combinations is derived in the proof of Proposition 3 in the Appendix.

of its cash flow equal to the continuation value. (Centralization mitigates this problem by raising the continuation value.)

The above argument suggests that if projects are strongly front- (high $\overline{\pi}_1$ but low $\overline{\pi}_2$) and backloaded (low $\overline{\pi}_1$ but high $\overline{\pi}_2$), it may be better to pool one front- and one backloaded project instead of two front- or two backloaded projects. The idea is that the high cash flow generated by the frontloaded project can be used to buy continuation rights for the (valuable) second tranche of the backloaded project. This intuition can be formalized. Suppose the probability of the low cash flow can take two values: p_H and p_L, where $p_H > p_L$. Frontloaded projects have $p_1 = p_L$ and $p_2 = p_H$, implying that $\overline{\pi}_1 = \overline{\pi}_L > \overline{\pi}_H = \overline{\pi}_2$. Backloaded projects have $p_1 = p_H$ and $p_2 = p_L$, implying that $\overline{\pi}_1 = \overline{\pi}_H < \overline{\pi}_L = \overline{\pi}_2$. The expected two-period cash flow is the same for both projects. We obtain the following result.

PROPOSITION 5: *Suppose Assumptions 1 and 3 hold. If $\overline{\pi}_L - \overline{\pi}_H$ is sufficiently large, implying that projects are sufficiently front- and backloaded, it is optimal to pool one front- and one backloaded project rather than two front- or two backloaded projects.*

Proposition 5 has implications for investment policy. To maintain a balanced portfolio, firms might optimally want to forgo profitable investments in favor of investments that are less profitable but have a more favorable cash-flow pattern. To give an extreme example of cash-flow balancing, suppose there are two kinds of projects: (a) Frontloaded projects generating an expected cash flow of $\overline{\pi}$ in the first period and zero in the second period, and (b) backloaded projects generating zero in the first period and an expected cash flow of $\overline{\pi}$ in the second period. For simplicity, suppose in a period where no cash flow is generated, the investment cost is zero. Both projects are thus effectively one-period projects. From Bolton and Scharfstein (1990), we know that neither the front- nor the backloaded project alone—nor a bundle consisting of two front- or two backloaded projects—can raise external finance. By contrast, a bundle consisting of one front- and one backloaded project can raise external finance if the investment condition (3) holds.

IV. Empirical Implications

This section summarizes the empirical implications. The first implication follows directly from the optimal contract. Consider a low-cash-flow project (or division). If the cash flow of the other project is also low, the refinancing probability is zero. By contrast, if the cash flow of the other project is high, the refinancing probability is between 0.5 and 1. The argument for the high-cash-flow project is analogous.

IMPLICATION 1: *Divisional investment is positively related to the past cash flow of other divisions.*

Lamont (1997) and Shin and Stulz (1998) provide supporting evidence. Lamont studies the reaction of U.S. oil companies to the 1986 oil price decline. He finds that a lower cash flow in the companies' core business leads to investment cuts in non-oil-related divisions. Similarly, Shin and Stulz find that the investment of smaller divisions is positively related to the cash flow of other divisions.

In our model, the fraction of nonverifiable cash flow $\pi_h - \pi_l$ measures the magnitude of the agency problem between the firm and the investor. If all cash flow is verifiable, there is no value to project pooling. If some, but not too much cash flow can be diverted, project pooling is unambiguously valuable. Finally, if enough cash flow can be diverted to allow self-financing of follow-up investments, the value of project pooling is again low.

IMPLICATION 2: *Internal capital markets are most valuable if agency problems between firms and investors are small (but positive), and less valuable if they are large.*

The result contrasts with Stein's (1997) result that internal capital markets are most valuable if agency problems are severe. The empirical evidence on this issue is mixed. Consistent with Stein's argument, Hubbard and Palia (1999) find that the highest bidder returns in diversifying acquisitions in the 1960s were earned when financially unconstrained buyers acquired constrained target firms. Hubbard and Palia interpret this as evidence that capital markets viewed the formation of conglomerates in the 1960s as an efficient response to the information deficiencies of external capital markets, which were arguably greater at that time. On the other hand, Servaes (1996) finds that conglomerates in the 1960s traded at a substantial discount, which is difficult to reconcile with Hubbard and Palia's interpretation. Similarly, Claessens et al. (1999) document diversification patterns for corporations in the United States, Japan, and eight Asian countries, some of which do not have well-developed external capital markets. The authors do not find a clear pattern of different degrees of diversification across countries at different levels of development, concluding that "this contrasts with the internal capital markets hypothesis ... which would suggest that firms in less-developed countries diversify more to reap the benefits of internal markets" (p. 8).[9]

Direct support for Implication 2 is provided by Lins and Servaes (2001). Using data from Asian emerging markets countries, Lins and Servaes find that the diversification discount is greatest when management control rights substantially exceed their cash flow rights. To the extent that the difference between managerial control rights and cash-flow rights proxies for the severity of the agency problem between management and investors, this suggests an inverse relation between the value of internal capital markets and the extent of the managerial agency problem, as suggested in this paper.

The next two implications relate a firm's propensity to access external finance to exogenous characteristics such as operating productivity and the degree of firm diversification.

[9] Khanna and Palepu (2000) find that Indian firms affiliated with highly diversifed business groups outperform other firms. The authors point out, however, that internal capital markets have nothing to do with this. Unlike, for example, Japanese keiretsu, Indian business groups have no common internal capital market.

IMPLICATION 3: *Low-productivity conglomerates should have a higher, and high-productivity conglomerates should have a lower propensity to access external finance than comparable stand-alone firms.*

IMPLICATION 4: *The propensity of conglomerates to access external finance should be positively related to their degree of diversification.*

Implication 3 follows from the analysis leading to Proposition 2. It follows from a comparison of the investment threshold under decentralized and centralized borrowing. Implication 4 follows from the analysis leading to Proposition 3. It does not compare stand-alone firms and conglomerates, but conglomerates with different project correlations.

Implication 3 has, to our knowledge, not yet been tested. While Comment and Jarrell (1995) and Peyer (2001) both find that conglomerates and stand-alones have different propensities to access external finance, neither paper compares low- and high-productivity (or low- and high-performance) firms separately.[10] Implication 4 appears to be consistent with the empirical evidence. While Comment and Jarrell find that highly and less diversified conglomerates have similar propensities to access external capital markets, their analysis does not control for internal capital market efficiency. Peyer refines Comment and Jarrell's analysis by discriminating between firms with efficient and inefficient internal capital markets. He finds that—provided the internal capital allocation is efficient (which is the case in our model)—the propensity of conglomerates to access external finance increases with their degree of diversification.

Implications 1 to 4 are general statements that hold regardless of whether the organizational form is chosen optimally. The next two implications rest on the assumption that the organizational form is chosen optimally. Implication 5 is a direct corollary to Proposition 2, which is the central result of our paper.

IMPLICATION 5: *Conglomerates should have a lower average productivity than stand-alone firms.*

Implication 5 suggests that the diversification decision is endogenous: Low-productivity firms diversify while high-productivity firms do not. Using plant-level data, Maksimovic and Phillips (2002) find that—for all but the smallest firms in their sample—conglomerate firms in the United States are indeed less productive than single-segment firms. (The smallest size category constitutes 3.3 percent of their sample.) Similarly, Berger and Ofek (1995) (for the United States) and Lins and Servaes (2001) (for emerging markets countries) find that diversified firms have a smaller operating profitability than stand-alone firms, and Lang

[10] Comment and Jarrell (1995) find that conglomerates use less external finance than single-segment firms, although the difference is small. Peyer (2001) finds that conglomerates with efficient internal capital markets use more external finance than single-segment firms. Our model would suggest that differences in productivity might explain some of the cross-sectional variation in these studies.

and Stulz (1994) find that diversifying firms are poor performers relative to firms that do not diversify. Finally, Campa and Kedia (1999) and Graham, Lemmon, and Wolf (2002) find that diversifying firms already traded at a discount prior to the diversification, and that targets in diversifying acquisitions had already been discounted before they were acquired, respectively. Contrary evidence is provided by Schoar (2002), who finds that plants of diversified firms are more productive than plants of single-segment firms.

The next statement follows from Proposition 4. It rests on the notion that the incentives to engage in self-financing, and hence the costs of centralization, are lower if the follow-up investment is relatively unattractive.

IMPLICATION 6: *Compared to stand-alone firms, conglomerates should be more prevalent in slow-growing or declining industries.*

Few studies have examined the relation between conglomeration and industry growth. Consistent with our hypothesis, Lang and Stulz (1994) find that diversified firms tend to be concentrated in industries with fewer growth opportunities. Similarly, Burch, Nanda, and Narayanan (2000) report a negative correlation between industry conglomeration and investment opportunities as measured by industry market-to-book ratios.

The last implication follows from Proposition 5. It compares different investment policies for conglomerates.

IMPLICATION 7: *Conglomerates operating both in growing and mature/declining industries should have a higher propensity to access external finance than conglomerates operating only in growing or only in mature/declining industries.*

While based on a different logic than models of internal cash-flow recycling, the implications for investment policy are similar: Firms should hold a balanced portfolio of projects generating immediate cash ("cash cows") and projects generating cash in the future ("growth projects"). We are not aware of empirical work examining the relation between financing constraints and the composition of a firm's investment portfolio.

V. Concluding Remarks

Financial contracting models typically consider an entrepreneur who raises funds for a single project. In this setting, questions regarding organizational structure or the role of internal capital markets cannot be addressed. On the other hand, internal capital markets models, while analyzing the choice between centralization and decentralization, do not consider optimal contracts between headquarters and outside investors. This paper links both literatures, thereby tying together internal and external capital markets.

We derive the optimal contract for both centralized firms where headquarters borrows on behalf of multiple projects and decentralized, or stand-alone, firms where individual project managers borrow separately on the external capital market. Centralization has benefits and costs. On the benefit side, headquarters uses excess liquidity from high-cash-flow projects to buy continuation rights for low-cash-flow projects. This, in turn, allows headquarters to make greater repayments, which relaxes financing constraints ex ante. On the cost side, headquarters—by pooling cash flows from several projects—might pursue follow-up investments without returning to the capital market. This makes it more difficult for investors to discipline the firm, which tightens financing constraints.

We believe our model yields insights which are applicable to other areas of economics and finance. By showing that cash-flow pooling can strengthen a firm's ability to expropriate investors, the paper is one of few papers emphasizing the potential costs of cash-flow pooling.[11] Other models, especially in the financial intermediation literature, rest largely on the benefits of cash-flow pooling (e.g., Diamond (1984)). Introducing costs in these models might yield additional insights. Second, internal capital markets—via their effect on financing constraints—might affect the strategic behavior of firms in the product market. For instance, in Bolton and Scharfstein (1990), the presence of financing constraints creates incentives for deep-pocket firms to lower the profits of financially constrained rivals. In this paper, we show that grouping several financially constrained firms together can reduce financing constraints, and therefore the incentives of competitors to prey. Third, internal capital markets might play an important role for the credit channel and monetary transmission mechanism. In particular, to the extent that they alleviate credit constraints, internal capital markets can damp the effect of shocks on business lending and hence stabilize production and economic growth.[12]

Appendix

Proof of Proposition 1: It remains to derive the optimal contract under centralized borrowing given Assumptions 1 and 2. The rest follows from the argument in the text.

Instead of solving the problem (4) to (7), we solve a relaxed problem where the global incentive compatibility constraint (5) is replaced with the downward constraints that neither type (h,h) nor type (h,l) has an incentive to mimic type (l,l). We subsequently show that the solution to this relaxed problem also solves the original problem. In the relaxed problem, the investor solves (4) subject to the limited liability constraints (6) and (7) and the downwards incentive compatibility constraints

$$r(s) - R^1(s) + \beta(s)[2\overline{\pi} - R^2(s)] \geq r(s) - R^1(l,l) + \beta(l,l)[2\overline{\pi} - R^2(l,l)] \qquad \text{(A1)}$$

[11] Another paper pointing out that cash-flow pooling may entail costs is Axelson (1999), who analyzes the costs and benefits of pooling assets in a common value auction. If the number of bidders is large relative to the number of assets, pooling is costly, as it decreases bidding competition in the upper tail of the signal distribution, and, hence, seller revenues.

[12] For a discussion of the macroeconomic implications of credit constraints see Bernanke, Gertler, and Gilchrist (2000).

where $s \in \{(h,h), (h,l)\}$. Denote these constraints by $C(h,h)$ and $C(h,l)$, respectively. The following two lemmas considerably simplify the analysis.

LEMMA A1: *At any optimum, it must hold that* $\beta(l,l) = 0$ and $R^1(l,l) = 2\pi_l$.

Proof of Lemma A1: We argue to a contradiction. Suppose $\beta(l,l) > 0$ and define $\bar{R}^1(l,l) := 2\pi_l$ and $\bar{R}^2(l,l) := R^2(l,l) - 2\pi_l + R^1(l,l)$. If $\beta(l,l) < 1$ replacing $R^1(l,l)$ and $R^2(l,l)$ with $\bar{R}^1(l,l)$ and $\bar{R}^2(l,l)$ strictly increases the investor's expected profit, whereas if $\beta(l,l) = 1$ replacing $R^1(l,l)$ and $R^2(l,l)$ with $\bar{R}^1(l,l)$ and $\bar{R}^2(l,l)$ leaves the investor's expected profit unchanged. Moreover, if $C(h,h)$, $C(h,l)$, and the two limited liability constraints are satisfied under $R^1(l,l)$ and $R^2(l,l)$, they are also satisfied under $\bar{R}^1(l,l)$ and $\bar{R}^2(l,l)$.

From the second-period limited liability constraint for type (l,l), it follows that $\bar{R}^2(l,l) - 2I < 0$. On the other hand, since $\bar{\pi} - I > 0$ and $\bar{R}^2(l,l) \leq 2\pi_l$, it must be true that $2\bar{\pi} - \bar{R}^2(l,l) > 0$. Accordingly, reducing $\beta(l,l)$ strictly improves the investor's expected profit without violating any of the incentive compatibility constraints, which contradicts the optimality of $\beta(l,l) > 0$. Given that $\beta(l,l) = 0$ is optimal, the fact that $R^1(l,l) = 0$ is also optimal is obvious. Q.E.D.

LEMMA A2: *At any optimum, the constraints* $C(h,l)$ *and* $C(h,h)$ *must bind.*

Proof of Lemma A2: We argue again to a contradiction. Suppose $C(h,h)$ is slack. If $\beta(h,h) = 0$ then $C(h,h)$ implies that the first-period limited liability constraint for type (h,h) is also slack. But this implies that the investor can improve his expected profit by raising $R^1(h,h)$ without violating any constraint, contradiction. If $\beta(h,h) \in (0,1)$, the unique optimal payments for type (h,h) are $R^1(h,h) = \pi_l + \pi_h$ and $R^2(h,h) = 2\pi_l$. Since we showed above that $R^1(l,l) = 2\pi_l$ and $\beta(l,l) = 0$, this violates $C(h,h)$, contradiction. Finally, if $\beta(h,h) = 1$, any optimal contract must satisfy $R^1(h,h) + R^2(h,h) = 2\pi_h + 2\pi_l$. Since $2(\pi_h - \pi_l) > 2(\bar{\pi} - \pi_l)$, this violates $C(h,h)$, contradiction.

Next, suppose $C(h,l)$ is slack. If $\beta(h,l) = 0$, the argument is the same as above. If $\beta(h,l) \in (0,1)$, the unique optimal payments for type (h,l) are $R^1(h,l) = \pi_h + \pi_l$ and $R^2(h,l) = 2\pi_l$. Observe that if $2\beta(h,l)(\bar{\pi} - \pi_l) \geq \pi_h - \pi_l$, this contract is indeed incentive compatible. Since $2(\pi_{l-I}) < 0$, however, the investor is strictly better off by reducing $\beta(h,l)$, contradiction. Finally, if $\beta(h,l) = 1$, any optimal contract must satisfy $R^1(h,l) + R^2(h,l) = \pi_h + \pi_l + 2\pi_l$. In particular, this implies that any optimal contract yields the same profit to the investor as a contract where $R^1(h,l) = \pi_h + \pi_l$ and $R^2(h,l) = 2\pi_l$. As we showed above, however, the investor would then want to decrease $\beta(h,l)$, contradiction. Q.E.D.

The first of the above lemmas implies that the lowest type (l,l) receives no rent in equilibrium. The second lemma is a standard feature of contracting problems of this sort. Equipped with these two lemmas, we can now derive the optimal contract.

LEMMA A3: *The following contract is optimal*:

(1) *Type* (l,l):$\beta(l,l) = 0$ *and* $R^1(l,l) = 2\pi_l$.
(2) *Type* (l,h): $\beta(h,l) = 1/[2(1-p)]$, $R^1(h,l) = \pi_h + \pi_l$, *and* $R^2(h,l) = 2\pi_l$ *if* $p \leq 1/2$, *and* $\beta(h,l) = 1$, $R^1(h,l) = 2\bar{\pi}$, *and* $R^2(h,l) = 2\pi_l$ *if* $p \geq 1/2$.
(3) *Type* (h,h): $\beta(h,h) = 1$, $R^1(h,h) = 2\bar{\pi}$, *and* $R^2(h,h) = 2\pi_l$.

Proof of Lemma A3: Setting $\beta(l,l) = 0$ and $R^1(l,l) = 2\pi_l$ and inserting the binding $C(h,l)$ and $C(h,h)$ constraints in (4) we can rewrite the objective function as

$$-2(\pi_l - I) + 2\pi_l + 4p(1-p)\beta(h,l)(\bar{\pi} - I) + 2(1-p)^2\beta(h,h)(\bar{\pi} - I). \tag{A2}$$

By inspection, (A2) is strictly increasing in both $\beta(h,l)$ and $\beta(h,h)$, implying that the solution is $\beta(h,l) = \beta(h,h) = 1$, if feasible. If $2\bar{\pi} \le \pi_h + \pi_l$, setting $\beta(h,l) = \beta(h,h) = 1$ is indeed feasible. The optimal payments $R^1(h,l)$, $R^2(h,l)$, $R^1(h,h)$, and $R^2(h,h)$ then follow from $C(h,l)$, $C(h,h)$, and the respective limited liability constraints.

If $2\bar{\pi} > \pi_h + \pi_l$, setting $\beta(h,l) = 1$ violates either $C(h,l)$ or the second-period limited liability constraint for type (h,l). Accordingly, we must have $\beta(h,l) < 1$. Next, observe that $2\bar{\pi} > R^2(h,l)$. To see this, suppose to the contrary that $2\bar{\pi} \le R^2(h,l)$. Subtracting the binding $C(h,l)$ constraint from the second-period limited liability constraint for type (h,l) gives

$$\pi_h + \pi_l \ge R^2(h,l) + \beta(h,l)[2\bar{\pi} - R^2(h,l)]. \tag{A3}$$

If $2\bar{\pi} = R^2(h,l)$ this violates $2\bar{\pi} > \pi_h + \pi_l$, contradiction. Suppose, therefore, that $2\bar{\pi} < R^2(h,l)$. Solving (A3) for $\beta(h,l)$ we have $\beta(h,l) \ge [\pi_h + \pi_l - R^2(h,l)]/[2\bar{\pi} - R^2(h,l)]$, which is strictly greater than one since $2\bar{\pi} < R^2(h,l)$ and $2\bar{\pi} > \pi_h + \pi_l$ together imply that $\pi_h + \pi_l < R^2(h,l)$, contradiction. Solving the binding $C(h,l)$ constraint for $\beta(h,l)$, we obtain $\beta(h,l) = [R^1(h,l) - 2\pi_l]/[2\bar{\pi} - R^2(h,l)]$. Moreover, since we have $2\bar{\pi} > R^2(h,l)$, it must hold that $\partial\beta(h,l)/\partial R^1(h,2) > \partial\beta(h,l)/\partial R^2(h,l) > 0$, implying that both the first- and second-period limited liability constraint for type (h,l) must bind. Solving the binding limited liability constraints for $R^1(h,l)$ and $R^2(h,l)$, we have $R^1(h,l) = \pi_h + \pi_l$ and $R^2(h,l) = 2\pi_l$. Inserting these values in $\beta(h,l) = [R^1(h,l) - 2\pi_l]/[2\bar{\pi} - R^2(h,l)]$ yields

$$\beta(h,l) = \frac{\pi_h - \pi_l}{2(\bar{\pi} - \pi_l)} = \frac{1}{2(1-p)}, \tag{A4}$$

where the second equality follows from the definition of $\bar{\pi}$.

It remains to show that the solution to the relaxed problem also solves the original problem (4) to (7). Since $C(h,l)$ and $C(h,h)$ are both binding, all other incentive compatibility constraints must bind as well, which implies that the solution is globally incentive compatible. Q.E.D.

Proof of Proposition 2: It remains to derive the optimal contract under centralized borrowing given Assumptions 1 and 3. The rest follows from the argument in the text.

LEMMA A4: *The following contract is optimal*:

1. *Type* (l,l): $\beta(l,l) = 0$ *and* $R^1(l,l) = 2\pi_l$.
2. *Type* (h,l): $\beta(h,l) = 1/[2(1-p)]$, $R^1(h,l) = \pi_h + \pi_l$, *and* $R^2(h,l) = 2\pi_l$ *if* $p \le 1/2$, *and* $\beta(h,l) = 1$, $R^1(h,l) = 2\bar{\pi}$, *and* $R^2(h,l) = 2\pi_l$ *if* $p \ge 1/2$.
3. *Type* (h,h): $\beta(h,h) = 1$, $R^1(h,h) = 2\pi_h$, *and* $R^2(h,h) = \bar{\pi} - 2(\pi_h - \pi_l) + I$.

Proof of Lemma A4: As in the proof of Proposition 1, we solve again a relaxed problem. The corresponding incentive compatibility constraint for type (*h*,*h*), which explicitly takes into account the possibility that type (*h*,*h*) can finance one or more second-period projects with internal funds by mimicking type (*l*,*l*), is denoted by $\bar{C}(h,h)$. Type (*h*,*h*)'s payoff from deviating and mimicking type (*l*,*l*) is then as follows:

$$U^D(h,\ h):$$
$$= \begin{cases} 2\pi_h - R^1(l,l) + \beta(l,l)[2\bar{\pi} - R^2(l,l)] \\ +[1-\beta(l,l)](\bar{\pi} - I) & \text{if } I \le 2\pi_h - R^1(l,l) < 2I \\ \\ 2\pi_h - R^1(l,l) + \beta(l,l)[2\bar{\pi} - R^2(l,l)] \\ +[1-\beta(l,l)]2(\bar{\pi} - I) & \text{if } 2\pi_h - R^1(l,l) \ge 2I. \end{cases} \tag{A5}$$

Since $R^1(l,l) \le 2\pi_l$, the case where $2\pi_h - R^1(l,l) < I$ can be safely ignored as it violates Assumption 3. Moreover, Lemmas A1 to A2 in the proof of Proposition 1 continue to hold (with $C(h,h)$ being replaced by $\bar{C}(h,h)$). Since $\beta(l,l) = 0$ and $R^1(l,l) = 2\pi_l$, Assumption 3 implies that $U^D(h,h) = 2(\pi_h - \pi_l) + \bar{\pi} - I$. Similar to the proof of Lemma A1, the investor's objective function can then be rewritten as

$$-2(\pi_l - I) + 2p(1-p)\beta(h,l)2(\bar{\pi} - I) + (1-p)^2(2\beta(h,h) - 1)(\bar{\pi} - I). \tag{A6}$$

Given that (A6) is strictly increasing in both $\beta(h,l)$ and $\beta(h,h)$, the arguments in the proof of Proposition 1 extend to the current proof. In particular, the optimal contracts for types (*l*,*l*) and (*h*,*l*) are the same as in Proposition 1. Furthermore, we have that $\beta(h,h) = 1$, which, together with $\bar{C}(h,h)$, implies that $R^1(h,h) = 2\pi_h$ and $R^2(h,h) = \bar{\pi} + I - 2(\pi_h - \pi_l)$. To verify that the neglected incentive compatibility constraints hold, note that it is impossible for type (*h*,*l*) to make a repayment of $R^1(h,h) = 2\pi_h$ at date 1. Q.E.D.

Proof of Proposition 3: We first derive the joint probabilities for types (*l*,*l*), (*h*,*l*), and (*h*,*h*) for arbitrary correlation coefficients. Denote the random variables associated with the two project cash flows by *X* and *Y*, respectively. The joint probabilities are $\omega := \Pr(x = \pi_l,\ y = \pi_h) = \Pr(x = \pi_h,\ y = \pi_l)$, $\Pr(x = y = \pi_l) = p - \omega$, and $\Pr(x = y = \pi_h) = 1 - p - \omega$. Since $\rho := \text{Cov}(X,Y)/\sigma_X\sigma_Y$ and $\sigma_X = \sigma_Y$ we have $\rho = 1 - \omega/p(1-p)$. Solving for ω we obtain the probabilities given in the text. Moreover, since $\omega \le \min[p, 1-p]$, it follows that the correlation coefficient is bounded from below by $\underline{\rho} := 1 - (\min[p, 1-p])/[p(1-p)]$. (This function characterizes the set of feasible (ρ,p)-combinations.)

While the optimal contract under centralized borrowing is the same as that derived in the proof of Proposition 2, the investor's expected profit has changed as the probabilities for types (*l*,*l*), (*h*,*l*), and (*h*,*h*) have changed. Inserting the terms of the optimal contract in the investor's objective function while taking into account the new probabilities, we then have that the investor's expected profit equals $2(\pi_l - I) + [1 - p + p(1-\rho)(1+p)](\overline{\pi} - I)$ if $p \leq 1/2$ and $2(\pi_l - I) + [1 + 3p(1-\rho)](1-p)(\overline{\pi} - I)$ if $p \geqslant 1/2$. Comparing these values with the investor's expected profit under decentralized borrowing, $2(\pi_l - I) + (1-p)2(\overline{\pi} - I)$, we obtain the following result.

LEMMA A5: *If Assumptions 1 and 3 hold and projects are arbitrarily correlated, the comparison between centralized and decentralized borrowing is as follows.*

(1) $\rho \in (2/3, 1]$: *Decentralized borrowing is optimal.*
(2) $\rho \in (1/3, 2/3]$: *If* $p \leq 1/[3(1-\rho)]$, *decentralized borrowing is optimal, whereas if* $p \geq 1/[3(1-\rho)]$, *centralized borrowing is optimal.*
(3) $\rho \in (-1/2, 1/3]$: *If* $p \leq \overline{p}(\rho) := \left[\rho - 2 + \sqrt{8 + \rho^2 - 8\rho}\right]/[2(1-\rho)]$, *decentralized borrowing is optimal, whereas if* $p \geq \overline{p}$, *centralized borrowing is optimal.*
(4) $\rho \in [-1, -1/2]$: *Centralized borrowing is optimal.*

It is easy to check that the functions $1/[3(1-\rho)]$ and $\overline{p}(\rho)$ are both strictly increasing and intersect at $\rho = 1/3$, which completes the proof. Q.E.D.

Proof of Proposition 4: The proof is analogous to that of Proposition 2. The optimal contract under decentralized borrowing is the same as in Section I.B, except that $R^1(h) = \overline{\pi}_2$. The optimal contract under centralized borrowing given Assumptions 1 and 3 is the same as in Section I.D, except that $R^1(h, l) = 2\overline{\pi}_2$ if $p_2 \geq 1/2$, $\beta(h,l) = 1/[2(1-p_2)]$ if $p_2 < 1/2$, and $R^2(h,h) = \overline{\pi}_2 - 2(\pi_h - \pi_l) + I$. Inserting the optimal contract in the investor's objective function, we have that under decentralized borrowing the investor invests at date 0 if and only if

$$I \leq \overline{\pi}_2 - \frac{\overline{\pi}_2 - \pi_l}{2 - p_1}. \tag{A7}$$

By contrast, under centralized borrowing given Assumptions 1 and 3, he invests at date 0 if and only if

$$I \leq \overline{\pi}_2 - \frac{\overline{\pi}_2 - \pi_l}{1 + 2(1-p_1)p_1 + \frac{(1-p_1)^2}{2}} \tag{A8}$$

if $p_2 \geq 1/2$, and

$$I \leq \overline{\pi}_2 - \frac{\overline{\pi}_2 - \pi_l}{1 + \frac{(1-p_1)p_1}{(1-p_2)} + \frac{(1-p_1)^2}{2}} \tag{A9}$$

if $p_2 \leq 1/2$. Comparing these expressions yields the result. Q.E.D.

Proof of Proposition 5: If $\overline{\pi}_L - \overline{\pi}_H$ is large, we have that $p_L < 1/2 < p_H$. Consider first the investment threshold if either two front- or two backloaded projects are pooled. From the proof of Proposition 4, we have that

$$I \leq \pi_l + (\pi_h - \pi_l)(1 - p_H)\frac{4(1-p_L)p_L + (1-p_L)^2}{2 + 4(1-p_L)p_L + (1-p_L)^2} \tag{A10}$$

if two front-loaded projects are pooled, and

$$I \leq \pi_l + (\pi_h - \pi_l)(1-p_H)^2 \frac{2p_H + (1-p_H)(1-p_L)}{2(1-p_L) + 2(1-p_H)p_H + (1-p_H)^2(1-p_L)} \quad \text{(A11)}$$

if two backloaded projects projects are pooled. As $p_H - p_L \to 1$, the spread $\overline{\pi}_L - \overline{\pi}_H = (\pi_h - \pi_l)(p_H - p_L)$ widens, and both (A10) and (A11) converge to π_l.

Consider next the investment threshold if one front- and one backloaded project are pooled. We first characterize the optimal contract, where we can build on arguments in the proof of Proposition 2. The contract with type (l,l) is identical to that in the proof of Proposition 2. Regarding type (h,l), we can treat the state where the frontloaded project has a high cash flow and the backloaded project has a low cash flow equivalently to the state where the backloaded project has a high cash flow and the frontloaded project has a low cash flow. Under the optimal contract, the investor pays I with probability one at date 1, which ensures that the firm can continue the profitable backloaded project. The optimal repayment is $\overline{\pi}_L$ at date 1 and π_l at date 2. As for type (h,h), the investor pays again I with probability one at date 1. Due to the additional self-financing constraint, however, the investor can extract at most $2\pi_l$ at date 1 and zero at date 2. Substituting these specifications into the investor's profit function yields the investment threshold

$$I \leq \pi_l + (\pi_h - \pi_l)(1-p_L)\frac{p_H(1-p_L) + p_L(1-p_H)}{2 + p_H(1-p_L) + p_L(1-p_H)}, \quad \text{(A12)}$$

which converges to $\pi_l + (\pi_h - \pi_l)/3 > \pi_l$ as $p_H - p_L \to 1$. Q.E.D.

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