Intertemporal Capital Allocation and Corporate Investment

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Abstract

This paper analyzes the optimal capital allocation mechanism when divisional managers are privately informed about the arrival of future investment projects. An optimal allocation mechanism can include a stipulation that only the basic level of investment can take place in the period after a large investment was made even though this is ex post suboptimal.

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"If division management wanted to, they could increase [their initially fixed] capital allocation by making a good case for it. But this would require a major effort and would use up some of the division's "credit" with corporate headquarters." **Ross (1986)**

1 Introduction

According to Ross (1986), discretionary projects require additional effort and consideration in the capital budgeting process. This is especially true in financially constrained firms. In some cases, division managers may simply prefer to not submit an investment proposal in order to preserve their "credit" with headquarters for future investment opportunities. This decision to conserve credit can not be justified with a static capital allocation mechanism. Instead, the argument suggests a dynamic capital allocation mechanism is employed in financially constrained firms.

In determining the allocation of a firm's scarce capital budget, headquarters weighs investment alternatives identified by informed division managers. In some cases, the best alternative is a competing project that occurs contemporaneously. However, the best alternative use of the firm's capital is often an investment opportunity that arrives with uncertainty in the future. Therefore, even if headquarters can costlessly monitor the quality of all projects proposed by division managers, division managers may still possess an information advantage with respect to the likelihood that profitable opportunities are on the horizon. Without this information, headquarters can not efficiently allocate its scarce capital.

Division managers are not likely to credibly communicate the likelihood of future profitable investment opportunities. Even though a division managers may benefit from profitable projects, their investment incentives are often not perfectly aligned with those of headquarters. For example, a division manager obtains utility not only when the project is profitable but also from perquisite consumption associated with investment. As we will demonstrate, this agency problem creates and incentive for a division manager to understate the probability of profitable future projects in financially constrained firms. Smaller future investment needs reduce the required rate of return for current projects as capital conservation concerns are diminished. In such circumstances, the capital allocation mechanism serves not only the purpose of allocating capital efficiently but may also be designed to elicit information about the probability of new projects in the future from a privately informed division manager.

We show that in these circumstances headquarters frequently finds it optimal to grant a capital request for a project of moderate profitability under the condition that the division accepts that only the so called "mandatory" capital investments will be made in the next period irrespective of any other projects available at that time, i.e., headquarters commits to denying funding for all discretionary projects in the future.[1] Such an intertemporal capital allocation rule restricts the level of overall investment in the division and therefore limits the need to raise costly external capital. In addition, this policy enables headquarters – at least for a certain parameter range – to induce the truthful revelation of the division manager's assessment of the division's

[1] Mandatory capital allocations are those caused by regulations, existing contracts, capital maintenance, replacement of outdated equipment and product quality considerations [Ross (1986)].

investment outlook.

Under such a rule, a division manager who expects a profitable project in the coming period has incentive to pass up the current marginal discretionary project, because accepting it implies foregoing a high level of expected utility from investing next period. A manager who associates a low probability to having a profitable project next period prefers to accept the capital allocation in the current period. This truthful revelation allows headquarters to reduce the hurdle rate in the current period as the division manager accepts a grant when he predicts a low probability of investment. The cost of such an intertemporal capital allocation mechanism is that headquarters must commit to denying funding to projects that are value enhancing when judged as stand-alone projects.

We find that dynamic capital allocation mechanism are more frequently found in firms facing more severe financial constraints. While it is not surprising that capital preservation considerations are more important in firms with tighter financial constraints, our finding is consistent with the empirical result that when a significant investment is observed in a division, it takes on average longer to observe another large investment when, ceteris paribus, financial constraints are more severe [Whited (2005)]. In our model, since the dynamic capital allocation mechanism reduces the expected size of next period's budget whenever a significant investment is made in the current period, a larger fraction of overall investment in a division (or plant) is concentrated in one period. Thus, the model demonstrates how a dynamic capital allocation mechanism can lead to "lumpy" intertemporal investment flows [Doms and Dunne (1998) and Cooper, Haltiwanger and Power (1999)].

A growing literature examines capital allocation mechanisms in internal capital markets. Our paper most closely resembles the literature that analyzes capital allocation rules of headquarters subject to agency problems or asymmetric information. For example, Harris and Raviv (1996) describe capital allocation mechanisms when monitoring is costly. In their model, headquarters finds it optimal to ration capital in order to save on monitoring costs. We abstract from monitoring costs but introduce asymmetric information about the probability of future project arrival. This renders our setting inherently dynamic and leads to a dynamic capital allocation mechanism similar to that described in Ross (1986).

Harris and Raviv (1998) also discuss a dynamic capital allocation mechanism. They argue that when monitoring is costly, it is optimal to allow divisions to "roll over" capital budgets to future periods. This rollover of unused funds reduces a division manager's incentive to invest immediately as the funds are certain to be available in the future. In our setting, headquarters will never delegate the investment decision to the division manager because headquarters is fully informed about project quality at the time of the investment decision. In addition, our model examines the relation between the degree of financing constraints and the extent to which a dynamic capital allocation mechanism is optimal.

Ross (1986) describes how the degree of financial constraints affect the type of capital budgeting mechanism employed within the firm. He finds that more financially constrained firms tend to not allocate capital according to posted hurdle rates but through a process in which projects compete for allocation from a fixed budget. If a division wants to fund projects beyond its typical allocation, the division uses up "credit" with headquarters. Such a policy of "using up credit" is an example of a capital allocation mechanism that makes it harder to receive capital after a period of large investment as described in this paper.

Much of the literature analyzes the extent to which delegation of capital budgeting decisions within the firm can lead to increased investment efficiency [Harris and Raviv (1998 and 2005), Marino and Matsusaka (2005), and

Ozbas (2005)]. In our model, we argue that it is never optimal to delegate investment authority as informational problems can be addressed more efficiently by introducing dynamic capital allocation mechanisms.

Finally, a significant body of work studies the differences between internal and external capital markets and whether internal capital markets allocate too much or too little capital to certain divisions [for example, Stein (2003) and the papers cited therein, Goel, Nanda and Narayanan (2004), and Bernardo, Luo and Wang (2005)]. Since our model examines the capital budgeting decision within a single division, we can not address issues related to multidivision firms.

The remainder of the paper is organized as follows: Section 2 outlines the model and Section 3 describes the optimal capital allocation in the benchmark case of symmetric information about the probability of the arrival of a profitable future project. Section 4.1 shows how capital is optimally allocated when the division manager is better informed about the project arrival rate and headquarters lacks the power to commit to restricting its action space in the future. Section 4.2 allows for such commitment. Section 5 discusses two potential extensions. Section 6 concludes.

2 Model

Players

We model a firm with a headquarters and one division. We assume headquarters acts in the interest of the firm's shareholders. Headquarters has access to capital but cannot ex ante determine with certainty the profitability of investing this capital. The division is headed by a manager who has private information regarding the profitability of investment projects over two periods but has no access to capital on his own. Headquarters would like to use the manager's private information to allocate capital across the two periods, but the manager has preferences that prevent him from revealing his information truthfully unless provided with incentives to do so. Our objective is to characterize the capital budgeting mechanism that maximizes expected profits to shareholders.

Investment opportunities

At the beginning of each of two periods, $t = 0, 1$, the division manager identifies an investment project. Each project requires a capital outlay of one unit and yields a positive gross cash flow at the end of the second period, $t = 2$. The cash flow of the first-period project is labeled $b_1 > 0$ and the cash flow of the second-period project $b_2 > 0$. To simplify computations we place some additional structure on b_2 and assume that $b_2 \in \left\{b_2^L, b_2^H\right\}$ with $0 < b_2^L < 1 < b_2^H$. Thus, only a project with a cash flow of b_2^H yields more than its cash outlay. We also assume that the first-period project has to be initiated at $t = 0$ to yield b_1. If delayed, its cash flow is non-positive.

Capital budget

Headquarters is endowed with one unit of capital and has access to an additional unit of capital at a cost $c > 0$, i.e., headquarters faces a "soft capital constraint". The additional cost may result from informational asymmetries associated with accessing external finance. Alternatively, the additional cost can be interpreted as the net present value lost in reallocating capital within the firm. Since we are interested in the internal allocation of capital within the firm, we assume the manager can only obtain capital from headquarters.

Preferences

Both headquarters and the division manager are risk neutral. We assume headquarters maximizes the net present value of investment. Headquarters' utility U^H is defined as

$$U^H = \begin{cases} (b_1 - 1) & \text{when headquarters funds first-period investment} \\ (b_2 - 1) & \text{when headquarters funds second-period investment} \\ (b_1 - 1) + (b_2 - 1 - c) & \text{when headquarters funds first- and second-period investment} \end{cases}.$$

Whenever headquarters chooses to fund only one investment project, either first- or second-period investment but not both, the cost of investment is 1. However, when headquarters chooses to fund both first- and second-period investments, headquarters must raise additional capital at cost c. Hence, the cost of capital varies across the headquarter's time horizon.

To introduce a preference for capital allocation in a simple way, the division manager is assumed to ignore the cost of investment and to obtain a private, non-contractible benefit proportional to gross project cash flow.[2] Division manager utility U^M is defined as

$$U^M = \begin{cases} qb_1 & \text{when headquarters funds first-period investment} \\ qb_2 & \text{when headquarters funds second-period investment} \\ q\left(b_1 + b_2\right) & \text{when headquarters funds first- and second-period investment} \end{cases},$$

where q is a positive constant. Because the manager ignores the cost of investment, he strictly prefers to submit all projects for approval to headquarters regardless of their economic value.

Information

In order to focus on the role of financial constraints on capital budgeting, we abstract from costly monitoring and assume that headquarters can observe project cash flows during the process of a capital request by the division manager at no cost.[3] There remains, however, one informational advantage of the manager at $t = 0$. At $t = 1$ a project with a high cash flow, b_2^H, is observed either with probability $p^G \in (0, 1)$ (which we will refer to as favorable investment outlook) or with probability $p^B \in \left(0, p^G\right)$ (unfavorable investment outlook). A project with a low cash flow, b_2^L, is realized with the complementary probability, $1 - p^G$ or $1 - p^B$, respectively. While the manager knows perfectly whether b_2^H is observed with p^G or with p^B, headquarters *ex ante* assigns a probability of 0.5 to each of the two investment outlooks.

Sequence of actions

Figure 1 provides a time line for the model. At the beginning of the first period, $t = 0$, the division manager learns the cash flow of the first period project to be received at $t = 2$. After a capital request by the manager for project funding, headquarters observes the cash flow. The division manager is also privately informed about the probability of a profitable investment opportunity in the second period. Next, headquarters commits to a capital allocation mechanism and informs the division manager about the mechanism. If the manager was

[2] This assumption is standard in the internal capital markets literature. See, for example, Stein (1997).

[3] We assume headquarters possesses a technology that precludes the possibilities of both "under-reporting" and "over-reporting" in project proposals. We will return to this assumption in section 4.2.

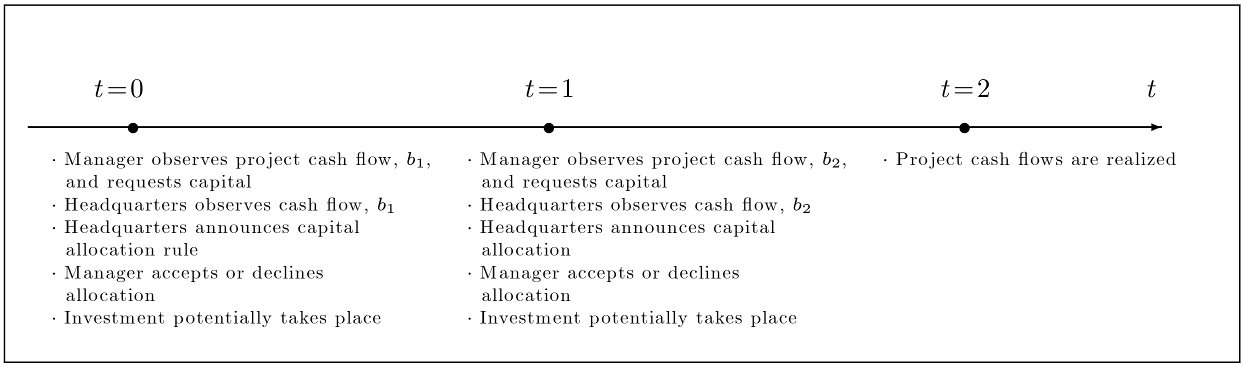

Figure 1: Timing of decisions

offered a capital allocation he can accept or reject the capital. As will become clear below, rejecting capital may be optimal for the manager if headquarters imposes restrictions on second-period investment whenever first-period investment takes place. If the manager accepts the capital allocation, the money is transferred to the division and investment takes place.

At $t = 1$, the division manager learns the cash flow of the second period project, b_2^L or b_2^H. The realization of the cash flow is governed by the random variable characterizing a favorable or an unfavorable investment outlook. The remaining stages are identical to those at $t = 0$.

At $t = 2$, the cash flows from the projects are realized.

In our analysis, we impose the parametric assumption that $b_2^H > 1 + c$. If this restriction is violated, it is never optimal to invest in both periods. Such a "hard capital constraint" is straightforward to analyze and does not permit interesting capital allocation mechanisms.

In the model, headquarters must decide whether or not to fund proposed projects using its existing unit of capital and its ability to raise additional capital at cost c. In formulating its decision, headquarters' strategy space includes the determination of hurdle rates for investment projects in both periods.[4] These hurdles rates may potentially be large, i.e., headquarters may decide to deny a project funding regardless of the level of its payoff.

In defining headquarters' capital allocation mechanism, we examine mechanisms that differ in their level of commitment. Capital budgeting mechanisms that require no commitment on behalf of headquarters are mechanisms in which the decision to fund first-period projects does not restrict the strategy space of headquarters in determining whether or not to fund second-period investment. Capital budgeting mechanisms that require commitment restrict the strategy space of headquarters in the second period. We are interested in whether or not headquarters finds it optimal to commit to a capital allocation mechanism today that restricts its flexibility to accept or reject funding proposals tomorrow.

[4] Because we assume there is no cost associated with monitoring project cash flows, headquarters capital allocation schemes will always employ monitoring with probability one. Thus, auditing constitutes a trivial part of headquarters strategy space. In Harris and Raviv (1996 and 1998), auditing is costly. Hence, headquarters' strategy space includes the monitoring probability, the amount of capital allocated with no monitoring, and the amount of capital allocated with monitoring.

3 Benchmark Case: Symmetric Information

Before analyzing headquarters' capital allocation problem under asymmetric information, we consider the allocation of capital when headquarters knows as of $t = 0$ the investment outlook for investment in the second period as a benchmark.

Suppose the investment outlook is favorable. In this case, headquarters will accept the proposal for period one investment provided that the following condition holds

$$(b_1 - 1) + p^G \left(b_2^H - 1 - c\right) \geq p^G \left(b_2^H - 1\right). \tag{1}$$

The left hand side of equation (1) is the net present value of accepting the manager's first period proposal of b_1 and with probability p^G accepting the second-period project proposal b_2^H. Since headquarters uses its unit of endowed capital to fund the first-period project, it must obtain additional capital at cost c to fund the second-period project. The second-period project is profitable, because of the parametric assumption $b_2^H > 1 + c$. The right hand side of equation (1) is the net present value from rejecting the manager's first-period capital proposal and using the unit of endowed capital to fund the second-period project that returns b_2^H.

By rearranging (1), we can identify the hurdle rate for first-period projects when the economic outlook is favorable, i.e., $b_G = 1 + p^G c$. For all $b_1 \in [b_G, \infty)$, headquarters provides funding for the first-period project. Similarly, when the economic outlook is unfavorable, the hurdle rate for first-period projects is $b_B = 1 + p^B c$.

The hurdle rate for first-period projects is greater for favorable investment outlooks than for unfavorable outlooks. Knowing the investment outlook is favorable, headquarters realizes it is more likely to need capital for investment in the second period. Headquarters faces two choices as of $t = 0$: reserve the unit of endowed capital and focus on the potentially higher returns whenever b_2^H is realized or use the unit of endowed capital to fund b_1 and raise additional capital in the event b_2^H is realized.

Suppose b_1 is marginally profitable, i.e., $b_1 = 1+\varepsilon$ with ε positive but small. By using its unit of endowed capital to fund this project, the difference in headquarter's utility between funding projects in left hand side and right hand side of equation (1) is $\varepsilon - p^G c$.Whenever the cost of additional capital is non-negligible, headquarters prefers to reject marginal first-period projects. For investment in the first-period project to be optimal, headquarters must increase the hurdle rate for the first-period project above the myopic cost of capital of one.[5] Headquarters raises the hurdle rate by more the greater the probability of encountering b_2^H in the second period.

4 Second-Best Outcomes

When the manager is privately informed about the investment outlook for the second periods, he will not truthfully disclose a favorable investment outlook unless provided with the correct incentives. This follows from two previous findings: (1) headquarters lowers the hurdle rate for first period investment whenever the investment outlook deteriorates, and (2) the manager prefers more investment to less. Since the manager's utility

[5] Even when headquarters knows with certainty project quality, it is optimal for headquarters to set hurdle rates above the myopic cost of capital. We are more likely to see this result in financially constrained firms. This is the finding of Ross (1986). In contrast, the hurdle rate increases in Harris and Raviv (1996) as a result of asymmetric information about project quality.

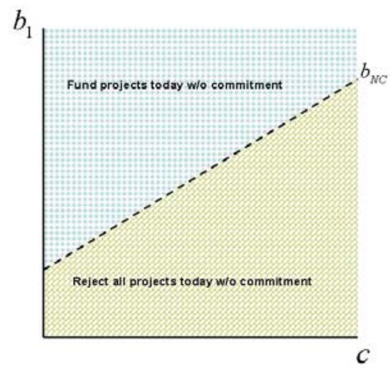

Figure 2: **Capital Budgeting without Commitment**. For any pair (b_1, c), the figure portrays the hurdle rates for first period projects identified by capital allocation mechanisms without commitment.

is proportional to the total gross cash flow of all accepted projects, he has incentive to report an unfavorable outlook in order to lower the hurdle rate for first period investment.

4.1 Capital Allocation Under Asymmetric Information without Commitment

Headquarters understands the incentive to play down the investment outlook and assigns equal probability to both investment outlooks, favorable and unfavorable, whenever managers are privately informed and headquarters does not provide managers will sufficient incentives to truthfully disclose the state of the world. Therefore, under asymmetric information, the hurdle rate for first-period investment is determined by the following condition:

$$(b_1 - 1) + \frac{p^G + p^B}{2}\left(b_2^H - 1 - c\right) \geq \frac{p^G + p^B}{2}\left(b_2^H - 1\right). \tag{2}$$

Equation (2) and equation (1) are similar. The only difference being, in the present case, headquarter does not know with certainty the investment outlook and assigns equal probability to both favorable and unfavorable outlooks.

By rearranging (1), we identify the hurdle rate for first-period investment projects when managers are privately informed, i.e., $b_{NC} = 1 + \frac{p^G + p^B}{2}c$. This hurdle rate can be used to implement a capital allocation mechanism without commitment for projects in the first period. Headquarters provides funding for all first-period projects with returns $b_1 \geq b_{NC}$. For $b_1 < b_{NC}$, headquarters denies funding for first-period projects. This allocation mechanism does not commit headquarters to a policy rule for accepting projects in the second period. Headquarters funds all second-period projects whose returns are b_2^H. Figure 2 provides a characterization of this capital budgeting mechanism.

Whenever headquarters is uninformed about the future investment outlook, the hurdle rate for first-period projects lies between the hurdle rates under symmetric information described previously. This new hurdle rate has implications for the utility of headquarters and the amount of investment observed in equilibrium.

4.2 Capital Allocation Under Asymmetric Information with Commitment

The capital allocation mechanism described in the previous section does not require headquarters to commit to restricting its decision making power in the second period. This capital allocation mechanism without commitment does not attempt to extract private information about the future investment outlook from managers in the first period.

In this section, we analyze whether there exists a capital allocation mechanism that allows headquarters to improve the efficiency of capital allocation when managers are privately informed. In order to improve efficiency, headquarters must define a capital allocation mechanism that leads to truthful revelation by managers of the future investment outlook.

Consider a first-period capital allocation mechanism in which, for a certain range of b_1, headquarters commits to denying funding for all second-period projects whenever management receives funding for its first-period project. One advantage to this capital allocation mechanism is that headquarters will never require additional capital at cost c. We are first identifying whether or not for a certain range of b_1, this capital allocation mechanism with commitment will lead to perfect revelation of the future investment opportunity by the division manager.

Under this capital budgeting mechanism, managers with favorable investment opportunities prefer to forego first-period investment whenever

$$b_1 \leq p^G b_2^H \equiv \bar{b}^S. \tag{3}$$

Similarly, managers with unfavorable investment opportunities will prefer second-period investment to first-period investment with no chance of funding for their second-period project whenever

$$b_1 \leq p^B b_2^H \equiv \underline{b}^S. \tag{4}$$

From equation (3) and (4), we see that a capital budgeting mechanism with commitment provides scope for headquarters to take advantage of the weaker preference for the first-period project if the manager faces a favorable investment outlook. This is possible whenever $b_1 \in \left(\bar{b}^S, \underline{b}^S\right)$, where the superscript S denotes "separation" as in separating equilibrium.

While a separating equilibrium is possible, headquarters may or may not find it advantageous. The benefit of the separating equilibrium is that headquarters can encourage more first-period investment by lowering the hurdle rate on first-period investment from b_{NC} to b_B. The cost of the separating equilibrium is that headquarters commits to denying funding for all second period projects whenever the division level manager accepts funding in the first period, i.e., headquarters denies funding for b_2^H even though $b_2^H > 1 + c$.

Assume $b_1 \in \left(\bar{b}^S, \underline{b}^S\right)$. Headquarters is indifferent between a capital allocation mechanism with commitment and simply denying funding to all first period projects whenever

$$\frac{1}{2}(b_1 - 1) + \frac{1}{2}p^G\left(b_2^H - 1\right) = \frac{1}{2}\left(p^G + p^B\right)\left(b_2^H - 1\right). \tag{5}$$

The left hand side is the utility headquarters receives under the capital allocation mechanism with commitment, i.e., the separating equilibrium. Managers self-select into one of two policies. Managers with unfavorable investment outlooks request funding for projects in the first period and headquarters commits to denying funding for their investment projects in the second period. Managers with favorable investment outlooks do not request funding today and in return receive funding for all second-period projects that promise b_2^H.

The right hand side identifies headquarters' utility whenever headquarters denies funding to all first-period investment. Here, headquarters provides no incentive for managers to self-select. Hence, in the pooling equilibrium, headquarters does not know with certainty at $t = 0$ whether or not the investment outlook is favorable or not.

Define $\underline{b}^C = 1 + p^B \left(b^H - 1\right)$, where $\underline{b}^C > \underline{b}^S$ can be easily verified. For $b_1 \in \left(\underline{b}^S, \underline{b}^C\right)$, headquarters finds it optimal to deny approval for a first-period investment even though it can encourage a separating equilibrium by implementing the capital budgeting mechanism with commitment. For $b_1 \in \left(\underline{b}^C, \overline{b}^S\right)$, headquarters prefers to implement the capital budgeting mechanism with commitment over simply denying all first-period projects. However, for b_1 sufficiently large, headquarters may prefer to fund the first-period project and evaluate the second-period project after it arrives instead committing to deny all second-period projects whenever managers request capital in the first period.

Assume $b_1 \in \left(\underline{b}^C, \overline{b}^S\right)$. Headquarters is indifferent between a capital allocation mechanism with commitment and a capital allocation mechanism in which headquarters funds the first-period project and evaluates the second-period project after it arrives whenever

$$\frac{1}{2}\left(b_1 - 1\right) + \frac{1}{2} p^G \left(b_2^H - 1\right) = \left(b_1 - 1\right) + \frac{p^G + p^B}{2}\left(b_2^H - 1 - c\right). \tag{6}$$

The left hand side is identical to that found in equation (6). The right hand side is the utility headquarters receives from funding the first-period project and evaluating the second-period project after it arrives.

From equation (6), we identify the threshold $\overline{b}_C = 1 - p^B \left(b_2^H - 1\right) + \left(p^G + p^B\right) c$. For all $b_1 \in \left(\underline{b}^C, \overline{b}^G\right)$ and $b_1 < \overline{b}_C$, headquarters strictly prefers the capital allocation mechanism with commitment.

Proposition 1 *Assume $b_H > \frac{1-p^B}{p^G-p^B}$. For $b_1 \in \left(\underline{b}^C, \min\left[\overline{b}^C, \overline{b}^S\right]\right)$ there exists a $c^*\left(b_1\right) \in \left(0, b^H - 1\right)$, there exists a perfect Bayesian equilibrium strategy of capital allocation with commitment for every $c \geq c^*\left(b_1\right)$.*

Proof. *If $b_H > \frac{1-p^B}{p^G-p^B}$, it is easy to verify $\underline{b}^S < \underline{b}^C < \overline{b}^C < \overline{b}^S$. Thus, any b_1 satisfying $b_1 \in \left(\underline{b}^C, \min\left[\overline{b}^C, \overline{b}^S\right]\right)$ provides the correct incentives for the division manager to reveal his private information regarding the investment outlook by either accepting funding for b_1 or denying funding for b_1 when headquarters employs a capital budgeting with commitment when $c \geq c^*\left(b_1\right)$. Headquarters prefers this policy to either denying funding to all first period projects or reviewing projects period by period without commitment. Since both headquarters and the division manager prefer this policy, there exists a perfect Bayesian equilibrium strategy of capital allocation with commitment for $b_1 \in \left(\underline{b}^C, \min\left[\overline{b}^C, \overline{b}^S\right]\right)$ whenever $b_H > \frac{1-p^B}{p^G-p^B}$.* ■

Figure 3 provides a complete characterization of the capital budgeting mechanisms employed by headquarters.

The key difference between Figure 2 and Figure 3 is that for a certain parameter range headquarters prefers to implement a capital budgeting mechanism with commitment. For first-period investment projects with

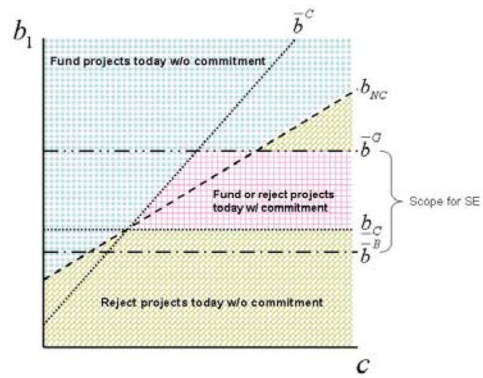

Figure 3: **Capital Budgeting with and without Commitment**. For any pair (b_1, c), the figure portrays the hurdle rates for first period projects identified by capital allocation mechanisms with and without commitment.

moderate returns and sufficiently large cost of external financing, headquarters can improve the efficiency of capital allocation by committing to denying funding for all second-period projects whenever a division manager receives funding for its first-period project. For a given cost of external financing, the higher the returns promised by the first period project, the more likely headquarters cannot commit to this policy and prefers instead to evaluate projects period by period using a capital budgeting mechanism without commitment. Conversely, for a given cost of external financing, the lower the returns promised by the first period project, the more likely headquarters will deny funding for all first-period projects.

The figure also demonstrates that capital allocation with commitment is more likely the higher the cost of external finance. Commitment allows headquarters to reduce the parameter space in which it is optimal to simply reject all first-period projects. This occurs because in the separating equilibrium achieved by commitment, division managers with unfavorable investment outlooks accept a capital allocation in the first period. Therefore, headquarters can lower the hurdle rate for first period investment from b_{NC} to $\underline{b}^C$.[6] Commitment also allows headquarters to reduce the parameter space in which it is optimal to evaluate projects period by period. This occurs because division managers with favorable outlooks decline first-period investment opportunities. Thus, the need to conserve capital for second-period projects is lessened and headquarters can fund even more profitable investment opportunities today submitted by managers with unfavorable outlooks.

As portrayed in Figure 3, for extremely large cost of external finance, a perfect Bayesian strategy exists in which headquarters denies funding for all first-period projects and funds only second-period projects that promise b_2^H. This equilibrium may be difficult to sustain in a more general setting. If under-reporting of project quality is feasible, the division manager facing an unfavorable investment outlook will have incentive to under-report the quality of period one investment in order to increase his chance of receiving funding for his investment project in the first period. Under-reporting by this division manager will erode the ability of a capital budgeting

[6]Note that $\underline{b}^C$ is still strictly greater than b^B.

mechanism with commitment to achieve a separating equilibrium and will alter the equilibrium outcome. To avoid the problem of under-reporting we assume in section (2) that under-reporting is not possible. Alternatively, we could impose the parametric assumption, $b_2^H > \frac{(1-p^B)+(1-p^G)}{p^G-p^B}$. This assumption is sufficient to lead to a perfect Bayesian equilibrium strategy capital allocation with commitment and it rules out the possibility that under-reporting is optimal for the divisional manager.

Empirical studies document that at the plant level a large percentage of investments occurs in very few years. For example, Doms and Dunne (1998) report that from 25% to 40% of an average plant's cumulative investment over 17 years is concentrated in a single year. Our results suggest that internal capital allocation procedures may contribute to these findings. While a strategy of period by period evaluation, may lead to investment in both periods, using an intertemporal commitment strategy implies that the division invests at most in one of the two years, meaning that all investment is concentrated in one period. In Figure 3 the relevant combination of values of b_1 and c is the triangle formed by the lines characterizing $\overline{b}^C$, b_{NC} and $\overline{b}^G$. In this triangle there is a positive probability that investments take place in both periods under an allocation policy without commitment but this probability is always zero under a policy with commitment.

Empirical work has also found that the probability of a large investment in the current period as a function of the timing of the latest project is lower for firms with more severe financial constraints [Whited (2005)]. Our results indicate that internal capital allocation mechanisms may play a role for these findings. Intertemporal commitment is most attractive for firms with significant financial constraints. Under such a policy, an investment in period one will not be followed by a second-period investment. If headquarters follows instead a policy of period-by-period evaluation, a first-period investment does not exclude an investment in the period thereafter.

5 Extensions

5.1 Stochastic Denial

In our model, we show that committing to not granting capital in the second period after a first-period investment is made can lead to more efficient capital allocation. In our definition of commitment, we limit headquarters' strategy space by imposing that it denies funding to second-period projects with probability one. Allowing for the possibility of stochastic denial of profitable projects in the second period makes an intertemporal commitment strategy even more attractive. In determining the denial probability, headquarters will choose a level such that a division manager facing a favorable investment outlook is indifferent between accepting and foregoing the first-period capital allocation. This implies that within the relevant parameter range the denial probability is an increasing function in the cash flow of the first-period project, b_1.[7] While this may seem counterintuitive at

[7] In fact, the equilibrium level of denial probability will be linear and increasing in b_1. In setting the equilibrium level, headquarters solves the following

$$(b_1 - 1) + (1 - p(S))\, p^G \left(b_2^H - 1\right) = p^G \left(b_2^H - 1\right),$$

where $p(S)$ identifies the equilibrium strategy for the denial probability. Solving for $p(S)$ yields

$$p(S) = \frac{b_1 - 1}{p^G \left(b_2^H - 1\right)}.$$

first glance, it holds because a larger b_1 requires a higher probability of denial to render the manager with a favorable investment outlook indifferent.

In this paper, we restrict ourselves to a non-stochastic policy, because committing to a stochastic policy of not considering second-period investment is more difficult to achieve. Credible intertemporal commitment is typically achievable when similar situations occur repeatedly and players have the opportunity to "punish" another player when observing an action that deviates from the equilibrium strategy. If headquarters attempts to commit to a stochastic investment denial policy, it takes more rounds to observe whether headquarters indeed chooses the probability announced and provides an incentive for headquarters to deviate from the commitment strategy and accept a higher level of profitable proposals given that doing so is profit maximizing from a second-period perspective.[8]

5.2 Performance Pay

An alternative way to achieve a separation between division managers with favorable and unfavorable investment outlooks is to pay the manager a bonus when a cash flow of b^H is realized at $t = 2$ after he foregoes first-period investment. Since the bonus can be designed in a way that only division managers with favorable investment will find it worthwhile to forego investment today in return for receiving a bonus from the second-period project, division managers will self-select into receiving this bonus and not. The cost of the bonus is that it dilutes the net present value of the investment returns whenever the bonus is paid out of project cash flows. The benefit of the bonus is that it doesn't prevent headquarters from funding second-period investment projects all together.

For example, consider the following capital budgeting mechanism. Headquarters designs the bonus contract such that the manager who faces a favorable investment outlook is indifferent between accepting the contract and foregoing the first-period capital allocation to denying the bonus and petitioning for a capital allocation in the first period. Here, the bonus contract provides a carrot rather than a stick and is costly as the bonus payment reduces firm profit. The advantage of the contract over an intertemporally restricting capital allocation is that second-period investment of a manager with an unfavorable investment outlook is not eliminated. We suspect that this type of capital budgeting allocation mechanism will be beneficial only in circumstances where the division manager who faces an unfavorable investment outlook has sufficiently high likelihood of encountering a second period investment project of b_2^H. Alternatively, headquarters will prefer to implement a capital allocation mechanism with commitment whenever p^B is relatively small.

6 Conclusion

This paper demonstrates that, consistent with field study evidence, firms facing capital restrictions can find it optimal to stipulate that after a division accepts a significant capital allocation it will have to wait some time until it receives another significant allocation. Such a policy leads the division manager to disclose his information about the extent of future investment opportunities.

[8] An additional problem of a stochastic denial policy arises when there is the possibility of under-reporting b_1. In this case, a division manager has an incentive to do so as the denial probability chosen by headquarters is increasing in $b_1$and the manager can increase his utility by reporting a smaller b_1.

The described policy is consistent with empirical evidence that investment at the plant level is concentrated in few periods and that firms facing ceteris paribus more severe financial constraints display more periods of idleness after significant investments.

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