Integration, Organizational Processes and Allocation of Resources

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Abstract

Does the level of integration of a firm affect the quality of information available to its top decision makers responsible for allocating resources? Motivated by the pervasiveness of specific knowledge in large multi-division firms, I develop a model of internal competition for corporate resources among specialist managers and show that: (i) managers of integrated firms exaggerate the payoffs of their projects to obtain resources despite potentially adverse career consequences, and (ii) the exaggeration problem worsens with increased integration and reduces the allocative efficiency of an integrated firm. Control rights based on asset ownership enable the firm to set "the rules of the game" and improve managerial behavior through organizational processes such as rigid capital budgets, job rotation, centralization and hierarchies.

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To assume all the knowledge to be given to a single mind is to assume the problem away and to disregard everything that is important and significant in the real world.

F. A. Hayek

1 Introduction

Specific knowledge is pervasive not only in capital markets but also at large integrated[1] firms. Yet our understanding of the latter, asymmetric information within the firm, is much less advanced than our understanding of the former, asymmetric information between the market and the firm, developed by corporate finance research in the last thirty years. How does increased integration affect allocative efficiency? And what can firms do to improve their allocation of resources?

This paper addresses these questions in a model of internal competition for corporate resources among specialist managers and makes two broad contributions. First, the paper shows why some competing managers would exaggerate the payoffs of their projects despite potentially adverse career consequences ex-post, and why the equilibrium quality of strategic communication between corporate headquarters and specialist managers would worsen with increased integration. Second, the paper shows how various organizational structures and processes such as rigid capital budgets, job rotation, centralization and hierarchies can be viewed as indirect ways to influence and improve managerial behavior, and thereby increase allocative efficiency in a model that links internal capital and labor markets.[2]

To describe the resource allocation process of a firm in a realistic way, I use specific knowledge as the main modeling ingredient and focus on strategic communication between an uninformed corporate headquarters and its specialist managers. Specifically, I consider a two-period setting where specialist managers compete for corporate resources in each period by communicating to

[1] The paper does not take a particular stance about whether it is related integration (vertical, horizontal) or unrelated integration (lateral) that leads to asymmetric information within the firm – though one may naturally expect the paper's emphasis on specific knowledge to be more pervasive in laterally integrated firms than in vertically or horizontally integrated firms.

[2] Such a link between resource allocation and the structure and functioning of organizations can potentially help us think about the effect of integration on firm behavior generally and corporate investment specifically. As Mullainathan and Scharfstein (2001) point out, "... while we know something about the forces that determine firm boundaries, we know relatively little about how these boundaries affect actual firm behavior. This is a major limitation in our understanding of the nature of the firm."

corporate headquarters the payoffs of their projects. Since managers are assumed to have unique expertise and prefer a larger empire over a smaller empire, they are tempted to make exaggerated statements to increase their chances of obtaining resources for their projects – though not every manager actually chooses to make an exaggerated statement because ex-post failure to achieve stated targets endogenously leads to a negative updating on managerial talent.

In the model, the temptation to exaggerate is stronger for managers for whom the reputational cost is lower – generating an equilibrium in which only less talented managers for whom the future holds less promise choose to exaggerate the payoffs of their projects. More interestingly, the quality of strategic communication in equilibrium worsens with increased integration as the presence of more managers makes it less likely for a honest strategy to obtain resources. In the specific context of the model, a manager who follows an honest strategy when competing for resources against only one manager (analyzed in subsection 3.1) chooses to exaggerate when competing against two or more managers (subsection 3.2).

The paper then explores various organizational solutions. I first show how rigidity in capital budgeting can improve the quality of communication and allocative efficiency by reducing the intensity of competition for resources among managers. This result indicates a natural limit on how aggressive an uninformed corporate headquarters can be in allocating resources and provides an alternative explanation for what has typically been argued as socialism in internal capital markets, the seemingly lower sensitivity of integrated (multi-segment) firms to investment opportunities in their industries. The paper proposes a number of proxies and specific tests to empirically differentiate between the two explanations.

In addition, I show how job rotation makes managers currently assigned to less profitable assets more forthcoming by providing them with the chance of being assigned to possibly more profitable assets in the future. Then, I show how centralization can improve behavior by getting managers to engage in team production that is successful only if communication is accurate. Finally, I show how delegation and hierarchies can improve communication by constraining internal competition.

There is ample clinical evidence in the management literature suggesting the prevalence of the kinds of within-firm informational asymmetry that is central to my model. For example, Bower's classic study (1970) provides insights about the degree of informational asymmetry between corporate headquarters and division managers. Conceding that the expertise and information necessary to make project proposals reside in managers who are much closer to markets, he writes:

> In fact, once a project emerges from the initial stages of definition it is not only hard

to change it, but in some cases hard to reject it. Too much time has been invested, too many organizational stakes get committed, and at very high levels of management too little substantive expertise exists to justify second guessing the proposers. (p. 54)

Bower also provides evidence of the agency problem that leads to exaggeration in my model.[3] As much as the gap in technical expertise, an additional problem appears to be the parochial attitude of managers who tend to regard their lines of business as having some special importance. The following quotes from interviews conducted by Bower show how this parochialism can be particularly taxing when managers propose project ideas that compete for the firm's limited resources:

> There will always be a segment of business you'll still want to be in, regardless of financial criteria... I told my group that they should not worry about the approval of their projects. (p. 9)
>
> We're making 5% on all those 35% projects. (p. 13)
>
> And any manager worth having can produce numbers that will make a project look good. (p. 15)

The paper proceeds as follows. Section 2 relates the paper to previous research and discusses the modeling choices in some detail. Section 3 develops the basic model. I show that managers of integrated firms exaggerate the payoffs of their projects to obtain resources despite potentially adverse career consequences and that the equilibrium quality of strategic communication worsens with increased integration. In Section 4, I investigate the implications of these results for allocative efficiency. Section 5 considers organizational remedies that can indirectly improve managerial behavior and hence allocative efficiency. In Section 6, I discuss testable implications of the ideas developed in Sections 3, 4 and 5. I provide concluding remarks in Section 7.

2 Modeling Integration, Organizational Processes and Allocation of Resources

Separate literatures on integration, internal resource allocation and organizational economics have advanced along several different paths, generally depending on assumptions made about information and commitment. This section briefly places the paper with respect to these related literatures by noting and motivating its key modeling choices.

[3] See Jensen (2001) for examples of widespread misrepresentation in the context of annual business planning.

The Coasian literature on integration[4] has explored primarily two issues, namely the problem of hold-up and transaction costs, as the fundamental determinants of firm boundaries. The prevailing model of integration of Grossman and Hart (1986) and Hart and Moore (1990) assumes that (i) integration simply reallocates bargaining power over profits, (ii) efficiency is always achieved through renegotiation, and (iii) owner-managers have the specific knowledge to implement the efficient outcome. In contrast, I assume that the very size of an integrated firm makes it impossible for any one manager, owner or non-owner, to have the specific knowledge necessary to achieving the efficient outcome, and that integrated firms instead have to rely on information provided by specialist managers. I also assume that specialist managers do not bargain over personal profits, but rather compete for the firm's limited resources. These assumptions motivate the paper's strategic communication (signaling) approach with internal competition to analyze the joint problem of integration and resources allocation.[5]

A relatively recent internal capital markets literature in corporate finance also investigates the nature and efficiency of internal resource allocation. Building on the incomplete contracts approach pioneered by Grossman and Hart (1986), and Hart and Moore (1990), Gertner, Scharfstein and Stein (1994) show why control rights based on asset ownership may reduce managerial effort incentives in internal capital markets. Stein (1997) extends the control ideas of GSS and shows that an informed corporate headquarters can relax credit constraints by combining several projects under one roof and actively shifting funds from one project to another. Neither paper explores how a firm can use these control rights to shape managerial behavior through organizational processes and structure. Scharfstein and Stein (2000) and Brusco and Panunzi (2000) show that corporate headquarters may knowingly allocate resources inefficiently[6] as a way to improve ex-ante effort incentives. Although this paper also predicts capital allocations that are inefficient relative to first-best, the underlying mechanisms are quite different. Both prior papers focus on the effort aspect of the agency problem whereas this paper focuses on strategic communication.

Harris and Raviv (1996, 1998) explore capital budgeting rules for a single manager in isolation using the revelation principle. Bernardo, Cai and Luo (2001) add moral hazard to the problem. The mechanism design approach of these papers assumes commitment power to decision rules that

[4] Most notably, Williamson (1975, 1985), Klein, Crawford, and Alchian (1978), Grossman and Hart (1986), Hart and Moore (1990) and Baker, Gibbons and Murphy (2001, 2002).

[5] Bolton and Scharfstein (1998) also emphasize the need to incorporate the Berle and Means perspective on agency into the Coasian view of the firm.

[6] Rajan, Servaes and Zingales (2000) predict similar inefficiencies due to internal power struggles.

are ex-post inefficient.[7] For completeness, I show in the appendix that the optimal mechanism for my model also involves decisions that are ex-post inefficient. Hence, given truthful revelation and complete information, commitment to inefficient course of actions is necessary. The strategic communication approach of this paper does not assume such commitment power and so does not use the revelation principle.[8]

A growing literature on the economics of organizational design also investigates organizational structures such as delegation and hierarchies. Marino and Matsusaka (2001) focus on decision rules in a one-period one-manager setting and investigate the effects of differing degrees of delegation on information transmission.[9] Dessein (2002) and Harris and Raviv (2002) investigate the effects of complete delegation.[10] Milgrom and Roberts (1988) consider a model in which managers can shift effort away from their current jobs to lobby for a better job. In comparison, this paper analyzes various organizational processes and structures more broadly in a multi-period setting and explores additional issues such as reputation and internal competition. Stein (2002) explores the effect of hierarchies on the production of specific knowledge. Garicano (2000) explores the role of hierarchies in organizing the acquisition of hard knowledge. This paper investigates issues that arise with the strategic communication of specific knowledge, connects them to career concerns, and demonstrates a potentially important link between internal capital and labor markets.

There are other alternative and certainly interesting approaches to integration. Maksimovic and Phillips (2001) develop a profit-maximizing model of a conglomerate where optimal growth in different industries is driven by differences in profitability and firm-specific managerial talent. Their approach abstracts from the asymmetric information considerations of this paper and takes the number of industries as given. Matsusaka (2001) views integration as a search process by

[7] For instance, the manager in Harris and Raviv (1996, 1998) reveals his true project type to corporate headquarters under the threat of a costly audit and, with a nonzero probability, real money is spent to verify the manager's claim – even though it is in fact known to be perfectly true. In addition, investment is distorted despite truthful revelation and complete information.

[8] A long tradition of signaling models in corporate finance also does not assume commitment power and as a result does not use the revelation principle. Similarly, the incomplete contracting approach in contract theory generally and corporate finance specifically rests on related foundational arguments and does not use the revelation principle. As Hart and Moore (1999) point out, both cases (where there is and where there is not commitment power) are worthy of study.

[9] Aghion and Tirole (1997), and Baker, Gibbons and Murphy (1999) explore the effect on effort incentives.

[10] On a related note, these works build on Crawford and Sobel's (1982) model of strategic communication and also do not use the revelation principle.

which firms experiment and find a good fit for their organizational capabilities. Berkovitch, Israel and Tolkowsky (2000) explore the decision to integrate as a trade-off between the need to manage agency problems and the need to obtain information from the market.

3 The Model

Suppose there are two types of managers, who may be either g (good) or b (bad), with probabilities β and $1-\beta$, respectively. Further suppose that there are two types of projects, which may again be either good or bad, with returns R_H (high) and R_L (low), respectively. Projects of bad managers always turn out to be bad. Projects of good managers, on the other hand, can be good with probability μ and bad with probability $1-\mu$.[11,12]

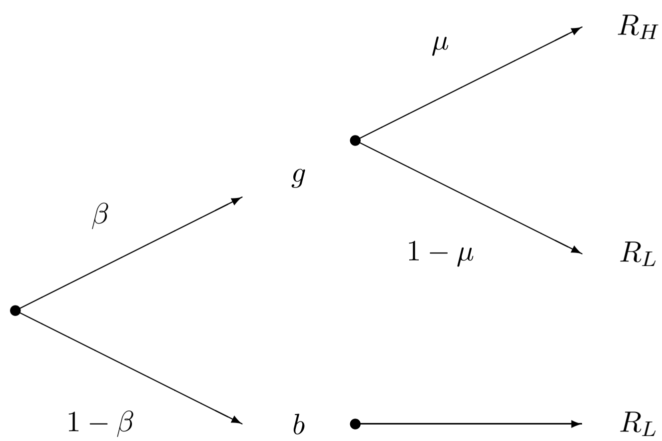


Figure 1: Managerial Talent and Project Outcomes

Managers know whether they are good or bad.[13] Moreover, managers are assumed to be empire-builders and hence derive private benefits from managing as big a capital budget as possible. Furthermore, managers are assumed to prefer a more profitable empire over a less profitable empire.

[11] This is the sense in which a good manager is better than a bad manager.

[12] The results are robust to the generalization that a bad manager gets a good project with a probability less than $1-\mu$. However, the game and the reputational conditions (further below) that are necessary to make the game interesting get messier. All that is required for the main message of the paper to hold is that the future hold less promise for some type of managers than others.

[13] An alternative formulation could be to assume that managers do not know whether they are good or bad but update their priors (before corporate headquarters does) as they get good or bad project ideas.

Formally, their utility function is given by:

$$U_i(K_i, R_i) = K_i R_i \quad (1)$$

[14]

Competition for corporate resources K takes place over two periods. In period 1, each manager comes up with a project idea. If the manager is bad, he always comes up with a bad project. If the manager is good, he can come up with either a good project or a bad project. After coming up with a project idea, each manager then makes a statement about the type of his project, h (high) or l (low).[15] Based on statements made, the firm's capital budget K then gets allocated to the seemingly best projects.[16] In period 2, each manager gets a new project idea as in period 1. Managers discount their period-2 payoffs at a rate $\delta < 1$.

The cross-product of possible manager types and project types in period 1 constitutes the relevant type within the game, yielding three types of managers which I name type-A, type-B and type-C. A type-A manager is a good manager and has a good project in period 1. A type-B manager is a good manager but has a bad project in period 1. A type-C manager is a bad manager and always has a bad project.

Based on statements made and project results observed in period 1, including the results of projects that were not undertaken,[17] corporate headquarters forms a posterior about the type of its managers, and determines which among them are eligible to compete for the firm's resources in period 2.

I assume that a good manager would be patient enough to wait for a potentially better project idea in the future if he had a bad project idea today, but thought that the future held more promise.

[14] The assumption of constant returns to scale technology is not necessary for qualitative conclusions of the paper. Both increasing and decreasing returns to scale would produce the same important conclusions. With constant returns to scale, the firm's total resources become irrelevant. This assumption also renders the model's predictions consistent with any amount of external financing the firm receives in equilibrium, see Stein (1997, 2002).

[15] The idea that at very high levels of management too little substantive expertise exists to evaluate and compare projects, and that a manager with significant specialized knowledge, if he so chooses, can make either statement regardless of his true project type is central to the model. This is also a significant technological deviation from classic career concerns models of Holmström (1982) and Holmström and Ricart i Costa (1986).

[16] Obviously the assumption that corporate headquarters is completely uninformed is not intended to be realistic. A richer setting where division managers are relatively more informed about the specifics of their projects than corporate headquarters would generate qualitatively similar results.

[17] Observability of results for projects that were not undertaken is without loss of generality and, if anything, reduces a manager's temptation to exaggerate. In general, nonobservability would only make the communication problem worse.

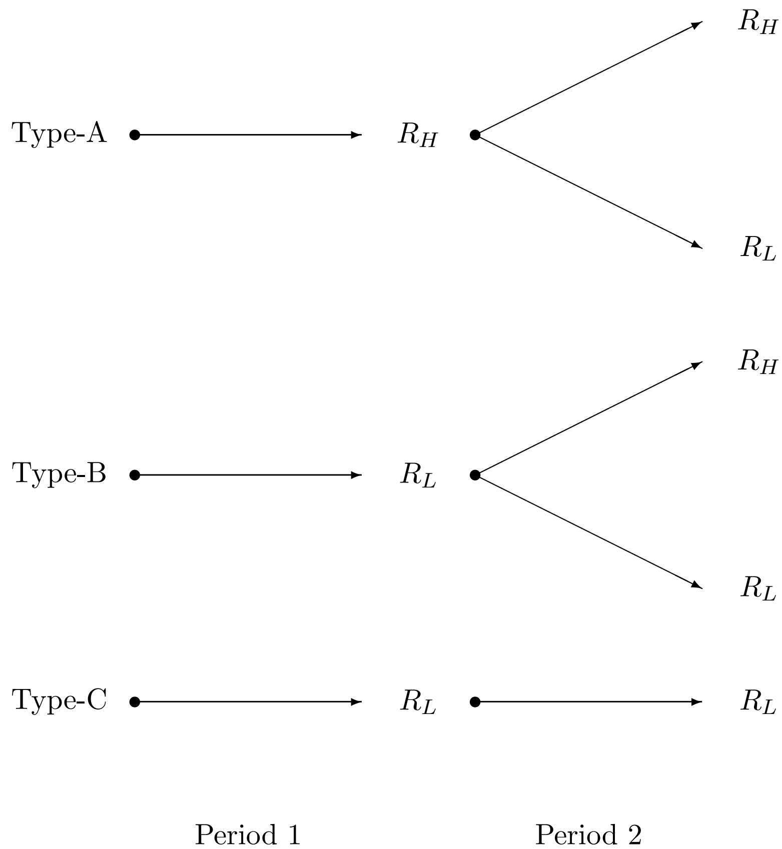


Figure 2: Manager Types

In the context of the model, this implies

$$R_L < \delta R_E \tag{2}$$

where $R_E \equiv [\mu R_H + (1-\mu) R_L]$.

Both gross returns R_H and R_L are assumed to be greater than 1. This assumption can be relaxed if one is willing to impose an additional layer of agency problem between investors and corporate headquarters as in Scharfstein and Stein (2000). In either case, corporate headquarters would choose to utilize the firm's resources fully in each period.

As a solution concept, I use the standard Bayesian Perfect Nash Equilibrium (BPNE). Out of equilibrium beliefs, when and if necessary, satisfy the Cho-Kreps (1987) intuitive criterion.

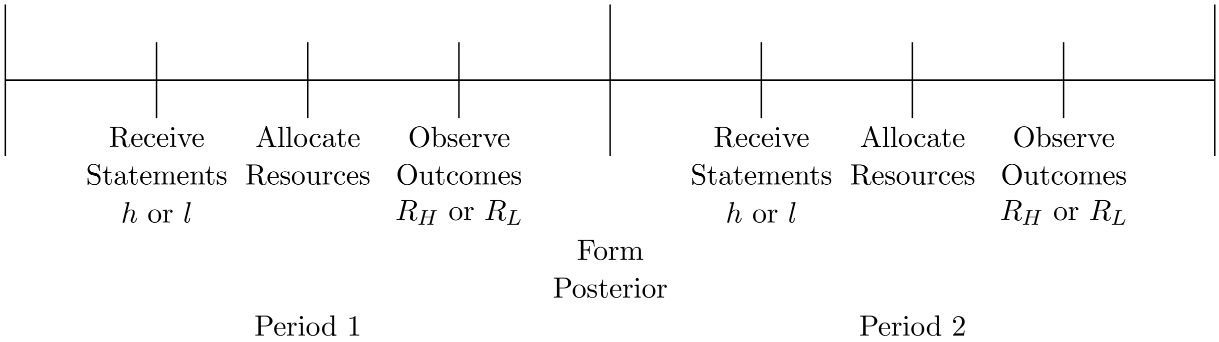


Figure 3: Timeline

3.1 Two-Manager Competition

An important first point to notice is that announcing h strictly dominates announcing l in period 2. And since statements made then do not convey any useful information, corporate headquarters would allocate the firm's period-2 capital budget K equally among the managers who tie for the highest posterior probability of being a good manager (following period-1 competition).[18]

Lemma 1 *In period* 2, *every manager reports a good project.*

A second point to notice is that, in the case of a one-manager firm, there is no need for communication for the purposes of allocating capital and hence there would be no exaggeration within the firm. I refer to this as the *stand-alone* case.

When there is competition for limited corporate resources, however, managers may be tempted to make exaggerated statements to increase their chances of obtaining resources for their projects. The following proposition shows how such exaggeration may come about in a two-manager firm.

Proposition 1 *The unique Cho-Kreps equilibrium for two managers is as follows: In period* 1, *bad managers with bad projects (type-C) claim that they have good projects whereas good managers (type-A and type-B) do not engage in such exaggeration.*

Given the conjectured BPNE, only project proposals made by type-C managers in period 1 fail to attain their stated targets and consequently reveal their managers as such. A high project outcome in period 1 reveals that the manager is a type-A manager. And, on the equilibrium path,

[18] If managers were not identical ex-ante, it would be optimal to tilt the capital budget against the stronger types as in Lazear and Rosen (1981), and Bulow and Roberts (1989). Since I abstract from such heterogeneity, it is indeed optimal to divide the capital budget equally among the managers who tie for the highest posterior probability.

project proposals made by type-B managers in period 1 attain their stated targets. Therefore, the posterior beliefs after observing the statements and project results in period 1 are

$$P(g \mid h, R_H) = 1 \tag{3a}$$

$$P(g \mid h, R_L) = 0 \tag{3b}$$

$$P(g \mid l, R_H) = 1 \text{ (out of equilibrium)} \tag{3c}$$

$$P(g \mid l, R_L) = 1 \tag{3d}$$

Note that although (3c) is out of equilibrium, it is not arbitrary. Only projects managed by good managers can produce R_H in period 1. These posterior beliefs determine the allocation of capital in period 2. Lemma 1 summarizes the optimal period-2 strategy. Solving the model backwards, payoff to a type-A manager (who is a good manager with a good project in period 1) from announcing h in period 1 is

$$(1-\beta)\underbrace{\left[\frac{1}{2}KR_H + \delta KR_E\right]}_{\text{Facing type-C}} + \beta\left[\mu\underbrace{\left(\frac{1}{2}KR_H + \frac{1}{2}\delta KR_E\right)}_{\text{Facing type-A}} + (1-\mu)\underbrace{\left(KR_H + \frac{1}{2}\delta KR_E\right)}_{\text{Facing type-B}}\right] \tag{4}$$

It is perhaps worth explaining the first payoff structure in some detail. When facing a type-C manager, a type-A manager gets half of the capital budget and all of the capital budget in period 1 and period 2, respectively. He gets only half of the capital budget in period 1 because the other manager, who is type-C, states h despite having a bad project. After failing to attain his stated target, however, a type-C manager is identified as a bad manager and consequently gets no capital in period 2. When the other manager too is a type-A manager, the capital budget is divided equally in both periods. Finally, when facing a type-B manager, a type-A manager gets all of the capital budget and half of the capital budget in period 1 and period 2, respectively. He gets all of the capital budget in period 1 because the other manager, who is type-B, states l. After this truthful statement, a type-B manager is identified as a good manager and consequently gets half of the capital budget in period 2.

Payoff to a type-A manager from announcing l in period 1 is

$$(1-\beta)\underbrace{[0 + \delta KR_E]}_{\text{Facing type-C}} + \beta\left[\mu\underbrace{\left(0 + \frac{1}{2}\delta KR_E\right)}_{\text{Facing type-A}} + (1-\mu)\underbrace{\left(\frac{1}{2}KR_H + \frac{1}{2}\delta KR_E\right)}_{\text{Facing type-B}}\right] \tag{5}$$

A type-A manager clearly has nothing to benefit from announcing l.[19] He gives up half of the capital budget in period 1 regardless of the type of the other manager and gains nothing in return. He has a good project and announcing h is the best response.

Payoff to a type-B manager (who is a good manager with a bad project in period 1) from announcing l in period 1 is

$$(1-\beta)\left[0+\delta K R_E\right]+\beta\left[\mu\left(0+\frac{1}{2}\delta K R_E\right)+(1-\mu)\left(\frac{1}{2}K R_L+\frac{1}{2}\delta K R_E\right)\right] \tag{6}$$

Payoff to a type-B manager from announcing h in period 1 is

$$(1-\beta)\left[\frac{1}{2}K R_L+\frac{1}{2}\delta K R_E\right]+\beta\left[\mu\left(\frac{1}{2}K R_L+0\right)+(1-\mu)\left(K R_L+0\right)\right] \tag{7}$$

The difference is

$$(1-\beta)\left[\frac{1}{2}K\left(\delta R_E-R_L\right)\right]+\beta\left[\mu\left(\frac{1}{2}K\left(\delta R_E-R_L\right)\right)+(1-\mu)\left(\frac{1}{2}K\left(\delta R_E-R_L\right)\right)\right] \tag{8}$$

Note that the difference is $\frac{1}{2}K\left(\delta R_E-R_L\right)$ regardless of the type of the other manager. So the expected difference is also

$$\frac{1}{2}K\left(\delta R_E-R_L\right) \tag{9}$$

The expected difference is positive by the assumption stated in (2) and announcing l dominates announcing h for a type-B manager. So what keeps a type-B manager honest when he can announce h and potentially get more funding in period 1? The answer is his concern for period 2. A type-B manager could indeed exaggerate by announcing h and receive more funding in period 1 ($\frac{1}{2}K$ in every state compared to announcing l), but failing to attain his stated target would label him as a bad manager and lead to less funding in period 2 ($\frac{1}{2}K$ in every state). If instead he announces l, he receives less funding in period 1 ($\frac{1}{2}K$ in every state compared to announcing h). That is, in return for preserving his reputation as a good manager, he receives more funding in period 2 ($\frac{1}{2}K$ in every state) when he expects to have a better project idea. Simply put, the gain that he can obtain by deviating in period 1 is not worth the consequent loss in period 2.

Payoff to a type-C manager (who is a bad manager with a bad project in period 1) from announcing h in period 1 is

$$(1-\beta)\left[\frac{1}{2}K R_L+\frac{1}{2}\delta K R_L\right]+\beta\left[\mu\left(\frac{1}{2}K R_L+0\right)+(1-\mu)\left(K R_L+0\right)\right] \tag{10}$$

[19] This is also true for any equilibrium and generalizes to the case of n managers.

Payoff to a type-C manager from announcing l in period 1 is

$$(1-\beta)\left[0+\delta K R_L\right]+\beta\left[\mu\left(0+\frac{1}{2}\delta K R_L\right)+(1-\mu)\left(\frac{1}{2}K R_L+\frac{1}{2}\delta K R_L\right)\right] \tag{11}$$

The difference is

$$(1-\beta)\left[\frac{1}{2}K R_L(1-\delta)\right]+\beta\left[\mu\left(\frac{1}{2}K R_L(1-\delta)\right)+(1-\mu)\left(\frac{1}{2}K R_L(1-\delta)\right)\right] \tag{12}$$

Note again that the difference is constant across all possible states of nature. The expected difference is

$$\frac{1}{2}K R_L(1-\delta) \tag{13}$$

Given any amount of time discounting $\delta < 1$, the difference is positive and announcing h dominates announcing l for a type-C manager. The trade-off faced by a type-C manager is similar to that faced by a type-B manager. A type-C manager could indeed pretend to be a type-B manager by announcing l, receive less funding in period 1 compared to announcing h ($\frac{1}{2}K$ in every state), and in return, receive more funding in period 2 ($\frac{1}{2}K$ in every state). But since a type-C manager knows that the future does not hold much promise for him and that he will not have a better project idea in period 2, he prefers getting more funding sooner in period 1. Therefore the conjectured BPNE is indeed an equilibrium.

In the appendix, I show that the only other possible equilibrium is a pooling equilibrium where every type of manager announces h in period 1. But this pooling equilibrium does not survive the Cho-Kreps refinement and so Proposition 1 identifies the game's unique Cho-Kreps equilibrium. The complete proof of uniqueness as well as the rest of the proofs are provided in the appendix.

3.2 Three-Manager and n-Manager Competition

For higher levels of internal competition, even type-B managers, who are good and therefore can expect to have brighter futures, may lose their patience and exaggerate just like type-C managers in period 1. The following proposition specifies the conditions under which type-B managers start to exaggerate as the number of competing managers increases from two to three.

Let g be the expected improvement in project quality from period 1 to period 2 for type-B managers $\left(\frac{\delta R_E}{R_L}\right)$.

Proposition 2 *With three managers and for $\beta > \frac{2g-1}{1-\mu+g}$ and $\mu < 2-g$, good managers with bad projects (type-B) lose their patience and start to claim with a mixing probability that they have good projects in period 1 just like bad managers with bad projects (type-C).*

The intuition for the three-manager case rests on the fact that a manager can increase the expected amount of funding that he receives over two periods by exaggerating in period 1. This is not to say that he faces no reputational costs in period 2. A manager, who increases period-1 funding by exaggerating, is sure to lose some period-2 funding as a consequence of negative updating on his talent. But despite this reputational cost, a manager can still come out ahead in terms of the expected total quantity of funding received over two periods by exaggerating in period 1. This was certainly not possible in the case of two managers where the only possible equilibrium trade-off was between an equal amount of period-1 funding and period-2 funding.[20]

Nevertheless, it is still not clear that a type-B manager would choose to exaggerate in period 1 to increase the expected total quantity of funding that he receives over two periods. He clearly prefers having more funding over less funding. But he also prefers funding in period 2 (when he might have a better project idea) over funding in period 1 (when he has a bad project idea). For a type-B manager to lose patience then, a tighter condition than a mere expected quantity gain must be met. Specifically, the expected return-weighted gain in period-1 funding must be greater than the consequent return-weighted loss in period-2 funding.

Two factors help this tighter condition to be met (i) high β and (ii) low μ. To see this point, assume for a moment that type-B managers remain truthful and state l in period 1 as in the two-manager case. Since both type-A managers and type-C managers state h, a type-B manager gets funding in period 1 only if all other managers state l. That is, a type-B manager gets funding in period 1 only if all other managers turn out to be type-B. When this happens, however, it is very tempting for one of the type-B managers to state h and get funding away from all other type-B managers. Of course, a type-B manager does not know for sure if all other managers are type-B. They can be type-A or type-C also. But a high β and a low μ make it more likely that they are type-B ($\beta(1-\mu)$), and less likely that they are type-A or type-C $(1-\beta(1-\mu))$. Moreover, a low μ reduces the reputational cost in period 2 by making it less likely that one of the other managers is type-A ($\beta\mu$).

The intuition outlined above also applies to the case of n-manager competition and becomes stronger as n gets large. The following proposition specifies the conditions under which type-B managers exaggerate in period 1 for n large enough. This case is interesting to study since one can

[20] With two managers, one manager's gain from exaggeration has to be the other manager's loss. This constraint is relaxed when there are three or more managers. The extra manager breaks the one-on-one constraint and allows a richer trade-off to arise in equilibrium.

look at the problem in population form (instead of having to consider all possible sample outcomes) and see the period-2 (reputation) vs. period-1 funding trade-off in the simplest way.

Proposition 3 *For number of managers n large enough, $\beta > \frac{g}{1+g(1-\mu)}$ and $\mu < \frac{1}{g}$, good managers with bad projects (type-B) lose their patience and claim with a mixing probability that they have good projects in period 1 just like bad managers with bad projects (type-C).*

When n is large enough, remaining truthful and stating l in period 1 has an extreme cost for type-B managers – no funding in period 1 since there is almost always at least one type-A manager who would state h in period 1. On the other hand, when n is large enough, exaggerating and stating h to receive some funding in period 1 has an extreme reputational cost in period 2 – no funding in period 2 since there is almost always at least one type-A manager who is then known to be good.[21]

In the appendix, I generalize this result and then present some numerical results. Specifically, I show that exaggeration temptations increase with n, holding β and μ constant. So, in a nutshell, the main message to take away from this section is that increased integration and the intrinsic internal competition for resources potentially can make it more difficult to elicit useful information from specialist managers.[22,23]

4 Integration and Allocative Efficiency

The analysis in the previous section indicates that extracting the much needed information from specialist managers to actively shift resources from bad projects to good projects (Williamson, 1975) may not be easy and, in fact, may get more difficult with increased integration. I now analyze this cost of integration on allocative efficiency.

[21] Again, all that is required is a higher posterior probability of being a good manager.

[22] One can think of this adverse effect on the quality of strategic communication as "diseconomies of management" that Coase (1937) assumes exogenously to prevent the counterfactual prediction that the entire economy be owned by one big firm to solve potential hold-up problems.

[23] The model also has a valuable insight to contribute to the age-old central planning debate. For instance, Hayek (1945) argues that any form of centralized economic management is bound to fail because central planners will not and cannot have knowledge of "particular circumstances of time and place". With a slight reinterpretation of managers as government agencies and corporate headquarters as the central planner, the model tells us that it could be the intensity of competition for resources (large n) that reduces the quality of information available to the central planner. This would complement the well-accepted bounded rationality arguments of Simon (1955).

As it is common in much of the literature on integration, the analysis of this section compares the allocative efficiency of independent firms with the allocative efficiency of their merged counterpart. To give an example, the analysis merges two one-manager firms, each with its own resources, into a two-manager firm with twice the resources. More generally for $n_2 > n_1$, the analysis merges $\frac{n_2}{n_1}$ n_1-manager firms, each with $K\frac{n_1}{n_2}$ resources, into a n_2-manager firm with K resources. In effect, the analysis keeps the amount of resources per manager constant at $\frac{K}{n_2}$.

An interesting question that comes up when making such comparisons is the potential effect that integration may have on the amount of resources that the firm can obtain externally. Stein (1997, 2002) shows how a firm can relax external credit constraints and increase per-project financing by integrating projects under one roof. Since I abstract from such an effect and take the amount of financing per manager to be constant, the comparisons below leave out a potential benefit of integration in mitigating capital market frictions.

It is important to note that the main result of the paper – the adverse effect of integration on the quality of strategic communication – is quite independent of the possibility of integration relaxing external credit constraints. In the model, managers take the amount of the firm's resources K to be given and then formulate their equilibrium strategies according to the number of managers with whom they have to compete. Hence, the model allows for a clear separation between issues that are external and internal to the firm.

I start by comparing the allocative efficiency of two independent stand-alone firms with that of their integrated counterpart.

$$A_{2S} = K(1+\delta)\left[R_L + \beta\mu(R_H - R_L)\right] \tag{14}$$

This expression represents the expected return that two stand-alone firms (each with $\frac{K}{2}$) can generate over two periods.

4.1 First-Best

With full information, an integrated firm can achieve higher allocative efficiency and exceed that of two independent stand-alone firms by moving funds to the best opportunity available.

$$A_{2I}^{FB} - A_{2S} = (1+\delta)\left[\underbrace{\beta(1-\beta)\mu}_{(i)} + \underbrace{\beta^2\mu(1-\mu)}_{(ii)}\right] K(R_H - R_L) > 0 \tag{15}$$

An integrated firm creates value in both periods when it has both a bad project and a good project. Specifically, an integrated firm creates value when it has (i) both a good manager (β) and a bad manager $(1-\beta)$, and the good manager has a good project (μ), (ii) two good managers $(\beta \times \beta)$, one with a good project (μ) and the other with a bad project $(1-\mu)$. By shifting resources to the better project, an integrated firm achieves higher allocative efficiency than two independent stand-alone firms.

4.2 Second-Best

When an integrated firm has to rely on strategic communication, its allocative efficiency suffers. Compared to first-best, the difference is negative.

$$A_{2I}^{SB} - A_{2I}^{FB} = -\left[\underbrace{\beta(1-\beta)\mu}_{(i)} + \underbrace{\delta\beta^2\mu(1-\mu)}_{(ii)}\right] K(R_H - R_L) < 0 \tag{16}$$

The reduction in allocative efficiency relative to first-best is due to (i) a bad manager $(1-\beta)$ with a bad project claiming to have a good project and getting funding when there is a good manager (β) who could use that funding in a good project (μ) in period 1, (ii) a good manager (β) with a bad project $(1-\mu)$ claiming to have a good project and getting funding when there is a good manager (β) who could use that funding in a good project (μ) in period 2 (δ). Moreover, the reduction is substantial when the cost of undertaking a bad project instead of a good project $(R_H - R_L)$ is high.

There are some other noteworthy differences compared to first-best. For example, there are instances in which a type-C manager claims to have a good project and gets funding at the expense of a type-B manager in period 1. Although in my model a type-B manager too has a bad project in period 1, he holds more promise than a type-C manager for period 2. In a more general model, one could imagine such diversion from type-B managers to type-C managers to be also costly, e.g. multiplicative investment technology, learning by doing, etc.

Compared to a stand-alone firm, the difference in allocative efficiency is positive.

$$A_{2I}^{SB} - A_{2S} = \left[\underbrace{\beta^2\mu(1-\mu)}_{(i)} + \underbrace{\delta\beta(1-\beta)\mu}_{(ii)}\right] K(R_H - R_L) > 0 \tag{17}$$

An integrated firm improves allocative efficiency relative to two stand-alone firms by shifting funds from (i) a good manager (β) with a bad project $(1-\mu)$ to a good manager (β) with a good

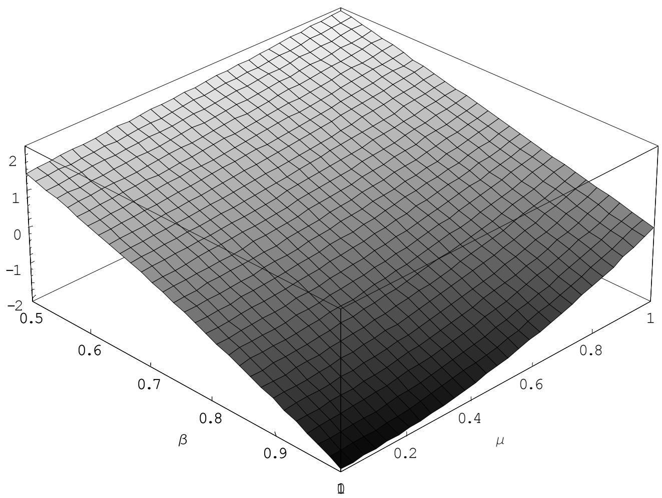


Figure 4: Difference in allocative efficiency

project (μ) in period 1, and (ii) a bad manager $(1-\beta)$ with a bad project to a good manager (β) with a good project (μ) in period 2 (δ).

I next look at the allocative efficiency of a three-manager firm and, for expositional reasons, assume parameter values are such that type-B managers start to exaggerate in period 1. Note that if I do not restrict attention to parameter values of β and μ for which the quality of communication gets worse, increased integration would continue to create value. Assuming that the inequality stated in (2) is satisfied marginally ($g = 1$), β (the chances that competition will be tough) must be greater than 0.5 so that type-B managers lose patience and choose to exaggerate in period 1.

Since the analytic expression for $A_{3I}^{SB} - A_{2I}^{SB}$ is not particularly intuitive, I plot it numerically in Figure 4. One would expect allocative efficiency to suffer as type-B managers choose to exaggerate more, that is when β is high and μ is low, as outlined in the previous section. Figure 4 shows that this is indeed the case. As β increases and μ decreases, the allocative efficiency of a three-manager firm declines and eventually falls below that of a two-manager firm.

Depending on the level of integration, further integration may increase or decrease allocative efficiency in the model. The following proposition specifies the conditions under which too much integration reduces allocative efficiency and so limited integration is desirable.

Proposition 4 *For* $\beta > \frac{g}{1+g(1-\mu)}$, $\mu < \frac{1}{g}$ *and* $g < g^*$, A_{nI}^{SB} *(n large enough) is less than* A_{2I}^{SB}.

Therefore, when future reputation is not valuable enough ($g < g^*$) to counter the adverse effect of integration on the quality of strategic communication, limited integration is desirable.

4.3 Alternative Interpretations and Discussion

Interestingly, the model can also be interpreted as a bank intermediating finance to a portfolio of projects. Similar to a firm, a bank too may want to pool projects as long as further integration (diversification) increases allocative efficiency.

Another interesting interpretation involves using the model to contrast internal capital markets with external capital markets. The model indicates that perhaps external capital markets are plagued by what most would agree is their fundamental strength, unfettered competition. As the model shows, too much competition can make it hard to elicit specific knowledge. In such an environment, immense value could be created by credibly committing to less competition, and in some ways one can view firms as serving that purpose: acting as isolated islands and sheltering their managers from the intense economy wide competition for capital (for example, transform an economy with n managers and n one-manager firms into an economy with $\frac{n}{2}$ two-manager firms).

Holmström (1999) offers another rationale about why firms may arise as isolated islands and argues that concentrated ownership of assets under a single authority (the island) brings about instruments that can be used to influence and improve managerial behavior "in a manner richer and more varied" than what would be possible under separate ownership. For example, a firm can set work rules; rotate managers between different projects; design jobs; delegate authority; control exactly who knows what and when. Then control rights that come with asset ownership could enable firms to set "the rules of the game" to improve outcomes.

These ideas suggest a fundamental difference between a firm and a bank when it comes to intermediating finance. Armed with value-enhancing control rights, a firm might be able to alter and improve the game in ways that a bank in a mere lending relationship to the manager cannot. I explore such alterations involving organizational design in the next section.

5 Control Rights and Organizational Design

Many organizational processes and structures that we observe in practice help firms influence and improve managerial behavior. In this section, I explore how a firm might use some of them to improve allocative efficiency. In addition, I discuss why a bank may not be able to replicate them without the control rights that come with asset ownership.

5.1 Incentive Contracts

Incentive contracts can be powerful tools for aligning managers' interests with those of the rest of the firm. In the model, incentive contracts can induce better behavior by rewarding managers for being honest in their strategic communication. While it is important to note that the main result of the paper is not entirely robust to contracting, the analysis in the appendix section shows that incentive contracts can be prohibitively expensive.[24] For example, the expected cost approaches the firm's capital budget K for low values of β and μ when two managers are competing, and becomes arbitrarily large under further integration (even if private benefits are small). More generally, firms would find incentive contracts to be ineffective in cases where good projects have large payoffs but are relatively rare. In addition, a manager needs to be rewarded for admitting to a bad project and there are reasons to think that incentive contracts of this sort may not be productive for reasons outside the model.

For example, suppose that even a good manager with a good idea has to spend some personally costly effort to achieve a good project outcome. Then incentive contracts that reward a manager for admitting that he has a bad project can be very counterproductive. Especially if personal effort is costly enough, a good manager may never have the incentive to propose a good project and spend the effort to make it a success. Instead, he would take the easy route; submit a bad project or destroy output ex-post to collect the counterproductive reward. In fact this last point that managers can destroy output if they wish is generally imposed to constrain optimal contracts to be monotone (non-decreasing in output) in cases where the maximum likelihood ratio property is not satisfied. While observed incentive contracts are indeed monotone, this means that the firm would need other organizational solutions to improve the quality of strategic communication.

There are other reasons, technical and practical, for which incentive contracts may not be too helpful in improving communication. If preferences are not additively separable in income, compensating differentials will be incomplete and monetary incentives will not solve the problem fully (Milgrom, 1988). If projects are long-term in nature, as in most R&D intensive industries such as the pharmaceutical industry, incentive contracts that condition on initial project proposal and subsequent project outcome may not be even feasible. Interestingly, such industries also tend to have the rare-blockbuster project profile that renders incentive contracts ineffective as shown in the appendix and discussed above.

[24] One can usefully think of this result as a multi-period analog of the result in Stein (1997) footnote 5.

5.2 Rigid Divisional Capital Budgets

One simple way in which a firm can improve managerial behavior is by implementing a rigid divisional capital budget, which effectively reduces the level and intensity of internal competition. With less at stake, managers would be more forthcoming in their communication. I formalize this idea in the following proposition.

Proposition 5 *Making a portion of the capital budget non-contingent can eliminate exaggeration by bad managers (type-C) in period* 1*. Specifically, as long as the contingent portion does not exceed* $(1 - \beta\mu)\,\delta$ *share of the capital budget, every manager tells his true project type.*

A rigid capital budget improves managerial behavior in essentially two ways. First, a rigid capital budget reduces the potential gain from exaggeration by allocating some of the capital before managers get a chance to make their statements (also making the process sequentially rational). With less amount of capital open to competition, a manager has less to gain by exaggerating. Second, a rigid capital budget promises a non-contingent allocation in period 2 for managers who behave in period 1, in effect making it more costly to exaggerate.

But perhaps a more fundamental question is why a firm can have a rigid capital budget but a bank cannot. Combining adverse selection with control rights could provide a plausible start. Suppose that there is no asymmetric information in the beginning and that managers find out their types only after integration, say by working with the assets and getting their project ideas. Since there is some ex-ante uncertainty about managerial ability, managers initially would be willing to accept a rigid scheme. The problem, however, would be ex-post. Once a manager finds out that he is good, a rigid scheme would have a very hard time keeping him. Not so surprisingly, he would like to defect to a non-rigid scheme in period 2, if not in period 1 – the reason he may have to postpone defection until period 2 is that he may need the project result in period 1 to credibly prove that he is a good manager. At the same time, a rigid scheme would be a magnet for bad managers. With not much upside, bad managers would love to stay. Such degree of adverse selection would make it very hard for a bank to implement a rigid loan policy in a profitable way. And in fact, one would expect opportunistic banks to form in period 2 to exploit the situation and aggressively recruit good managers from period 1 as clients.[25]

With asset ownership, things would be a bit different as defection would no longer be that easy. A good manager who works for a firm cannot take the assets and defect to a bank that offers a

[25] Interestingly, this points to a useful role banks can play in financing proven projects or managers.

non-rigid loan policy in period 2. Of course, he himself can leave if he so chooses and become an entrepreneur.[26] But the point is that he cannot take with him the assets that potentially make him more valuable. Then to the extent that asset ownership helps a firm to gain leverage over its human assets, defection would be less of a problem and a firm would have a comparative advantage over a bank in implementing rigid schemes.

The decision to implement a rigid scheme ultimately depends on allocative efficiency. Even if rigidity can improve managerial behavior, it may be suboptimal nonetheless if information is not used aggressively enough. Compared to non-rigid second-best, the difference is increasing in the contingent share of the capital budget ν as expected.

$$A_{2I}^{RS} - A_{2I}^{SB} = K\beta\mu \left[\nu \left(1 - \beta\mu\right) - \left(1 - \mu\right)\left(\beta + \delta\left(1 - \beta\right)\right)\right]\left(R_H - R_L\right) \tag{18}$$

Proposition 6 *There exists δ^* such that the rigid scheme achieves higher allocative efficiency than the non-rigid scheme for $\delta > \delta^*$ and $\beta < \frac{1-\sqrt{1-\mu}}{\mu}$.*

Intuitively, rigid capital budgets are optimal when the probability (and hence the cost) of restraining good managers (β) is not high. Higher values of μ relax the upper bound since it is the possibility of good projects that make truthful communication and reallocation valuable.

Propositions 5 and 6 highlight a natural limit on how aggressive an uninformed corporate headquarters can be in allocating resources based on managers' claims. Moreover, they provide an alternative explanation for what has typically been argued as socialism in internal capital markets, the seemingly lower sensitivity of integrated (multi-segment) firms to investment opportunities in their industries. Rigidity may simply be the optimal response of a corporate headquarters that is less informed than its managers. In Section 6, I provide a few suggestions that should help to empirically differentiate between the two explanations.[27]

5.3 Job Rotation

The overwhelming view of both academics and practitioners seems to be that job rotation among managers, especially at high levels, is good and productive. General Electric is often cited as an

[26] Gromb and Scharfstein (2001) develop an equilibrium labor-market model of entrepreneurship which predicts high ability managers to become entrepreneurs.

[27] There seems to be an interesting business cycle implication of the model. To the extent that parameters β and μ increase in an economic upturn, integrated firms would have to implement even more rigid capital budgets.

example to argue how it can help not only managers gain invaluable experience but also firms spread best business practices. The popular press seems to agree (CEO super bowl, Fortune 1999).

> Exposure to many disparate businesses ... give executives more ideas and confidence than most business people ever acquire... Executives raised in such an environment get a couple of advantages. First, they just know more. Managerially, they've seen the world. They've built a greater fund of ideas and practices than managers who've spent a career in one industry. Second, they've seen ideas applied successfully across industries, making them less afraid to try the unconventional. You're very reluctant to turn the world upside down if it's the only world you know.

Job rotation can be very effective in the context of my model as well, but for a somewhat different reason. To see why, suppose that the source of informational asymmetry in the model is not about managerial talent but about asset quality. That is, some of the assets that the firm owns are profitable and some of them are not. Neither the firm nor the managers have knowledge of this at the time of integration, but managers find out more as they work closely with their assigned assets and get project ideas in period 1. Now imagine that a manager learns that the set of assets he is working with are not of high quality. As long as he is assigned to these assets, he knows not only that he will have a bad project in period 1, but also that he will not be able to come up with a good project idea in period 2. With the future not holding a lot of promise, he would choose to exaggerate in period 1. If instead there were some chance that he might be assigned to a possibly more profitable set of assets in period 2, he might be more forthcoming in his statements in period 1 because only doing so would bring about the new assignment in period 2. I interpret this chance of being assigned to a different set of assets in period 2 as job rotation.[28]

Proposition 7 *Rotating managers to a different set of assets in period* 2 *can eliminate exaggeration by bad managers (type-C) in period* 1*. Specifically, there exist a probability of job rotation* $\underline{p} \in (0, 1)$ *and* δ^{**} *such that every manager tells his true project type and allocative efficiency improves for* $p > \underline{p}$ *and* $\delta > \delta^{**}$*.*

Compared to a firm, a bank that is in a lending relationship to the manager cannot implement job rotation. Lacking the control rights that come with asset ownership, a bank does not have

[28] There are obviously other reasons for job rotation e.g. better matching of jobs and workers (Alchian and Demsetz, 1972), improved measurement of managerial talent to provide better performance contracts (Aron, 1988), etc.

nearly the degree of control that a firm has over careers. To the extent that such control over careers is important for manipulating managerial behavior, the theory presented here highlights why a firm might be a better financial intermediary than a bank.

Of course, job rotation is just one example of what a firm can do with careers more generally. For example, a firm can decide when and where to promote managers, design career paths, and so on. Then the theory presented here more broadly highlights how internal labor and capital markets are fundamentally and inextricably linked.

Finally, the idea of job rotation points to an interesting conjecture about why firms that are made up of unrelated businesses may not fare so well. Perhaps a fundamental reason for a diversification strategy to have dysfunctional consequences is that it forces managers to accumulate human capital that is too specific for the present job and of no use elsewhere in the firm, essentially rendering job rotation very difficult to implement. As the model demonstrates, getting trapped under bad assets can make a manager desperate and less forthcoming.

5.4 Centralization

The degree of centralization in production is perhaps one of the most important organizational design choices made by a firm. By centralizing certain aspects of production, a firm can achieve economies of scale otherwise unattainable or avoid wasteful duplication otherwise inevitable. These effects have been much discussed and explored in the literature. For this reason I do not pursue them here, although they have direct applications in the model. Instead I provide an unorthodox point of view on what centralization can do to foster more constructive and positive communication from managers.

Suppose that a firm can carve out a fraction θ of the assets from each manager and form a centralized unit with which each has to work. For concreteness, think of a firm where all the marketing and distribution assets are centralized. Managers have to work with this centralized function to market and distribute their products but otherwise are free from any interference in their day-to-day operations. Further suppose that the centralized function needs some sort of a statement from each manager to coordinate and plan actions to make the team production a success and achieve the project's full potential. The problem, however, could be that the centralized function is not allowed to receive private communication to improve coordination and instead has to rely on statements made by managers when they competed for corporate resources.

Portrayed in this way, it should be obvious why centralization would improve communication.

When a manager contemplates making an exaggerated statement to get more resources in such a firm, he will take into account not only the reputational consequences, but also the disruptive effect that his misleading statement may have on the centralized function. In some sense, this line of argument endogenizes the idea that exaggeration itself may be destructive and lead to lower project outcomes.

To see how the model works with a centralized unit, suppose that when a manager states h, the probability of him having a good project is $\widehat{\beta}$. This probability can be lower or higher than $\beta\mu$ depending on equilibrium strategies of the managers, but never zero since a type-A manager has no reason to state anything other than h. Upon receiving the statement, the centralized unit has two choices. It can plan for either h or l. When plans are made for h, the centralized unit runs the risk of miscoordination with a bad project with probability $1-\widehat{\beta}$. If instead plans are made for l, there still is a risk of miscoordination, but this time with a good project with probability $\widehat{\beta}$. Choosing the best out of two evils, plans would be made for h if

$$\widehat{\beta}\theta R_H > \left(1-\widehat{\beta}\right)\theta R_L \tag{19}$$

I assume that R_H is large enough so that plans are made for h when a manager states h. This assumption may seem too strong, but it really does not need to be. To see why, suppose that the coordination outcome is a logarithmic function, instead of the all-or-nothing formulation above. Then the program of the centralized unit would be

$$\max_x \log(x)\,\widehat{\beta}\theta R_H + \log(1-x)\left(1-\widehat{\beta}\right)\theta R_L \tag{20}$$

The optimal coordination response x^* would fall in the range $[0,1]$ and increase with R_H.

$$x^* = \frac{\widehat{\beta}R_H}{\widehat{\beta}R_H + \left(1-\widehat{\beta}\right)R_L} \tag{21}$$

The point is that, in either formulation, exaggeration would lead to a lower project outcome. To simplify the analysis, I continue with the all-or-nothing formulation. However, this simplification should not affect the main message.

Proposition 8 *Centralizing a fraction θ of the assets can eliminate exaggeration in both periods. Specifically, there exists a degree of centralization $\underline{\theta} \in (0,1)$ such that every manager tells his true project type in both periods for $\theta > \underline{\theta}$.*

In summary, centralization can play a significant role in implementing the desired equilibrium by increasing θ. By introducing some team production and forcing managers to internalize the disruptive effect that their misleading statements may have on the centralized function, a firm can improve the quality of communication.

5.5 Hierarchy

Hierarchies and delegation along divisional lines can be seen as organizational solutions to restrain internal competition and improve the quality of strategic communication.

To illustrate the basic idea, consider the following simple example where the firm has four managers. These managers can be organized in two ways. First, they can compete simultaneously for the whole capital budget K. This is the familiar flat organization (Figure 5). Second, the firm can hire two division managers and delegate to each of them half of the capital budget $\frac{K}{2}$. Each division manager then gets two managers that in turn compete simultaneously for the smaller capital budget $\frac{K}{2}$ (Figure 6). Which option is better in terms of allocative efficiency?

In general, there are two opposing effects to consider: selection versus communication. It is easy to see that, if corporate headquarters were perfectly informed about the projects presented by specialist managers, the flat structure would dominate. Selecting the best out of four would always lead to higher value, statistically speaking on average, than choosing the best out of two. As an offset though, the potential for exaggeration would be higher when four instead of two managers compete simultaneously for corporate resources. That is, there might be more exaggeration when internal competition is more intense. Indeed, depending on parameter values, the firm can end up in an equilibrium where not only type-C managers but also type-B managers exaggerate in period 1. Specifically, for high values of β, which lead to the dysfunctional equilibrium for the flat structure, the hierarchical structure may achieve higher allocative efficiency.

It would be interesting to push this idea further along the lines of the team-theoretic literature on organizational design, most notably Sah and Stiglitz (1986), Radner (1992, 1993), Bolton and Dewatripont (1994), and Garicano (2000). The model presented in this paper captures many real-world issues pertaining to asymmetric information that the operations research focus of this literature leaves out. Yet it is simple enough to explore the optimal design of hierarchies as done in the team-theoretic literature.

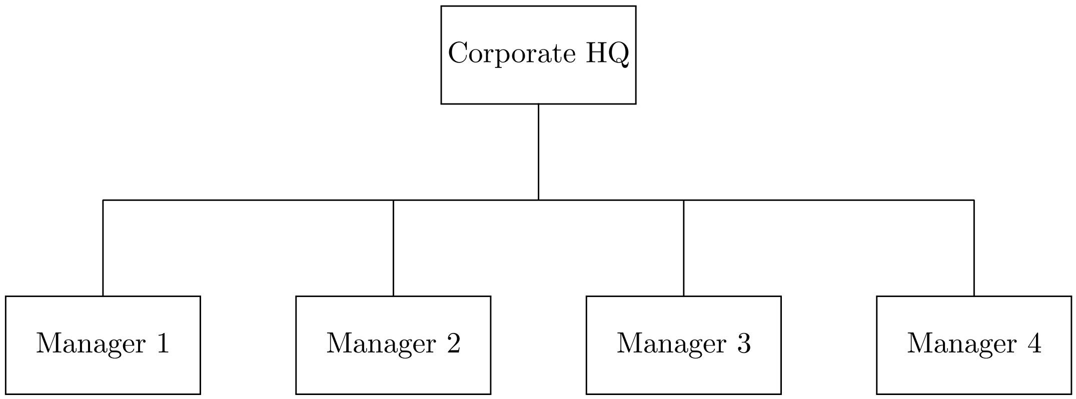


Figure 5: Flat Structure

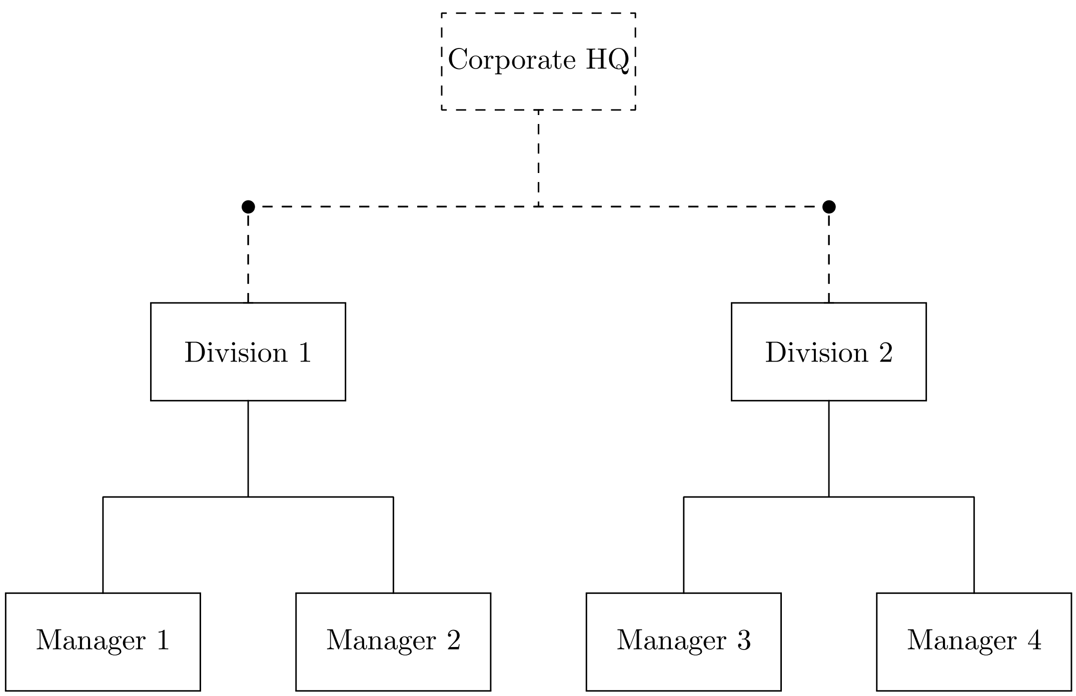


Figure 6: Hierarchical Structure

6 Testable Implications

The model has rich organizational implications that would benefit from an equally rich dataset on internal labor and capital markets with data on capital budgeting procedures, organizational structure, personnel policies and so forth. In this section, I discuss testable implications of the ideas developed in Propositions 5-8 using the somewhat coarse but widely available Compustat database.

Compustat firm and segment datasets provide basic segment-level accounting data such as sales, assets, operating profits, depreciation and capital spending for every distinct business that constitutes more than 10 percent of total sales. In fact, the segments in these files typically have a senior top manager who translates very nicely into the specialist manager in my model. Also the segment-level data can help determine whether a firm is integrated or not.

H1 *An integrated firm should have a more rigid capital budget than a non-integrated firm.*

H2 *An integrated firm in unrelated lines of business should have a more rigid capital budget than an integrated firm in related lines of business.*

H3 *A smaller segment of an integrated firm should have a more rigid divisional capital budget than a larger segment.*

Hypothesis 1 follows directly from Proposition 6. By restraining internal competition, an integrated firm can improve the quality of communication from managers and achieve higher allocative efficiency. That is, an integrated firm may optimally use less information to reduce the temptation of managers to make exaggerated statements.

Hypothesis 2 is based on the observation that organizational remedies such as centralization and hierarchies are more difficult to put into practice at a diversified integrated firm that is made up of unrelated businesses than a focused integrated firm that is made up of related businesses. As I have pointed out in the previous section, the difficulty with implementing some of these organizational solutions in a diversified integrated firm may simply have to do with feasibility than anything else.

For example, it is hard to imagine what can be centralized meaningfully in a firm made up of unrelated businesses. Also it is hard to imagine how one of the businesses could be placed under an unrelated business meaningfully in a hierarchy. Unable to use these organizational remedies effectively, one would expect a diversified integrated firm to use rigidity more than a focused integrated firm. In addition, the rigid portion of the capital budget can be interpreted naturally as a spending limit up to which the firm delegates spending decisions to the manager. Then one would expect to see more widespread use of spending limits in diversified integrated firms relative to focused integrated firms. From an empirical perspective, Hypothesis 2 provides a more stringent test of the model by using an observed variation in the composition of integrated firms.

Hypothesis 3 provides an interesting test of the relevance of specialized knowledge. While it is not a formal prediction of the model, the underlying assumption for it is fairly simple. Top decision makers, who are human beings, have limited cerebral and sensory capabilities (Simon, 1955). This imperfection means that their capacity to acquire specialized knowledge is limited. Faced with such a constraint, it would be only optimal to ration cerebral capacity and use it on areas and topics where the returns are the highest. In the context of this paper, that area and topic would be the larger segments of the firm to which a significant portion of the corporation's resources is committed. And as a result, the degree of informational asymmetry at higher levels of management would be relatively less for the larger segments than for the smaller segments.

With a slight modification, the model can also generate testable predictions regarding the effect of firm-level capital constraints on corporate investment behavior. For example, if corporate resources were not fixed and instead the firm could raise additional financing following an especially good set of reports from some of its managers, then managers with bad projects would have less of a need to exaggerate the quality of their projects to obtain resources. In the case of no external financing frictions, say probability one of raising additional funds, managers with bad projects would not be concerned that competing projects are potentially better than theirs, and so they would not exaggerate and the firm would not have to use rigidity to improve communication.[29]

As a final note, these hypotheses should not be interpreted as though integration brings with it only trouble and is always problematic, as sometimes have been argued in the conglomerate discount literature. There is no doubt that, by their very nature, integrated environments render the task of providing good incentives complex and difficult. But integration can also create opportunity and the ideas here show how firms can use organizational design to mitigate these problems.

7 Conclusion

This paper develops a model of internal competition for resources and shows that increased levels of integration can worsen the quality of strategic communication that is vital to allocating resources.

[29] To retain a role for reputation building through endogenous truth-telling for this case, one could relax the model's assumption about managers being perfectly informed about their projects and instead assume that some managers receive more precise signals about the quality of their projects than others.

The paper also shows that organizational remedies, such as rigidity in capital budgeting, rotation of managers, centralization and hierarchies, can be viewed as indirect attempts by a lesser informed headquarters to influence managerial behavior and thereby increase allocative efficiency.

The model abstracts from costly auditing and incentive contracting approaches that have been studied extensively in previous work. Instead, the paper explores the idea that reputation can provide powerful managerial incentives for truthful reporting in the resource allocation process when costly auditing and incentive contracting are not effective, and that these incentives can be harnessed usefully through organizational design. Projects that involve significant amount of proprietary and specific knowledge, and are long-term in nature, as in R&D intensive industries with long lags from project conception to completion, would best fit the model.

The model has rich organizational implications. For instance, it predicts the capital budgets of integrated firms to be more rigid than the capital budgets of nonintegrated firms. Moreover, it predicts such rigidity to be more pronounced in diversified integrated firms that operate in unrelated lines of business. Ozbas (2003) tests these predictions and finds supportive evidence.

One could extend the model to study corporate life-cycle questions related to growth and exit raised in Jensen (1993). For example, why do firms have more difficulty downsizing later in their lives than growing in their formative years? In a corporate environment where future opportunities are projected to decline, managers would choose to make exaggerated statements, knowing full well that the subsequent loss of future resources due to a damaged reputation is minimal. Of course, the opposite dynamics would play out in the case of growth. Moreover, the firm's present and future amount of resources could be endogenized as in Stein (1997) and Stein (2002) to explore the role of firm-level reputation in relaxing external credit constraints. As discussed earlier, another fruitful extension would be to explore firms as communication networks and address more precise hierarchy design questions that have been posed by the team-theoretic literature, which has so far left out real-world issues pertaining to asymmetric information that this model captures.

There appears to be ample opportunity for productive cross-fertilization between finance and organizational economics. More extensive data on organizational structure and personnel policies as in Rajan and Wulf (2003) would be useful for testing the paper's predictions about the impact of organizational processes and structure on the allocation of resources. It is somewhat disappointing that there has not been any significant amount of clinical research on these issues since the seminal work of Bower (1970). Such analyses would contribute tremendously to our understanding of the nature of the firm.

References

[1] Aghion, Philippe and Jean Tirole. 1997. Formal and Real Authority in Organizations. Journal of Political Economy 105:1-29.

[2] Alchian, Armen and Harold Demsetz. 1972. Production, Information Costs, and Economic Organization. American Economic Review 62:777-95.

[3] Aron, Debra. 1988. Ability, Moral Hazard, Firm Size and Diversification. Rand Journal of Economics 19:72-87.

[4] Baker, George, Robert Gibbons, and Kevin J. Murphy. 1999. Informal Authority in Organizations. Journal of Law, Economics, and Organization 15:56-73.

[5] Baker, George, Robert Gibbons, and Kevin J. Murphy. 2001. Bringing the Market Inside the Firm? American Economic Review Papers and Proceedings 91:212-18.

[6] Baker, George, Robert Gibbons, and Kevin J. Murphy. 2002. Relational Contracts and the Theory of the Firm. Quarterly Journal of Economics 117:39-83.

[7] Berkovitch, Elazar, Ronen Israel and Efrat Tolkowsky. 2000. The Boundaries of the Firm: The Choice Between Stand-Alone and Integrated Firms. Unpublished manuscript, Interdisciplinary Center Herzliya (IDC).

[8] Bernardo, Antonio E., Hongbin Cai and Jiang Luo. 2001. Capital Budgeting and Compensation with Asymmetric Information and Moral Hazard. Journal of Financial Economics 61:311-344.

[9] Bolton, Patrick and Mathias Dewatripont. 1994. The Firm as a Communication Network. Quarterly Journal of Economics 109:809-39.

[10] Bolton, Patrick and David Scharfstein. 1998. Corporate Finance, the Theory of the Firm, and Organizations. Journal of Economic Perspectives 12:95-114.

[11] Bower, Joseph. 1970. Managing the Resource Allocation Process. Harvard Business School Press.

[12] Bulow, Jeremy and John Roberts. 1989. The Simple Economics of Optimal Auctions. Journal of Political Economy 97:1060-90.

[13] Brusco, Sandro and Fausto Panunzi. 2000. Reallocation of Corporate Resources and Managerial Incentives in Internal Capital Markets. CEPR Discussion Paper.

[14] Cho, In-Koo and David M. Kreps. 1987. Signalling Games and Stable Equilibria. Quarterly Journal of Economics 102:179-221.

[15] Coase, Ronald. 1937. The Nature of the Firm. Economica 4:386-405.

[16] Chandler, Alfred. 1962. Strategy and Structure. Cambridge, MA: MIT Press.

[17] Crawford, Vincent P. and Joel Sobel. 1982. Strategic Information Transmission. Econometrica 50:1431-51.

[18] Crozier, Michel. 1964. The Bureaucratic Phenomenon. Chicago: University of Chicago Press.

[19] Dessein, Wouter. 2002. Authority and Communication in Organizations. Review of Economics Studies 69:811-838.

[20] Garicano, Luis. 2000. Hierarchies and the Organization of Knowledge in Production. Journal of Political Economy 108:874-904.

[21] Gertner, Robert, David Scharfstein, and Jeremy Stein. 1994. Internal Versus External Capital Markets. Quarterly Journal of Economics 109:1211-1230.

[22] Gromb, Denis and David Scharfstein. 2001. A Model of Entrepreneurial Activity. Unpublished manuscript, London Business School and Harvard Business School.

[23] Grossman, Sanford and Oliver Hart, 1986. The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration. Journal of Political Economy 94:691-719.

[24] Harris, Milton and Arthur Raviv. 1996. The Capital Budgeting Process: Incentives and Information. Journal of Finance 51:1139-74.

[25] Harris, Milton and Arthur Raviv. 1998. Capital Budgeting and Delegation. Journal of Financial Economics 50:259-289.

[26] Harris, Milton and Arthur Raviv. 2002. Allocation of Decision-Making Authority. Unpublished manuscript, University of Chicago.

[27] Hart, Oliver and John Moore. 1990. Property Rights and the Nature of the Firm. Journal of Political Economy 98:1119-1158.

[28] Hart, Oliver and John Moore. 1999. Foundations of Incomplete Contracts. Review of Economic Studies 66:115-138.

[29] Hayek, Friedrich A. 1945. The Use of Knowledge in Society. American Economic Review 35.

[30] Holmström, Bengt. 1982. Managerial Incentive Problems: A Dynamic Perspective. Republished in Review of Economic Studies 66:169-82 (1999).

[31] Holmström, Bengt. 1999. The Firm as a Subeconomy. Journal of Law, Economics, and Organization 15:74-102.

[32] Holmström, Bengt and Joan Ricart i Costa. 1986. Managerial Incentives and Capital Management. Quarterly Journal of Economics 101:835-860.

[33] Jensen, Michael C. 1993. The Modern Industrial Revolution, Exit, and the Failure of Internal Control Systems. Journal of Finance 48:831-880.

[34] Jensen, Michael C. 2001. Paying People to Lie: The Truth About the Budgeting Process. Unpublished manuscript, The Monitor Group and Harvard Business School.

[35] Klein, Benjamin, Robert Crawford, and Armen Alchian. 1978. Vertical Integration, Appropriable Rents, and the Competitive Contracting Process. Journal of Law and Economics 21:297-326.

[36] Lazear, Edward, and Sherwin Rosen. 1981. Rank-Order Tournaments as Optimum Labor Contracts. Journal of Political Economy 89:841-64.

[37] Maksimovic, Vojislav and Gordon Phillips. 2002. Do Conglomerate Firms Allocate Resources Inefficiently Across Industries? Theory and Evidence. Journal of Finance 57:721-67.

[38] Marino, Anthony M. and John G. Matsusaka. 2003. Decision Processes, Agency Problems, and Information: An Economic Analysis of Budget Procedures. Forthcoming in Review of Financial Studies.

[39] Matsusaka, John. 2001. Corporate Diversification, Value Maximization, and Organizational Capabilities. Journal of Business 74:409-31.

[40] Milgrom, Paul. 1988. Employment Contracts, Influence Activities and Organization Design. Journal of Political Economy 96:42-60.

[41] Milgrom, Paul and John Roberts. 1988. An Economic Approach to Influence Activities in Organizations. American Journal of Sociology 94:S154-S179.

[42] Mullainathan, Sendhil, and David Scharfstein. 2001. Do Firm Boundaries Matter? American Economic Review Papers and Proceedings 91:195-99.

[43] Ozbas, Oguzhan. 2003. Integration and Corporate Investment: Empirical Evidence on Rigid Capital Budgets. Working paper, USC.

[44] Radner, Roy. 1993. The Organization of Decentralized Information Processing. Econometrica 61:1109-46.

[45] Rajan, Raghuram and Julie Wulf. The Flattening Firm: Evidence from Panel Data on the Changing Nature of Corporate Hierarchies. Unpublished manuscript, University of Chicago and University of Pennsylvania.

[46] Rajan, Raghuram, Henri Servaes, and Luigi Zingales. 2000. The Cost of Diversity: The Diversification Discount and Inefficient Investment. Journal of Finance 55:35-80.

[47] Sah, Raj, and Joseph Stiglitz. 1986. The Architecture of Economic Systems: Hierarchies and Polyarchies. American Economic Review 76:716-27.

[48] Scharfstein, David, and Jeremy Stein. 2000. The Dark Side of Internal Capital Markets: Divisional Rent-Seeking and Inefficient Investment. Journal of Finance 55:2537-64.

[49] Simon, Herbert A. 1945. Administrative Behavior. Fourth Edition 1997. Free Press.

[50] Simon, Herbert A. 1955. A Behavioral Model of Rational Choice. Quarterly Journal of Economics 69:99-118.

[51] Stein, Jeremy. 1997. Internal Capital Markets and the Competition for Corporate Resources. Journal of Finance 52:111-33.

[52] Stein, Jeremy. 2002. Information Production and Capital Allocation: Decentralized versus Hierarchical Firms. Journal of Finance 57:1891-1921.

[53] Williamson, Oliver. 1975. Markets and Hierarchies: Analysis and Antitrust Implications. Free Press.

[54] Williamson, Oliver. 1985. The Economic Institutions of Capitalism. Free Press.

A Appendix

A.1 Proof of Propositions

Proof of Proposition 1 (Uniqueness). I first identify the possible equilibria and then show that only one of them meets the Cho-Kreps intuitive criterion.

The redundancy of period-2 competition helps to reduce the search for potential equilibria to period-1 strategies. With three types and three period-1 strategies (pure h, pure l, and mixing), there are 27 potential equilibria to check [3 (type-A) $\times$ 3 (type-B) $\times$ 3 (type-C)].

Noting that there can be no equilibrium in which type-A managers announce l in period 1 (in mixing or pure strategies) further cuts down the number of potential equilibria to nine [1 (type-A) $\times$ 3 (type-B) $\times$ 3 (type-C)]. To prove this by contradiction, assume that announcing l in period 1 is a best response. Since announcing l instead of h reduces period-1 funding with certainty, it must have a period-2 benefit. But the posterior for a type-A manager is the same regardless of what he states in period 1 – an R_H outcome in period 1 perfectly reveals him as a type-A manager. With a constant posterior, there can be no period-2 benefit, hence the contradiction. Similarly, there can be no equilibrium in which type-B managers announce h and type-C managers get revealed perfectly by announcing l in mixing or pure strategies. Without a period-2 benefit, announcing l in period 1 can never be a best response.

Using Proposition 1, one can also rule out the equilibrium where type-C managers announce h and type-B managers announce l in mixing strategies – remember announcing l is a best response for type-B managers. For the same reason, one can also rule out equilibria where type-B managers announce l and type-C managers announce l in mixing or pure strategies – remember announcing h is a best response for type-C managers despite being revealed as bad. With five equilibria eliminated, there are only four potential equilibria left to check.

Assume that type-B managers mix (announce h with probability α and l with probability $1-\alpha$) in period 1. Can announcing l be a best response for type-C managers?

Payoff to a type-C manager from announcing l in period 1 is

$$(1-\beta)\left[\frac{1}{2}KR_L+\frac{1}{2}\delta KR_L\right]+\beta\left[\mu\,(0+0)+(1-\mu)\left(\alpha\,[0+0]+(1-\alpha)\left[\frac{1}{2}KR_L+\frac{1}{2}\delta KR_L\right]\right)\right]$$

Payoff to a type-C manager from announcing h in period 1 is

$$(1-\beta)\,[KR_L+\delta KR_L]+\beta\left[\mu\left(\frac{1}{2}KR_L+0\right)+(1-\mu)\left(\alpha\left[\frac{1}{2}KR_L+\frac{1}{2}\delta KR_L\right]+(1-\alpha)\,[KR_L+\delta KR_L]\right)\right]$$

Announcing h clearly dominates announcing l for a type-C manager. Therefore, the conjecture cannot be an equilibrium.

Finally consider the equilibrium in which both type-B and type-C managers mix with probabilities α and γ, respectively. Depending on parameter values, there are two cases: (i) $P(g \mid h, R_L) > P(g \mid l, R_L)$, and (ii) $P(g \mid h, R_L) < P(g \mid l, R_L)$.

If $P(g \mid h, R_L) > P(g \mid l, R_L)$, payoff to a type-C manager from announcing l in period 1 is

$$(1-\beta)\left[\gamma(0+0)+(1-\gamma)\left(\frac{1}{2}KR_L+\frac{1}{2}\delta KR_L\right)\right]$$
$$+\beta\left[\mu(0+0)+(1-\mu)\left(\alpha[0+0]+(1-\alpha)\left[\frac{1}{2}KR_L+\frac{1}{2}\delta KR_L\right]\right)\right]$$

Payoff to a type-C manager from announcing h in period 1 is

$$(1-\beta)\left[\gamma\left(\frac{1}{2}KR_L+\frac{1}{2}\delta KR_L\right)+(1-\gamma)(KR_L+\delta KR_L)\right]$$
$$+\beta\left[\mu\left(\frac{1}{2}KR_L+0\right)+(1-\mu)\left(\alpha\left[\frac{1}{2}KR_L+\frac{1}{2}\delta KR_L\right]+(1-\alpha)[KR_L+\delta KR_L]\right)\right]$$

Announcing h clearly dominates announcing l for a type-C manager. Therefore, the conjecture cannot be an equilibrium.

If $P(g \mid h, R_L) < P(g \mid l, R_L)$, payoff to a type-C manager from announcing l in period 1 is

$$(1-\beta)\left[\gamma(0+\delta KR_L)+(1-\gamma)\left(\frac{1}{2}KR_L+\frac{1}{2}\delta KR_L\right)\right]$$
$$+\beta\left[\mu(0+0)+(1-\mu)\left(\alpha[0+\delta KR_L]+(1-\alpha)\left[\frac{1}{2}KR_L+\frac{1}{2}\delta KR_L\right]\right)\right]$$

Payoff to a type-C manager from announcing h in period 1 is

$$(1-\beta)\left[\gamma\left(\frac{1}{2}KR_L+\frac{1}{2}\delta KR_L\right)+(1-\gamma)(KR_L+0)\right]$$
$$+\beta\left[\mu\left(\frac{1}{2}KR_L+0\right)+(1-\mu)\left(\alpha\left[\frac{1}{2}KR_L+\frac{1}{2}\delta KR_L\right]+(1-\alpha)[KR_L+0]\right)\right]$$

Announcing h clearly dominates announcing l for a type-C manager. Therefore, the conjecture cannot be an equilibrium.

The only two potential equilibria left are the equilibrium identified in Proposition 1 and the pooling equilibrium where every type of manager announces h. However, to make this last possibility work as an equilibrium, the off-equilibrium belief $P(g \mid l, R_L)$ must be set at less than $P(g \mid h, R_L)$. Otherwise, announcing l may prove to be a profitable deviation for type-B managers – depending on how strong their reputational concerns are. At any rate, type-B managers can always force a separation from type-C managers by making a credible speech in the sense of Cho-Kreps and improve to the equilibrium identified in Proposition 1 where type-B managers are no longer mistaken as bad managers.■

Proof of Proposition 2. Type-B managers may lose their patience and start to exaggerate in period 1 just like type-C managers when there are three managers competing. To see this point, compare the payoff of type-B managers from announcing l to the payoff from announcing h in period 1 assuming the equilibrium identified in Proposition 1 for two managers.

When there are three managers, payoff to a type-B manager from announcing l in period 1 is

$$\begin{aligned}&(1-\beta)^2\left[0+\delta KR_E\right]+2\beta(1-\beta)\left[\mu\left(0+\frac{1}{2}\delta KR_E\right)+(1-\mu)\left(0+\frac{1}{2}\delta KR_E\right)\right]\\&+\beta^2\left[\mu^2\left(0+\frac{1}{3}\delta KR_E\right)+2\mu(1-\mu)\left(0+\frac{1}{3}\delta KR_E\right)+(1-\mu)^2\left(\frac{1}{3}KR_L+\frac{1}{3}\delta KR_E\right)\right]\end{aligned}$$

Payoff to a type-B manager from deviating and announcing h in period 1 is

$$\begin{aligned}&(1-\beta)^2\left[\frac{1}{3}KR_L+\frac{1}{3}\delta KR_E\right]+2\beta(1-\beta)\left[\mu\left(\frac{1}{3}KR_L+0\right)+(1-\mu)\left(\frac{1}{2}KR_L+0\right)\right]\\&+\beta^2\left[\mu^2\left(\frac{1}{3}KR_L+0\right)+2\mu(1-\mu)\left(\frac{1}{2}KR_L+0\right)+(1-\mu)^2\left(KR_L+0\right)\right]\end{aligned}$$

The difference is

$$\begin{aligned}&(1-\beta)^2\left[\frac{2}{3}\delta KR_E-\frac{1}{3}KR_L\right]+2\beta(1-\beta)\left[\mu\left(\frac{1}{2}\delta KR_E-\frac{1}{3}KR_L\right)+(1-\mu)\left(\frac{1}{2}\delta KR_E-\frac{1}{2}KR_L\right)\right]\\&+\beta^2\left[\mu^2\left(\frac{1}{3}\delta KR_E-\frac{1}{3}KR_L\right)+2\mu(1-\mu)\left(\frac{1}{3}\delta KR_E-\frac{1}{2}KR_L\right)+(1-\mu)^2\left(\frac{1}{3}\delta KR_E-\frac{2}{3}KR_L\right)\right]\\=\;&\frac{1}{3}KR_L\left[2g-1-\beta(1-\mu+g)\right]\end{aligned}$$

The difference is positive and announcing l dominates announcing h for a type-B manager for a range of parameter values, but not always. Specifically, the difference is positive only if $\beta<\frac{2g-1}{1-\mu+g}$, that is, when the probability of facing tough competition is low.

For tougher internal competition $\left(\beta>\frac{2g-1}{1-\mu+g}\right)$, type-B managers start to exaggerate in period 1. Specifically, conjecture an equilibrium in which type-B managers exaggerate with a mixing probability α in period 1. Given the conjectured BPNE, type-B managers may or may not fail to attain their stated targets in period 1. A high project outcome in period 1 reveals that the manager is a type-A manager. Therefore, the posterior beliefs after observing the statements and project results in period 1 are $P(g\mid h,R_H)=1$, $P(g\mid h,R_L)=\frac{\alpha\beta(1-\mu)}{\alpha\beta(1-\mu)+(1-\beta)}$, $P(g\mid l,R_H)=1$, and $P(g\mid l,R_L)=1$.

These posterior beliefs determine eligibility for period 2. Lemma 1 summarizes the optimal period-2 strategy. Payoff to a type-B manager from announcing l in period 1 is

$$\begin{aligned}
&(1-\beta)^2\left[0+\delta K R_E\right] \\
&+2\beta(1-\beta)\left[\mu\left(0+\frac{1}{2}\delta K R_E\right)+(1-\mu)\alpha(0+\delta K R_E)+(1-\mu)(1-\alpha)\left(0+\frac{1}{2}\delta K R_E\right)\right] \\
&+\beta^2\left[\begin{array}{c}
\mu^2\left(0+\frac{1}{3}\delta K R_E\right)+2\mu(1-\mu)\alpha\left(0+\frac{1}{2}\delta K R_E\right) \\
+2\mu(1-\mu)(1-\alpha)\left(0+\frac{1}{3}\delta K R_E\right)+(1-\mu)^2\alpha^2(0+\delta K R_E) \\
+(1-\mu)^2 2\alpha(1-\alpha)\left(0+\frac{1}{2}\delta K R_E\right)+(1-\mu)^2(1-\alpha)^2\left(\frac{1}{3}K R_L+\frac{1}{3}\delta K R_E\right)
\end{array}\right]
\end{aligned}$$

Payoff to a type-B manager from announcing h in period 1 is

$$\begin{aligned}
&(1-\beta)^2\left[\frac{1}{3}K R_L+\frac{1}{3}\delta K R_E\right] \\
&+2\beta(1-\beta)\left[\mu\left(\frac{1}{3}K R_L+0\right)+(1-\mu)\alpha\left(\frac{1}{3}K R_L+\frac{1}{3}\delta K R_E\right)+(1-\mu)(1-\alpha)\left(\frac{1}{2}K R_L+0\right)\right] \\
&+\beta^2\left[\begin{array}{c}
\mu^2\left(\frac{1}{3}K R_L+0\right)+2\mu(1-\mu)\alpha\left(\frac{1}{3}K R_L+0\right) \\
+2\mu(1-\mu)(1-\alpha)\left(\frac{1}{2}K R_L+0\right)+(1-\mu)^2\alpha^2\left(\frac{1}{3}K R_L+\frac{1}{3}\delta K R_E\right) \\
+(1-\mu)^2 2\alpha(1-\alpha)\left(\frac{1}{2}K R_L+0\right)+(1-\mu)^2(1-\alpha)^2(K R_L+0)
\end{array}\right]
\end{aligned}$$

Set the two payoffs equal to each other for the mixing strategy and solve for α

$$\alpha=\frac{1-2g+\beta(1-\mu+g)}{(1+g)\beta(1-\mu)}$$

For α to be a proper mixing probability, (i) $\beta>\frac{2g-1}{1-\mu+g}$ and (ii) $\mu<2-g$.■

Proof of Proposition 3. Type-B managers may lose their patience and start to exaggerate in period 1 just like type-C managers when n is large enough. To see this point, compare the payoff of type-B managers from announcing l to the payoff from announcing h in period 1, assuming the equilibrium identified in Proposition 1 for two managers. Note that for n large enough, one can use the population form instead of having to consider all possible sample outcomes separately.

Payoff to a type-B manager from announcing l in period 1 is

$$0\cdot R_L+\delta\frac{K}{n(\beta\mu+\beta(1-\mu))}R_E$$

Payoff to a type-B manager from deviating and announcing h in period 1 is

$$\frac{K}{n(\beta\mu+(1-\beta))}R_L+\delta\cdot 0\cdot R_E$$

The difference is

$$=\frac{K}{n}R_L\left[\frac{g}{\beta}-\frac{1}{\beta\mu+(1-\beta)}\right]$$

The difference is positive and announcing l dominates announcing h for a type-B manager for a range of parameter values, but not always. Specifically, the difference is positive only if $\beta < \frac{g}{1+g(1-\mu)}$, that is, when the probability of facing tough competition is low.

Under tougher internal competition $\left(\beta > \frac{g}{1+g(1-\mu)}\right)$, type-B managers start to exaggerate in period 1. Specifically, conjecture an equilibrium in which type-B managers exaggerate with a mixing probability α in period 1. Given the conjectured BPNE, posterior beliefs after observing the statements and project results in period 1 are as in the mixing equilibrium studied previously.

Payoff to a type-B manager from announcing l in period 1 is

$$0 \cdot R_L + \delta \frac{K}{n\left(\beta\mu + (1-\alpha)\beta(1-\mu)\right)} R_E$$

Payoff to a type-B manager from deviating and announcing h in period 1 is

$$\frac{K}{n\left(\beta\mu + (1-\beta) + \alpha\beta(1-\mu)\right)} R_L + \delta \cdot 0 \cdot R_E$$

Set the two payoffs equal to each other for the mixing strategy and solve for α

$$\alpha = \frac{\beta - g\left(1 - \beta(1-\mu)\right)}{(1+g)\beta(1-\mu)}$$

For α to be a proper mixing probability, (i) $\beta > \frac{g}{1+g(1-\mu)}$ and (ii) $\mu < \frac{1}{g}$.■

Proof of Proposition 4. For n large enough, $\beta > \frac{g}{1+g(1-\mu)}$ and $\mu < \frac{1}{g}$, type-B managers exaggerate with a mixing probability α in period 1.

$$\begin{aligned} A_{nI}^{SB} &= \frac{K}{\left(\beta\mu + (1-\beta) + \alpha\beta(1-\mu)\right)}\left(\beta\mu R_H + (1-\beta)R_L + \alpha\beta(1-\mu)R_L\right) \\ &\quad + \delta \frac{K}{\left(\beta\mu + (1-\alpha)\beta(1-\mu)\right)}\left(\beta\mu R_E + (1-\alpha)\beta(1-\mu)R_E\right) \end{aligned}$$

Substitute $\alpha = \frac{\beta - g(1-\beta(1-\mu))}{(1+g)\beta(1-\mu)}$ and $\delta = \frac{gR_L}{R_E}$, $A_{nI}^{SB} < A_{2I}^{SB}$ for $g < \frac{\beta^2(1+\beta\mu(1-\mu))R_E}{\beta R_E + (1-\beta)^2(1+\beta\mu)R_L} \equiv g^*$.■

Proof of Proposition 5. Given the conjectured BPNE, every manager attains his stated target in period 1. A high project outcome in period 1 reveals that the manager is type-A. The posterior beliefs after observing the statements and project results in period 1 are $P(g \mid h, R_H) = 1$, $P(g \mid h, R_L) = 0$ (out of equilibrium), $P(g \mid l, R_H) = 1$ (out of equilibrium), and $P(g \mid l, R_L) = \frac{\beta(1-\mu)}{\beta(1-\mu)+(1-\beta)}$.

These posterior beliefs determine eligibility for period 2. Lemma 1 summarizes the optimal period-2 strategy. Let ν denote the contingent share of the capital budget. A type-A manager has nothing to benefit from announcing l. He has a good project and announcing h dominates announcing l.

Payoff to a type-B manager from announcing l in period 1 is

$$\begin{aligned}&(1-\nu)\left[\frac{1}{2}K\left(R_L+(1-\beta\mu)\,\delta R_E\right)\right]\\&+\nu\left[(1-\beta)\left(\frac{1}{2}KR_L+\frac{1}{2}\delta KR_E\right)+\beta\left(\mu\,[0+0]+(1-\mu)\left[\frac{1}{2}KR_L+\frac{1}{2}\delta KR_E\right]\right)\right]\end{aligned}$$

Payoff to a type-B manager from announcing h in period 1 is

$$(1-\nu)\left[\frac{1}{2}KR_L+0\right]+\nu\left[(1-\beta)\left(KR_L+0\right)+\beta\left(\mu\left[\frac{1}{2}KR_L+0\right]+(1-\mu)\left[KR_L+0\right]\right)\right]$$

The difference is

$$\frac{1}{2}K\left[(1-\beta\mu)\,\delta R_E-\nu R_L\right]$$

Since the contingent portion of the capital budget ν is less than $(1-\beta\mu)\,\delta$, the difference is positive and announcing l dominates announcing h for a type-B manager.

Payoff to a type-C manager from announcing l in period 1 is

$$\begin{aligned}&(1-\nu)\left[\frac{1}{2}\left(1+(1-\beta\mu)\,\delta\right)KR_L\right]\\&+\nu\left[(1-\beta)\left(\frac{1}{2}KR_L+\frac{1}{2}\delta KR_L\right)+\beta\left(\mu\,[0+0]+(1-\mu)\left[\frac{1}{2}KR_L+\frac{1}{2}\delta KR_L\right]\right)\right]\end{aligned}$$

Payoff to a type-C manager from announcing h in period 1 is

$$(1-\nu)\left[\frac{1}{2}KR_L+0\right]+\nu\left[(1-\beta)\left(KR_L+0\right)+\beta\left(\mu\left[\frac{1}{2}KR_L+0\right]+(1-\mu)\left[KR_L+0\right]\right)\right]$$

The difference is

$$\frac{1}{2}KR_L\left[(1-\beta\mu)\,\delta-\nu\right]$$

Since the contingent portion of the capital budget ν is less than $(1-\beta\mu)\,\delta$, the difference is positive and announcing l dominates announcing h for a type-C manager.■

Proof of Proposition 6. Substitute $(1-\beta\mu)\,\delta$ for ν.

$$K\beta\mu\left[\delta\,(1-\beta\mu)^2-(1-\mu)\left(\beta+\delta\,(1-\beta)\right)\right](R_H-R_L)$$

The difference is positive for

$$\delta\left[(1-\beta\mu)^2-(1-\beta)\,(1-\mu)\right]>\beta\,(1-\mu)$$

Note that $(1-\beta\mu)^2-(1-\beta)\,(1-\mu)>0$. Therefore, the difference is positive for

$$\delta>\frac{\beta\,(1-\mu)}{(1-\beta\mu)^2-(1-\beta)\,(1-\mu)}\equiv\delta^*$$

δ^* is less than 1 for $(1-\beta\mu)^2 - (1-\mu) > 0$. Solving for the inequality, $\beta < \frac{1-\sqrt{1-\mu}}{\mu}$. Using L'Hôpital's rule, note that $\frac{1-\sqrt{1-\mu}}{\mu} \to \frac{1}{2}$ as $\mu \to 0$.■

Proof of Proposition 7. Posterior beliefs and eligibility for period 2 are the same as in the case of rigid capital budgets. Let p denote the probability of job rotation in period 2. A type-A manager has nothing to benefit from announcing l. He has a good project and announcing h dominates announcing l.

Payoff to a type-C manager from announcing l in period 1 is

$$(1-\beta)\left[\frac{1}{2}KR_L + \delta\frac{1}{2}KR_L\right] + \beta\left[\mu\left(\delta pKR_E\right) + (1-\mu)\left(\frac{1}{2}KR_L + \frac{1}{2}\delta\left[p\left(\frac{1}{2}KR_E\right) + (1-p)\left(\frac{1}{2}KR_L\right)\right]\right)\right]$$

Payoff to a type-C manager from announcing h in period 1 is

$$(1-\beta)\left[KR_L + 0\right] + \beta\left[\mu\left(\frac{1}{2}KR_L + 0\right) + (1-\mu)\left(KR_L + 0\right)\right]$$

The difference is positive for

$$p > \frac{\left(1-\delta\left(1-\beta\mu\right)\right)R_L}{\beta\delta\left(\left(1+\mu\right)R_E - \left(1-\mu\right)R_L\right)} \equiv \underline{p}$$

Payoff to a type-B manager from announcing l in period 1 is

$$(1-\beta)\left[\frac{1}{2}KR_L + \delta\left(p\left[\frac{1}{2}KR_L\right] + (1-p)\left[\frac{1}{2}KR_E\right]\right)\right] + \beta\left[\mu\left(\delta pKR_E\right) + (1-\mu)\left(\frac{1}{2}KR_L + \frac{1}{2}\delta KR_E\right)\right]$$

Note that this payoff is greater than that of a type-C manager by

$$\frac{1}{2}\delta K\left(1-p\right)\left(1-\beta\mu\right)\left(R_E - R_L\right)$$

Since the payoff to a type-B manager from announcing h in period 1 is the same as the payoff to a type-C manager, any p that works for a type-C manager would also work for a type-B manager. Note that $A_{2I}^{Rot} - A_{2I}^{SB} = K\beta\left(1-\beta\right)\mu\left(1-\delta\left(1-\mu\right)\right)\left(R_H - R_L\right) > 0$.

Finally, for $\underline{p}$ to be a proper probability, $\delta > \frac{R_L}{\beta(1+\mu)R_E + (1-\beta)R_L} \equiv \delta^{**}$.■

Proof of Proposition 8. Posterior beliefs and eligibility for period 2 are the same as in the case of rigid capital budgets. Note that every manager with some positive probability of being a good manager would be allowed to make a statement in period 2 since every manager is conjectured to report the true type of his project.

The binding constraint, across types and time, would be to induce a manager with a bad project in period 2 to tell the true type of his project when facing a type-A manager who has stated h and delivered R_H in period 1.

$$\mu\left[0\right] + (1-\mu)\left[\frac{1}{2}KR_L\right] > \mu\left[\frac{1}{2}KR_L\left(1-\theta\right)\right] + (1-\mu)\left[KR_L\left(1-\theta\right)\right]$$

Simplifying the expression yields $\theta > \frac{1}{2-\mu} \equiv \underline{\theta}$. ■

A.2 n-Manager Competition

This section characterizes the mixing probability of type-B managers for the case of n managers and presents some numerical results. In what follows, subscripts i, j, and k denote the number of type-A or type-B agents out of $n-1$ competing agents, the number of type-B agents out of i, and the number of type-B agents announcing h out of j, respectively.

Payoff to a type-B manager from announcing l in period 1 is

$$\sum_{i=0}^{n-1}\binom{n-1}{i}\beta^{i}(1-\beta)^{n-1-i}\sum_{j=0}^{i}\binom{i}{j}(1-\mu)^{j}\mu^{i-j}\sum_{k=0}^{j}\binom{j}{k}\alpha^{k}(1-\alpha)^{j-k}\left[u(i,j,k,l)\right]$$

where

$$\begin{aligned} u(i,j,k,l) &= \frac{1}{n}KR_L+\frac{1}{i-k+1}\delta KR_E \quad \text{if } i=n-1,\ j=n-1, \text{ and } k=0 \\ &= 0+\frac{1}{i-k+1}\delta KR_E \quad \text{otherwise} \end{aligned}$$

Payoff to a type-B manager from announcing h in period 1 is

$$\sum_{i=0}^{n-1}\binom{n-1}{i}\beta^{i}(1-\beta)^{n-1-i}\sum_{j=0}^{i}\binom{i}{j}(1-\mu)^{j}\mu^{i-j}\sum_{k=0}^{j}\binom{j}{k}\alpha^{k}(1-\alpha)^{j-k}\left[u(i,j,k,h)\right]$$

where

$$\begin{aligned} u(i,j,k,h) &= \frac{1}{n-j+k}KR_L+\frac{1}{n}\delta KR_E \quad \text{if } i=j=k \\ &= \frac{1}{n-j+k}KR_L+0 \quad \text{otherwise} \end{aligned}$$

Without loss of generality, normalize $u(i,j,k,l)$ and $u(i,j,k,h)$ by KR_L, and then set the two payoffs equal to each other to find α. The result is a polynomial of order $n-2$.

$$\sum_{i=0}^{n-2}a_i^n\alpha^i=0$$

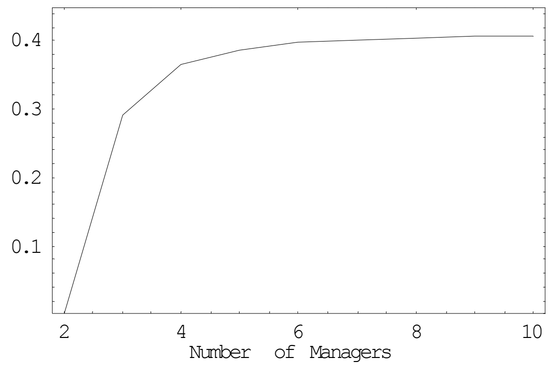
Polynomial coefficients are given by

$$a_i^n=\beta^i(1-\mu)^i\left(\sum_{j=0}^{n-2-i}\binom{i+j}{j}\beta^j\left((-1)^j\binom{n-1}{i+1+j}g-(-1)^i(1-\mu)^j\right)\right)$$

The polynomial has $n-2$ roots. Some of these roots are real and some of them are imaginary. But only one of the real roots is between 0 and 1. Numerical analysis shows that this real root increases as n increases.

$$\alpha'(n)>0$$

The following graph illustrates the monotonicity of $\alpha(n)$ for $\beta=.95$, $\mu=.05$, $g=1.25$.



Mixing Probability α

A.3 Incentive Contracts

In this section, I formalize the idea that incentive contracts necessary to improve communication can be prohibitively expensive. I do this by first conjecturing an equilibrium where every manager reports his true project type in both periods and then by specifying the least costly incentive contract that eliminates any profitable deviation from the conjectured equilibrium.

Let $\langle w_t \rangle$ be the incentive contract that specifies a payment at time t contingent on a manager's report and subsequent project outcome. As commonly assumed, limited liability requires each element of $\langle w_t \rangle$ to be positive.

Since the only profitable deviation for a manager in the model is to state that he has a good project when in fact he has a bad one, the least costly incentive contract reduces to a simple incentive contract in which a manager receives a strictly positive payment for reporting a bad project when he has a bad project and nothing otherwise. Let w_t be this payment at time t.

Two-Manager Case: Solving the model backwards, the payment necessary in period 2 to induce a manager to admit that he has a bad project, when facing another manager with a posterior probability p of being good, is

$$w_2 = (1-p)\left[KR_L - \frac{1}{2}KR_L\right] + p\left[\mu\left(\frac{1}{2}KR_L - 0\right) + (1-\mu)\left(KR_L - \frac{1}{2}KR_L\right)\right] = \frac{1}{2}KR_L$$

In period 1, the payment necessary to induce truthful reporting by a type-C manager is

$$\begin{aligned} w_1 &= (1-\beta)\left[KR_L - \frac{1}{2}KR_L - \frac{1}{2}\delta KR_L - \delta w_2\right] \\ &\quad +\beta\left[\begin{array}{c} \mu\left(\frac{1}{2}KR_L - 0 - \mu(0) - (1-\mu)\left(\frac{1}{2}\delta KR_L\right) - \delta w_2\right) \\ +(1-\mu)\left(KR_L - \frac{1}{2}KR_L - \mu(0) - (1-\mu)\left(\frac{1}{2}\delta KR_L\right) - \delta w_2\right) \end{array}\right] \\ &= \frac{1}{2}KR_L\left[1 - \delta\left(2 - \beta\mu\right)\right] \end{aligned}$$

Note that the payment necessary to induce honest communication from a type-B manager in period 1 is strictly lower than w_1 since, in contrast to a type-C manager, a type-B manager may have a better project idea in period 2. Also note that the limited liability constraint binds when $\delta > \frac{1}{2-\beta\mu}$. In that case, w_1 equals zero.

The expected cost of the incentive contract is $2\left(1-\beta\mu\right)\left[w_1+\delta w_2\right]$.

When $\delta \leq \frac{1}{2-\beta\mu}$,

$$E_w = K\left(1-\beta\mu\right)\left[1-\delta\left(1-\beta\mu\right)\right]R_L$$

When $\delta > \frac{1}{2-\beta\mu}$, $w_1 = 0$ and

$$E_w = K\left(1-\beta\mu\right)\delta R_L$$

For β and μ low enough, the expected cost approaches K, the firm's capital budget.■

Large n Case: Solving the model backwards for large n, the payment necessary in period 2 to induce a manager to admit that he has a bad project is

$$w_2 = \frac{KR_L}{n\beta\mu+1}$$

In period 1, the payment necessary to induce truthful reporting by a type-C manager is

$$w_1 = \frac{KR_L}{n\beta\mu+1} - \delta w_2$$

The expected cost of the incentive contract is

$$E_w = n\left(1-\beta\mu\right)\left[w_1+\delta w_2\right] \approx K\frac{\left(1-\beta\mu\right)}{\beta\mu}R_L$$

For β and μ low enough, the expected cost becomes prohibitively large. Interestingly enough, even if private benefits were not large so that the expected cost of the incentive contract was some $0 < \gamma \leq 1$ fraction of the expression above, the expected cost could still become prohibitively large under increased integration for low values of β and μ.■

A.4 Mechanism Design

This section adopts a mechanism design approach and uses the revelation principle to characterize the nature of optimal mechanisms in the basic model. I first start with the most general formulation and show that it can be reduced to a simpler problem when the two managers are ex-ante identical.

Let t_i be the type of manager $i \in \{1,2\}$ so $t_i \in T_i = \{\text{type-}A,\text{type-}B,\text{type-}C\}$ The general mechanism pre-specifies the amount of capital allocation to both managers in the event of a specific state s of t_i and $t_{\text{-}i}$ permutation. There are nine such permutations $[3\,(\text{manager-1}) \times 3\,(\text{manager-2})]$ so $s \in \{1,2,..,9\}$. Let $A_i\left(t_i,t_{\text{-}i},d\right)$ and $A_{\text{-}i}\left(t_i,t_{\text{-}i},d\right)$ denote capital allocations at date $d \in \{1,2\}$ in the event of state s of a t_i and $t_{\text{-}i}$ permutation. The mechanism optimizes over 36 variables $[2\,(\text{managers}) \times 9\,(\text{states}) \times 2\,(\text{dates})]$ – though in effect there are 18 variables since the model abstracts away from intertemporal experimenting and has the firm utilizing its resources K fully in both periods $\left(A\left(i,t_i,t_{\text{-}i},d\right) + A\left(\text{-}i,t_i,t_{\text{-}i},d\right) = K \;\forall t_i,t_{\text{-}i},d\right)$.

Incentive compatibility constraints (ICs) ensure truthful revelation for each i-t_i permutation. For example, for manager-1 of type-A, there are two ICs – it must be that announcing A dominates announcing B and C. More generally, there are six i-t_i permutations $[2\,(\text{managers}) \times 3\,(\text{types})]$ and hence 12 ICs $[2\,(\text{ICs}) \times 6\,(i - t_i \text{ permutations})]$. Since the model assumes that there are no better ex-ante employment opportunities, there are no participation constraints.

Finally, let $p_i\left(t_i\right)$ denote the probability of manager i being of type t_i, $C_{t_i}\left(i,A\right)$ the project cash flow from capital allocation A to manager i of type t_i, and δ the discount rate for period-2 payoffs.

I can now write the program.

$$\max_{\{A_i(t_i,t_{\text{-}i},d),A_{\text{-}i}(t_i,t_{\text{-}i},d)\}} \sum_{t_i}\sum_{t_{\text{-}i}}\sum_{d} p_i\left(t_i\right) p_{\text{-}i}\left(t_{\text{-}i}\right) \left(C_{t_i}\left(i,A_i\left(t_i,t_{\text{-}i},d\right)\right) + C_{t_{\text{-}i}}\left(\text{-}i,A_{\text{-}i}\left(t_i,t_{\text{-}i},d\right)\right)\right)\delta^{d-1}$$

$$s.t. \sum_{d}\sum_{t_{\text{-}i}} p_{\text{-}i}\left(t_{\text{-}i}\right)\left(C_{t_i}\left(i,A_i\left(t_i,t_{\text{-}i},d\right)\right) - C_{t_i}\left(i,A_i\left(m_i,t_{\text{-}i},d\right)\right)\right)\delta^{d-1} \geq 0 \quad \forall i,t_i \text{ and } m_i \in T_i/\left\{t_i\right\}$$

$$A_i\left(t_i,t_{\text{-}i},d\right) \geq 0 \quad \forall i,t_i,t_{\text{-}i},d$$

As mentioned earlier, the program is simpler when the two managers are ex-ante identical. There are six distinct states formed by the combination of t_i and $t_{\text{-}i}$ as opposed to the nine states formed by the permutation of t_i and $t_{\text{-}i}$. Let $s\left(t_i,t_{\text{-}i}\right)$ be the function mapping from managers' types t_i and $t_{\text{-}i}$ to the distinct state $s \in \{1,2,..,6\}$. For example $s\left(A,B\right) = s\left(B,A\right)$. Also let $A_i\left(s\left(t_i,t_{\text{-}i}\right),d\right)$ and $A_{\text{-}i}\left(s\left(t_i,t_{\text{-}i}\right),d\right)$ denote capital allocations at date $d \in \{1,2\}$ in the event of state $s\left(t_i,t_{\text{-}i}\right)$. The mechanism now optimizes over 24 variables $[2\,(\text{managers}) \times 6\,(\text{states}) \times 2\,(\text{dates})]$, though in effect there are 12 variables for the same reason as before. Also since $p_i\left(t\right) = p_{\text{-}i}\left(t\right)$

$\forall t \in \{\text{type-}A,\text{type-}B,\text{type-}C\}$ and the two managers have identical sets of ICs, the number of ICs goes down from twelve to six and $A_i(s(t_i, t_{\text{-}i}), d) = A_{\text{-}i}(s(t_i, t_{\text{-}i}), d) = \frac{1}{2}K \ \forall t_i = t_{\text{-}i}$.

Finally, let $p(s)$ denote the probability of state s. The program now is

$$\max_{\{A_i(s(t_i,t_{\text{-}i}),d),A_{\text{-}i}(s(t_i,t_{\text{-}i}),d)\}} \sum_s \sum_d p(s) \left(C_{t_i}(i, A_i(s(t_i, t_{\text{-}i}), d)) + C_{t_{\text{-}i}}(\text{-}i, A_{\text{-}i}(s(t_i, t_{\text{-}i}), d))\right) \delta^{d-1}$$

$$s.t. \sum_d \sum_{t_{\text{-}i}} p_{\text{-}i}(t_{\text{-}i}) \left(C_{t_i}(i, A_i(s(t_i, t_{\text{-}i}), d)) - C_{t_i}(i, A_i(s(m_i, t_{\text{-}i}), d))\right) \delta^{d-1} \geq 0 \quad \forall t_i \text{ and } m_i \in T_i / \{t_i\}$$

$$A_i(s(t_i, t_{\text{-}i}), d) \geq 0 \quad \forall i, s(t_i, t_{\text{-}i}), d$$

Solving the program for a range of parameter values of the basic model, it is easy to see that the optimal mechanism involves inefficient actions such as (i) allocating resources to a type-B manager in period 1 when there is a type-A manager, and (ii) allocating resources to a type-C manager in period 1 or 2 when there is a type-A manager. Here are a few examples where R_H and R_L satisfy the reputational condition (2) of the model (allocations are expressed as percentage of total).

State	$\{A,B\}$		$\{A,B\}$		$\{A,C\}$		$\{A,C\}$		$\{B,C\}$		$\{B,C\}$	
Period	$d=1$		$d=2$		$d=1$		$d=2$		$d=1$		$d=2$	
Manager	A	B	A	B	A	C	A	C	B	C	B	C
Case I	**0.59**	**0.41**	0.00	1.00	**0.59**	**0.41**	**0.00**	**1.00**	0.00	1.00	1.00	0.00
Case II	1.00	0.00	0.00	1.00	**0.95**	**0.05**	**0.00**	**1.00**	0.00	1.00	1.00	0.00
Case III	1.00	0.00	0.00	1.00	**0.55**	**0.45**	**0.00**	**1.00**	0.04	0.96	1.00	0.00
Case IV	1.00	0.00	0.00	1.00	**0.95**	**0.05**	**0.00**	**1.00**	0.00	1.00	1.00	0.00
Case V	1.00	0.00	0.00	1.00	**0.50**	**0.50**	**0.50**	**0.50**	0.00	1.00	1.00	0.00
Case VI	**0.99**	**0.01**	0.00	1.00	**0.99**	**0.01**	**0.00**	**1.00**	0.00	1.00	1.00	0.00
Case VII	1.00	0.00	0.00	1.00	**0.50**	**0.50**	**0.50**	**0.50**	0.00	1.00	1.00	0.00
Case VIII	1.00	0.00	0.00	1.00	**0.91**	**0.09**	**0.00**	**1.00**	0.37	0.63	1.00	0.00
EB	1.00	0.00	–	–	1.00	0.00	1.00	0.00	–	–	1.00	0.00

Case I: $\beta = 0.10, \mu = 0.10, \delta = 0.10$ Case II: $\beta = 0.10, \mu = 0.10, \delta = 0.90$

Case III: $\beta = 0.10, \mu = 0.90, \delta = 0.10$ Case IV: $\beta = 0.10, \mu = 0.90, \delta = 0.90$

Case V: $\beta = 0.90, \mu = 0.10, \delta = 0.10$ Case VI: $\beta = 0.90, \mu = 0.10, \delta = 0.90$

Case VII: $\beta = 0.90, \mu = 0.90, \delta = 0.10$ Case VIII: $\beta = 0.90, \mu = 0.90, \delta = 0.90$

EB is the efficient benchmark given truthful revelation and complete information.

Allocations that violate the efficient benchmark are in bold.