Integration, Organizational Processes and Allocation of Resources

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Abstract

This paper analyzes the effect of integration on the allocation of resources. I develop an equilibrium model of internal competition for corporate resources and show that managers of integrated firms exaggerate the quality of their projects to get funding. Moreover, I show that the problem gets worse with increased integration and puts an endogenous limit on the amount of value-enhancing redistribution that can be achieved in an integrated firm. I then argue that the control rights that come with asset ownership enable a firm to set "the rules of the game" and mitigate negative managerial behavior through organizational processes such as rigid capital budgets, job rotation, centralization and hierarchies. These results point to a comparative advantage that a firm has over other financial intermediaries in allocating resources.

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1 Introduction

Why do firms combine several projects? What is the effect of such integration on the allocation of resources? Do two firms acting independently allocate resources any differently than two firms integrated as one? These are important questions not only because the allocation of resources is a critical process by which an economy channels its scarce endowments to productive use, but also because integration plays a key role in how an economy organizes its methods of production.

The Coasian literature on integration[1] has explored primarily two issues, namely the problem of hold-up and transaction costs, as the fundamental forces determining the boundaries of the firm. The prevailing model of integration of Grossman, Hart and Moore takes asset ownership as a principal driver of incentives and envisions optimal assignment of assets among owner-managers as a way to understand integration. While the property rights approach has been useful in analyzing the determinants of vertical integration, both theoretically and empirically, it is unclear how one can broaden the model to understand the effect of integration on firm behavior such as the allocation of resources.[2] It is also unclear how one can extend the paradigm to analyze the effect of integration on the allocation of resources in large multi-division firms which are riddled with high levels of informational asymmetry and are run by managers with little or no ownership.[3] For analyzing the behavior of such firms, the central assumptions that integration simply reallocates bargaining power over profits, that efficiency is always achieved through renegotiation, and that owner-managers have the specific knowledge to implement the efficient outcome, are clearly problematic. First, the very size and complexity of the modern firm by and large make it impossible for any one manager, owner or non-owner, to have the necessary knowledge to implement the efficient outcome. Consequently, delegation is pervasive.[4] Second, corporate resources get allocated on the basis of information provided by specialist managers. Communication, while self-interested to a certain degree, plays a crucial role in that process. Third, specialist managers do not bargain over personal profits. Rather, they compete for the firm's limited resources.

To better understand the effect of integration on the allocation of resources then, one must account for the impact that integration has on the degree of informational asymmetry between corporate headquarters and its specialist managers, and on the nature of internal competition for the firm's limited resources. Such an impact surely has important consequences for the efficiency of internal decision-making and the effectiveness of corporate headquarters in allocating capital. In this paper, I focus on the communication process between corporate headquarters and specialist managers, and develop a simple model of internal competition for corporate resources. Specifically,

[1] Most notably, Williamson (1975, 1985), Klein, Crawford, and Alchian (1978), Grossman and Hart (1986), and Hart and Moore (1990).

[2] 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."

[3] Bolton and Scharfstein (1998) make a similar point and emphasize the need to incorporate the Berle and Means perspective on agency into the Coasian view of the firm.

[4] See Aghion and Tirole (1997), Baker, Gibbons and Murphy (1999).

I consider a two-period setting where specialist managers compete for corporate resources in each period by communicating the type 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 getting funding for their projects. In fact, if it were not for the multi-period nature of the model, that is if exaggeration had no future consequence and therefore were costless, exaggeration would be the only outcome in an integrated firm. Of course in reality, there are career consequences to making exaggerated statements. For example, managers who exaggerate potentially lose credibility ex-post. Or the decision to exaggerate may signal talent. My model has a similar career effect that endogenously makes exaggeration costly and induces managers to be more forthcoming in their statements.[5] Nonetheless, the temptation to exaggerate remains and is stronger for managers for whom the future holds less promise. For example, managers who are less talented exaggerate more than managers who are more talented because less talented managers have less to lose than more talented managers.[6] The effect of such behavior in the model is to reduce allocative efficiency as corporate headquarters has no information but communication from managers to allocate resources.[7] Perhaps more interestingly, the model predicts the quality of communication to get worse with increased integration. For example, managers who are otherwise honest when facing low levels of internal competition start to exaggerate when faced with higher levels of internal competition because the presence of more managers makes it more difficult to get funding while staying honest. Obviously, not all is bad with integration. An integrated firm can create value by pooling resources and shifting funds from bad projects to good projects. I take the possibility of such value-enhancing redistribution to be the principal benefit of integration.

To summarize then, there are two opposing effects of increased integration in my model. On the one hand, increased integration expands the opportunity set. This is good for allocative efficiency. On the other hand, increased integration intensifies the internal competition for corporate resources. This is bad for incentives, makes it harder to elicit useful information and hurts allocative efficiency. As a result, the theory predicts the optimal degree of integration to be the point which balances the marginal cost of integration from worsened quality of communication with the marginal benefit of integration from an expanded opportunity set. This aspect of the model more generally points to a theory of the firm based on the efficient allocation of resources.

The model also allows an alternative interpretation as a bank financing a portfolio of projects. Such an interpretation yields a theory of financial intermediation based on the same ideas. Similar to a firm, a bank too may want to expand as long as the marginal benefit of integration (diversification)

[5] See Baker, Gibbons and Murphy (2001a, 2001b) for a repeated-game perspective on integration. In the same spirit, repetition in my model enables the parties to utilize specialized knowledge that they cannot otherwise utilize in a one-shot game.

[6] The model allows other interpretations such as asset quality and line of business, e.g. the temptation to exaggerate is stronger for managers assigned to bad assets.

[7] 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.

exceeds the marginal cost. This line of argument captures the often-expressed contention against the counterfactual prediction of Diamond (1984) that there be one big bank financing the entire economy to economize on monitoring costs. The model provides an intuitive reason that shows the impracticality of this idea – it is simply and inherently difficult for numerous areas of lending expertise to coexist efficiently.

To further explore the differences between a firm and a bank, I draw on Holmström's (1999) view of the firm as a subeconomy. I argue that the control rights that come with asset ownership enable a firm to set "the rules of the game" and mitigate negative managerial behavior in ways that a bank cannot. Many organizational processes and structures that we observe in practice indeed come with asset ownership and can be viewed as altering the rules of the game. I show how some of them can improve allocative efficiency and make the firm a better financial intermediary than a bank. The notion that organizational processes and structure can shape managerial behavior is by no means new to this paper. Many organizational researchers have made similar arguments.[8] Organizational processes and structure, by defining the game, can change and improve behavior. For example, I show that a firm can improve communication and allocative efficiency by making some portion of its capital budget non-contingent. Of course, a natural question to ask is why a bank cannot offer a similarly rigid financing scheme. The answer lies in asset ownership. Not so surprisingly, it is very difficult to get a manager to stay in a rigid scheme once he finds out that he is good. By making certain that good managers are not able to defect with the physical assets that potentially make them more valuable, I argue that a firm can gain leverage over human capital that a bank without asset ownership cannot.

Another organizational remedy I consider is job rotation. I show that the chance of being assigned to a possibly more profitable set of assets gives hope to managers, who find themselves currently assigned to bad assets, and makes them more forthcoming. Needless to say, a bank cannot take a manager from one of its projects and assign him to another. As a matter of fact, job rotation is just one example of what a firm can do with careers more generally. To the extent that such control over careers is important for manipulating managerial behavior, a firm may be better at intermediating finance than a bank. In the same spirit, I show how centralization can improve behavior by getting managers to engage in team production that is successful only if communication is accurate. When a manager in a centralized firm thinks about making an exaggerated statement, he takes into account not only the reputational consequences that are part of the basic model but also the disruptive effect that his misleading statements may have on team production. Finally, I show how delegation and hierarchies can arise endogenously as a commitment device to constrain internal competition and improve the quality of communication.

There is ample clinical evidence in the management literature suggesting the prevalence of the kinds of informational asymmetry that drive my model. In what is now widely recognized as a classic on capital budgeting and resource allocation, Bower (1970) provides insights about the degree of

[8] Bower (1970), Chandler (1962), Crozier (1967), Simon (1945) to name a few. Milgrom and Robert (1988) is the closest in spirit with its emphasis on "influence activities".

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.[9] 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)

There is a related and growing literature that investigates the nature and efficiency of internal capital markets. Building on the incomplete contracts approach pioneered by Grossman and Hart (1986), and Hart and Moore (1990), Gertner, Scharfstein and Stein (1994) explore some of the differences between internal and external finance by emphasizing the extent to which the two modes of financing differ with regard to the allocation of control rights. As GSS point out, control rights reside with corporate headquarters (the investor) in an internal capital market, whereas they reside with the manager (and not the investor) in a bank-lending arrangement. Comparing the two modes of financing, GSS show that internal finance leads to higher investor monitoring but lower managerial effort than external finance. Their framework, however, does not address the potential communication problems as well as the question of how capital gets allocated across divisions that compete for the firm's limited resources.

Stein (1997), extending the control ideas of GSS, shows that corporate headquarters can create value by combining several projects under one roof and actively shifting funds from one project to another, a winner-picking role that a non-owner intermediary such as a bank cannot perform. In comparison, the model presented in this paper takes an opposite stance on the competence of corporate headquarters and on the role of division managers in the allocation of capital. Division managers are assumed to have the relevant expertise, giving them an active role in the allocation

[9] See Jensen (2001) for evidence of widespread misrepresentation in the context of the budgeting process.

of capital. And, any winner-picking strategy on the part of corporate headquarters, to the extent possible, relies on information contained in self-interested communication from division managers.

Scharfstein and Stein (2000) demonstrate how influence costs can lead to inefficiencies in capital allocation in a two-tier agency setting.[10] In their model, division managers extract greater overall compensation by engaging in rent-seeking activities and, in some cases, the increased compensation takes the form of preferential capital allocations that are inefficient.[11] Although the model presented in this paper too predicts capital allocations that are inefficient relative to the first-best allocation, the underlying mechanisms are quite different. For example, their model requires an agency problem at the level of the CEO whereas my model shows that this is not necessary. Moreover, the framework allows me to make further predictions regarding the effect of increased internal competition and to explore organizational remedies to deal with some of the problems.

Brusco and Panunzi (2000) argue that ex-post redistribution from one manager to another can be bad for ex-ante effort incentives and that it can be optimal to limit such redistribution.[12] However, their model focuses on the effort aspect of the agency problem which has received the bulk of the attention in previous work whereas my model focuses on the communication of specialized knowledge which, the clinical evidence suggests, is an important part of what goes on in internal capital markets.

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 away 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 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.

The paper proceeds as follows. Section 2 develops the basic model. I show that managers of integrated firms exaggerate their projects to get funding and that the problem gets worse with increased integration. In Section 3, I discuss the implications of self-interested communication for allocative efficiency. Section 4 considers organizational remedies that can indirectly improve managerial behavior and hence allocative efficiency. In Section 5, I discuss testable implications of the ideas developed in Sections 2, 3 and 4. I provide concluding remarks in Section 6.

[10] The two-tier agency approach is also somewhat reminiscent of March (1962) which portrays the firm as a political coalition and stresses the importance of taking a systems view to understanding decision-making within firms.

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

[12] An earlier work by Rotemberg and Saloner (1994) makes the same point for narrow business strategies.

2 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 $1-\mu$.[13,14]

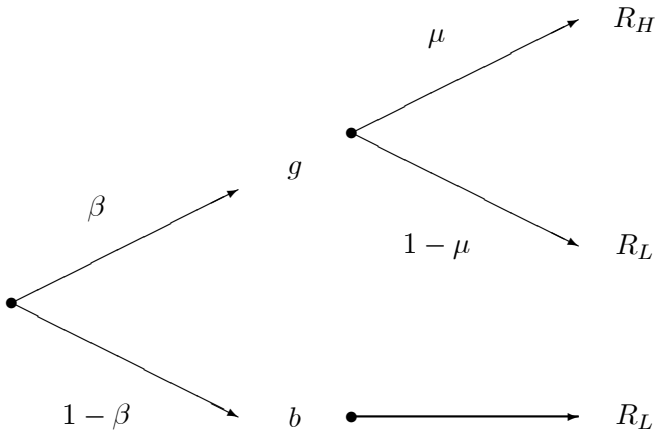

Figure 1: Managerial Talent and Project Outcomes

Managers know whether they are good or bad.[15] 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. Formally, their utility function is given by:

$$U(K_i, R_i) = K_i R_i \tag{1}$$

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).[16] Based on statements made, the firm's capital budget K then gets allocated to the seemingly best projects. In period 2, each manager gets a new project idea as in period 1.

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

[14] The results are robust to the generalization that a bad manager gets a good project with a probability less than $1-\mu$. All that is required is that the future hold less promise for some managers than others.

[15] An alternative formulation would be to assume that managers do not know whether they are good or bad but update their priors as they get good or bad project ideas.

[16] 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

Since managerial talent remains the same in period 2, one can also think about managerial talent as the line of business the manager is involved in. Managers discount their period-2 payoffs at a rate $\delta < 1$.

The cross-product of manager and project types in period 1 constitutes the relevant type within the game. There are three types of managers: A, B and 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.

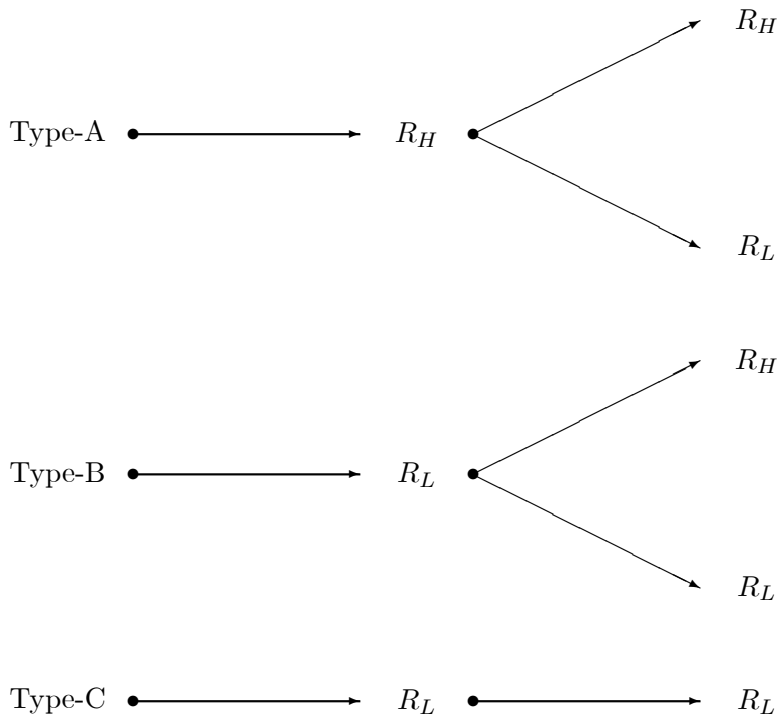

Figure 2: Manager Types

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.[18]

regardless of his true project type is central to the model. This is also a significant technological deviation from Holmström (1982).

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

[18] Perhaps this is the best place to dispense with an argument one might have against the modeling approach

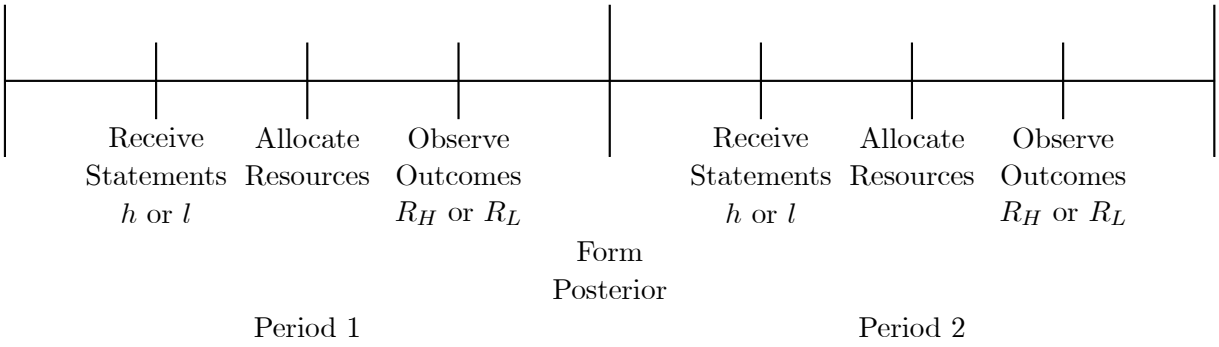

Figure 3: Timeline

I assume that a manager would be patient enough to wait for a potentially better project idea in the future if he did not have a good project idea today but thought that the future held some promise. 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 a solution concept, I use the standard Bayesian Perfect Nash Equilibrium (BPNE). Out of equilibrium beliefs, when and if necessary, are fixed so as to satisfy the Cho-Kreps intuitive criterion.

2.1 Two-Manager Competition

The first point to notice is that competition in period 2 is somewhat redundant. Expecting every manager to announce h if asked to compete in the last period, corporate headquarters might as well 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. For what follows, the issue of whether a formal period-2 competition is held or not does not make a difference.[19]

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

The second point to notice is that a manager isolated from internal competition would have no reason to make a false statement. In fact, when there is only one manager, there really is no need

taken in this paper: why not use the standard tools of mechanism design? I have various reasons and chief among them is the communication focus of this paper. The mechanism design approach generously assumes that incentive schemes can be based on the communication of specialized knowledge which, for all practical purposes, can be neither contracted nor understood by the superior. See Harris and Raviv (1996) for a mechanism design approach in which corporate headquarters is assumed to have the ability to find out the truth.

[19] 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 away from such heterogeneity, it is indeed optimal to divide the capital budget equally among the managers who tie for the highest posterior probability.

for communication for the purpose of allocating capital.[20] I refer to this as the *stand-alone* case.

When there is competition for limited corporate resources, however, managers may have an incentive to make exaggerated statements to increase their chances of getting funding for their projects. The following proposition shows how such exaggeration may come about even with only two managers competing.

Proposition 1 *The unique equilibrium for two managers is as follows: In period* 1*, bad managers (type-C) exaggerate and state that they have good projects whereas good managers (type-A and type-B) state their true project types.*

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. On the equilibrium path, 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

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

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

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

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

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 eligibility for period 2. Lemma 1 summarizes the optimal period-2 strategy. Solving the model backwards, payoff to a type-A manager 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

[20] Since an isolated manager making a truthful statement is not a unique equilibrium, I am implicitly deferring to reputational concerns. The more relevant point to realize is the inherent difficulty of staying honest when a manager faces internal competition.

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.[21] 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 from announcing l in period 1 is

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

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

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

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. Therefore, the expected difference is

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

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), and in return for being patient and demonstrating that he is 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. That is, 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 from announcing h in period 1 is

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

[21] 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

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

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

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

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. The proof of uniqueness as well as the rest of the proofs are provided in the appendix.

2.2 Three-Manager and n-Manager Competition

For higher levels of internal competition, even type-B managers may lose their patience and choose to exaggerate in period 1. In the appendix, I provide a full characterization of the three-manager case and show that type-B managers may choose to exaggerate first with a mixing probability and then in pure strategy as β, the probability of facing a good manager, increases.[22] I outline below the intuition for why type-B managers may lose patience and choose to exaggerate in period 1 as the number of competing managers increases from two to three.

When there are three managers, it turns out that a manager can increase the expected amount of funding 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. But even after taking this cost into account, it turns out that a manager may still come out ahead by exaggerating in period 1. This was certainly not possible when there were two managers. In fact, the only possible equilibrium trade-off was between an equal amount of period-1 funding and period-2 funding. And any one manager's gain from exaggeration had to be the other manager's loss. This one-on-one constraint gets relaxed, however, when there are three or more managers. In a sense the extra manager breaks the one-on-one budget and allows richer trade-offs to arise in equilibrium.

[22] Meanwhile type-C managers continue to exaggerate as before.

Nevertheless, it is still not clear that a type-B manager would choose to exaggerate in period 1 to increase the expected amount of funding 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 must be met. Specifically, the potential value-weighted increase in period-1 funding must be greater than the consequent value-weighted decrease in period-2 funding.

Three factors help this tighter condition to be met (i) high β, (ii) low μ and (iii) large n. To see why, assume for a moment that type-B managers remain truthful and state l in period 1. 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 a single type-B manager 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 even type-C. But a high β and a low μ make it less likely that they are type-A ($\beta\mu$) or type-C ($1-\beta$), and more likely that they are type-B ($\beta(1-\mu)$). 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 ($\beta\mu$). Furthermore, the temptation for a single type-B manager to deviate increases intensely as n gets large. In the appendix, I study the mixing equilibrium for the general case of n managers and show that the mixing probability increases with n. In addition, I show that the parameter space $\beta-\mu$ in which type-B managers lose patience and start to exaggerate expands with n.

In a nutshell then, the main message to take away from this section is that increased integration and the intrinsic internal competition for resources can be bad for incentives and potentially can make it more difficult to elicit useful information from specialist managers.[23,24] Needless to say, not all is bad with integration. An integrated firm can create value by pooling resources and shifting funds from bad projects to good projects. But to the extent that such value creation has to rely on self-interested communication from managers, the analysis suggests that there can be an endogenous limit on integration. This is the issue I turn to next.

[23] One can think of this as "diseconomies of management" that Coase (1937) had to assume exogenously so that his benefit-oriented theory of integration did not generate the counterfactual prediction that the entire economy should be owned by one big firm to root out any potential hold-up problem. It is comforting to see that the casual but intuitive diseconomy argument can arise endogenously in a simple equilibrium model of communication.

[24] The model also has a valuable insight to contribute to the age-old central planning debate. As Hayek have argued so eloquently in a number of his writings on the topic, 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". Perhaps the internal competition perspective has something to add to the debate in conjunction with the well-accepted bounded rationality arguments of Simon (1955).

3 Integration and Allocative Efficiency

An integrated firm can improve allocative efficiency by pooling resources and shifting funds from bad projects to good projects. The analysis in the previous section, however, indicates that extracting the much needed information to do this may not be easy and, in fact, may get more difficult with increased integration. So a natural question to ask is whether the two opposing effects could provide an endogenous limit on integration.

I start by comparing the allocative efficiency of two independent stand-alone firms with that of their integrated counterpart. To make comparison with first-best and second-best easier, I consider two independent stand-alone firms with a capital budget of $\frac{K}{2}$ each.

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

This expression simply represents the expected return that two stand-alone firms can generate over two periods. Full expressions regarding allocative efficiency are provided in the appendix.

3.1 First-Best

With full information, an integrated firm can achieve higher allocative efficiency and exceed the allocative performance of two independent stand-alone firms by simply moving funds to the best opportunity available. This is the pure winner-picking role also pointed out by Stein (1997). The improvement in allocative efficiency relative to a stand-alone firm is positive.

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

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

3.2 Second-Best

When an integrated firm has to rely on self-interested communication from managers, its allocative efficiency suffers, at least compared to first-best. Compared to first-best, the difference is negative.

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

The reduction in allocative efficiency relative to first-best is due to (i) a bad manager $\left(1-\beta\right)$ 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 $\left(1-\mu\right)$ 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.

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

Although less than the first-best improvement, the difference is still positive. 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 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).

The fact that A_{2I}^{SB} is always greater than A_{2S} should come as no surprise. Given the way the model is set up, integrating two managers will always dominate two independent managers. The intuition for this is quite simple. Suppose that every manager exaggerated and that, as a consequence, no funds could be shifted from one manager to the other. Since the same is true by default for two independent managers, it is clear that integrating two managers can do no worse. This suggests that the model developed so far is missing an important ingredient. Perhaps it is the fact that I have not attributed any explicit cost to exaggeration. Clearly, one can imagine reasons for why exaggeration can in itself be costly over and above what has been modeled in terms of financial returns. That is, aside from diverting resources away from better opportunities, one can imagine reasons for why exaggeration may in itself be destructive and lead to lower project outcomes. Then a stand-alone firm might achieve a higher allocative efficiency than an integrated firm. Compared to a stand-alone firm, there are many instances in which an integrated firm undertakes a project communicated as being good when in fact it is bad.

I do not pursue this point further for two reasons. First, I am somewhat reluctant to make such an exogenous assumption. Without a more first-principles understanding of the phenomena, it would be only speculation to draw conclusions. Second, the model already has rich enough dynamics to demonstrate that increased integration may not always improve allocative efficiency. Hence there is no need to make an exogenous assumption to close the model.

As an example, I look at the allocative efficiency of three managers. For expositional reasons, I assume parameter values are such that the equilibrium at least falls into the region where type-B managers exaggerate with a mixing probability α.[25] Note that if I do not make this assumption,

[25] Details of this case are left to the appendix.

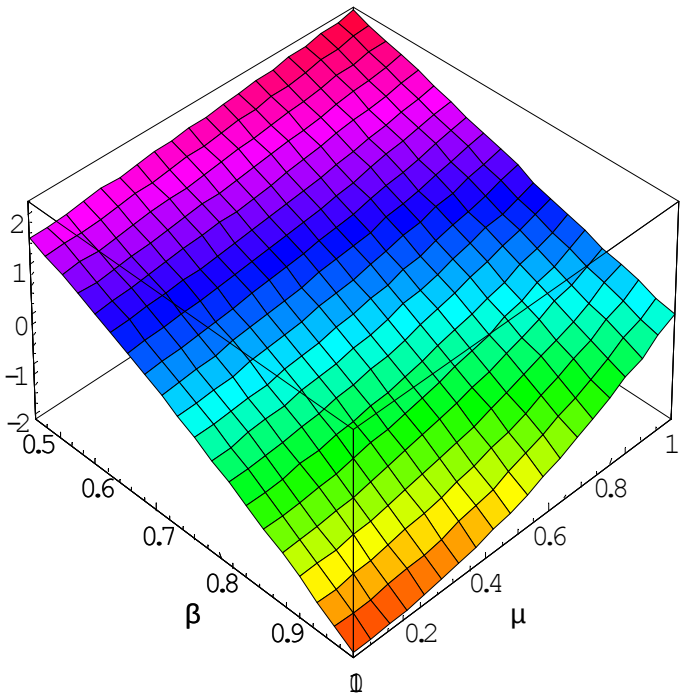

Figure 4: Difference in allocative efficiency

increased integration would continue to create value by expanding the opportunity set. To simplify the analysis, I set $\delta = 0.5$. Moreover, I assume that the inequality stated in (2) is satisfied marginally. With these parameters pinned down, β must be greater than 0.5 so that type-B managers lose patience and exaggerate with a mixing probability in period 1.

The analytic expression for $A_{3I}^{SB} - A_{2I}^{SB}$ is not particularly intuitive so instead I plot it numerically in Figure 4. One would expect allocative efficiency to suffer as type-B managers choose to exaggerate with a higher mixing probability, that is when β is high and μ is low. 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.

It is worth emphasizing the main result so far. The model suggests that there are two opposing effects at work. On the one hand, increased integration helps expand the opportunity set. This allows more value-enhancing redistribution from bad projects to good projects to take place. On the other hand, increased integration intensifies the internal competition for resources. This is bad for incentives and makes it harder to elicit useful information. The optimal point to stop further integration then is when the marginal cost of integration from worsened quality of communication exceeds the marginal benefit of integration from having a more expanded opportunity set. This aspect of the model more generally points to a theory of the firm based on the efficient allocation of resources.

Interestingly, the model can also be interpreted as a bank financing a portfolio of projects. Similar to a firm, a bank too may want to combine projects as long as the marginal benefit of

integration (diversification) exceeds the marginal cost. Perhaps what we have then is a theory of financial intermediation. Although the argument for limited integration and diversification is somewhat inconsistent with Diamond's (1984) model of a bank, it is indeed more realistic. We do not see one big bank financing the entire economy as predicted by Diamond's model. It is well understood that diversification is good but only to a certain degree. What researchers have argued is that issues related to technical expertise start to bind after a point. That is, as a bank diversifies into new areas of lending, efficiency starts to suffer. With a slight reinterpretation, this is what my model predicts, too. When one views a bank as a firm that is in the business of making loans, the analogy becomes clearer. Too much diversification into unrelated lines of lending business can be dysfunctional. Instead, a limited diversification strategy that brings out the best of integration but stops before the dark side kicks in might be preferred.

Finally, the model points to an interesting comparison between internal and external capital markets. Perhaps external capital markets are plagued by what most of us argue is their most fundamental strength, unfettered competition. As the model shows, however, too much competition can be a bad thing when it comes to eliciting specialized knowledge. In such an environment, there is immense value to be created by committing to less competition and, in some ways, one can view firms as serving that purpose. By acting as isolated islands, firms can shelter their managers from intense competition for capital and improve allocative efficiency.

Holmström's (1999) view of the firm as a subeconomy is especially relevant here.[26] Holmström argues that concentrated ownership of assets under a single authority (the island) brings with it a great variety of 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.[27] For example, a firm can set work rules; rotate managers between different projects; design jobs; delegate authority; control exactly who knows what and when. In effect, the control rights that come with asset ownership enable a firm to set "the rules of the game". To the extent that such control rights are important for improving managerial behavior, a firm might be a better financial intermediary than a bank.

The idea that asset ownership brings with it value-enhancing control rights has the potential to get us much closer to a theory of the firm based on the efficient allocation of resources. Armed with such control rights in a world riddled with informational asymmetries and significant externalities in contracting, a firm might be able to alter the game to improve efficiency in ways that a bank cannot. To complete the theory then, I need to show that such alterations are indeed possible.

[26] The Grossman-Hart-Moore paradigm taken literally, Holmström argues, can only explain why individuals own assets, but not why firms own assets. In reality of course, workers rarely own any assets. Instead, ownership of assets are clustered in firms.

[27] Holmström (1999), p.88

4 Control Rights and Organizational Design

The view of the firm as a subeconomy naturally brings an inescapable analogy between a government and a corporate headquarters. While this is not the place to argue whether second-best intervention is desirable or not in a market economy, it seems that such ideas have enormous potential inside firms. By internalizing some of the externality that different types of managers impose on each other, a corporate headquarters can influence and improve managerial behavior in a number of ways. Many organizational processes and structures that we observe in practice help firms achieve that exact goal. In this section, I explore how a firm might use some of them to improve allocative efficiency. But more importantly, I argue why a bank may not be able to replicate them without the control rights that come with asset ownership.

In the analysis that follows, I do not consider incentive contracts for a multitude of reasons. First, incentive contracts can be very costly in the presence of significant private benefits, that is when monetary incentives have limited effect on managerial behavior. I provide a formal proof of this argument in the appendix. Specifically, I look at incentive contracts that induce truthful reporting in my model and show that the cost of such incentive contracts can arbitrarily approach K, the firm's capital budget. Second, the problem of informational asymmetry is such that a manager needs to be rewarded for admitting that he has a bad project. Of course, there is nothing inherently wrong with such contracts, except that the idea does not sound familiar. How many firms do we know of that pay their managers for submitting bad project proposals? Third, suppose that even a good manager with a good idea has to spend some 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 and collect the counterproductive reward. Fourth, if preferences are not additively separable in income, compensating differentials will be incomplete.[28] Therefore in general, monetary incentives cannot be expected to solve the problem fully. Finally, I am more interested in exploring what a firm can do differently than a bank. There is no reason to assume that a bank cannot offer a financial contract that essentially replicates the payoff profile of what we call an incentive contract inside a firm.[29]

Before getting into further detail, I should emphasize a general lesson that emerges from the analysis. An effective design instrument does two things to improve managerial behavior. One, it reduces the potential gain from exaggeration. And two, it increases the cost. All of the design instruments considered next do more or less the same.

[28] Milgrom (1988).

[29] It has often been argued that firms are inherently better than markets at constructing performance measures and dealing with moral hazard. Such arguments are very convincing for low-level workers. But one would expect the comparative advantage to be much smaller, if any, for high-level managers who are the main focus of this paper.

4.1 Rigid Divisional Capital Budgets

A firm can improve managerial behavior by reducing internal competition. One natural way to reduce internal competition and improve managerial behavior is rigid divisional capital budgets. With less at stake, managers might be more forthcoming in their communication. I formalize this idea in Proposition 3.[30]

It is important to note that internal competition is always beneficial in a first-best setting. The idea of having less internal competition, in effect, putting some sand in the wheels to improve allocative efficiency is really a second-best argument.

Proposition 2 *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. 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.

The fundamental question now is, why is it that a firm can have a rigid capital budget but a bank cannot? The answer has to do with a combination of adverse selection and control rights. Suppose that there is no asymmetric information at 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, is 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.[31]

With asset ownership, things are a bit different as defection is no longer that easy. A good manager who works for a firm cannot take the assets and defect to a bank that offers a non-rigid loan policy in period 2. Of course, he himself can leave if he so chooses. In fact, we call them

[30] Milgrom and Roberts (1988) make a related point. An organization may optimally demand and use less information to avoid costly and wasteful effort by managers to influence decisions. See also Gibbons (1999) for a simple model along the same lines. Caillaud and Tirole (2001) provide a similar argument in the context of political parties.

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

entrepreneurs.[32] 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, there would be less defection and a firm would have a comparative advantage over a bank in implementing rigid schemes.[33]

Even if a rigid capital budget can improve managerial behavior, it may still not be optimal since information is used less aggressively. The decision to implement a rigid scheme ultimately depends on the resulting allocative efficiency. The full expression regarding A_{2I}^{RS} is provided in the appendix.

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

$$A_{2I}^{RS} - A_{2S} = \beta\mu\left[\nu\left(1-\beta\mu\right) + \delta\mu\left(1-\beta\right)\right]K\left(R_H - R_L\right) > 0 \tag{18}$$

where ν is the contingent portion of the capital budget. With a rigid scheme, an integrated firm is able to shift funds to type-A managers ($\beta\mu$) in period 1 from not only type-B managers but also type-C managers $(1-\beta\mu)$, albeit at a slower pace ν. As an offset, however, because of the pooling of type-B and type-C managers in period 1, an integrated firm with a rigid scheme is able to shift funds from only type-C managers to type-A managers in period 2.

Compared to non-rigid second-best, the difference is increasing in the contingent share of the capital budget ν as expected.

$$\begin{aligned} A_{2I}^{RS} - A_{2I}^{SB} &= A_{2I}^{R} - A_{2S} - \left(A_{2I}^{SB} - A_{2S}\right) \\ &= K\beta\mu\left[\nu\left(1-\beta\mu\right) - \left(1-\mu\right)\left(\beta + \delta\left(1-\beta\right)\right)\right]\left(R_H - R_L\right) \end{aligned} \tag{19}$$

Proposition 3 *There exists δ^* such that for $\delta > \delta^*$ the rigid scheme achieves higher allocative efficiency than the non-rigid scheme.*

Propositions 3 and 4 highlights a natural limit on how aggressive an uninformed corporate headquarters can be in picking winners. Moreover, it 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. Rigidity may simply be the optimal response of a corporate headquarters that is less informed than its managers. In Section 5, I provide a few suggestions that should help to empirically differentiate between the two explanations.[34]

As a final point, the idea that capital budgets of integrated firms cannot be too high-powered has parallels to the multi-tasking results of Holmström and Milgrom (1991). Informational asymmetry is the driving force as in their setting. Obviously the form is different, i.e. hidden information versus hidden action, but the fundamental competition among "unobservables" is the same.

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

[33] Rajan and Zingales (1998) propose a theory of the firm based on controlling employee access to physical assets.

[34] 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 than non-integrated firms.

4.2 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 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.[35]

> 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 has are profitable and some of them are not. Neither the firm nor the managers have knowledge of this at the time of integration, but the managers find out more as they work closely with the 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 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.[36]

Proposition 4 *Rotating managers to a different set of assets in period* 2 *can eliminate exaggeration by bad managers (type-C) in period* 1. *Specifically, there exists a probability of job rotation* $p \in (0,1)$ *and* δ^{**} *such that for* $\delta > \delta^{**}$, *every manager tells his true project type.*

In some sense, job rotation gives hope to a manager who is currently assigned to a bad set of assets. Of course, job rotation is just one example of what a firm can do with careers more generally. As the subeconomy view of the firm suggests, ownership of assets gives a firm the control rights with which to design the jobs related to them. For example, a firm can decide when and

[35] CEO super bowl. Fortune. Aug 2, 1999.

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

where to promote managers, create career paths, and so on. In effect, ownership of assets more generally allows a firm to run an internal labor market in a potentially value-enhancing way.

Without the control rights that come with asset ownership, a bank does not have the degree of control that a firm has over careers. Needless to say, a bank cannot take a manager from one of its projects and assign it to another. Then to the extent that such control over careers is important for manipulating managerial behavior, a firm might be a better financial intermediary than a bank.

Finally, the idea of job rotation points to an interesting conjecture about why firms that are made up of unrelated businesses do not appear to be faring so well and trade at lower valuation multiples than comparable firms that operate exclusively in a single line of business. Many explanations have been forwarded. But perhaps a more fundamental reason for a diversification strategy to have dysfunctional consequences is that it forces managers to accumulate human capital that ends up being too specific for the present job and of no use elsewhere in the firm, and makes it very hard to rotate them. As the model shows, getting trapped with a bad set of assets can make a manager desperate. There is ample indirect evidence that supports this conjecture. Scharfstein (1998) finds that diversified firms invest more in low-Q and less in high-Q businesses when compared to pure stand-alone firms. Gertner, Powers and Scharfstein (1999) find that spun-off units in high-Q businesses subsequently increase their investments. Certainly, it would be interesting to empirically investigate whether these observed patterns are due to a careers effect more directly.

4.3 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. Clearly, a bank cannot do this since it does not have the control rights that come with asset ownership. 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, is 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. If this is too abstract, it really should not be. Again for concreteness, think of a centralized marketing function that is making plans based on the project proposal that was presented to the corporate headquarters.

Private communication is not possible, say because the headquarters staff eats lunch in the same corporate cafeteria and can overhear private conversations.

Portrayed in this way, it should be obvious why centralization would improve managerial behavior. When a manager contemplates making an exaggerated statement to get more resources in a such 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. Parenthetically, the argument made here should not be confused with the standard monitoring argument that is often made in corporate finance. The way in which centralization is envisaged to induce positive managerial behavior is not by making corporate headquarters more informed about managers and projects, but by forcing managers to get involved in team production that is successful only if communication is accurate and forthcoming.

To see how the model works with a centralized unit, suppose that a manager states h and that 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

$$\widehat{\beta}\theta R_H > \left(1-\widehat{\beta}\right)\theta R_L \tag{20}$$

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

$$\max_x \log(x)\,\widehat{\beta}\theta R_H + \log(1-x)\left(1-\widehat{\beta}\right)\theta R_L \tag{21}$$

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

$$x^* = \frac{\widehat{\beta}R_H}{\widehat{\beta}R_H + \left(1-\widehat{\beta}\right)R_L} \tag{22}$$

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 should not affect the main message.

It is worth qualifying the idea before getting into further detail. The idea as presented so far does not ascribe any cost to centralization. As argued by Hayek (1945), efficiency dictates economic production to be undertaken by those who possess the relevant specialized knowledge and expertise. To the extent team production unnecessarily dilutes specialized knowledge and puts certain aspects

of production in the hands of less specialized managers, centralization can be inefficient and costly. Moreover, centralization might not even be feasible for a firm made up of unrelated businesses. This insight proves to be useful when I discuss testable implications in Section 5.

Proposition 5 *For $\theta < \theta_l$, bad managers (type-C) exaggerate and state that they have good projects whereas good managers (type-A and type-B) state their true project types. For $\theta > \theta_h$, every manager reports the true type of his project in both periods. There exists δ^{***} such that for $\delta > \delta^{***}$ the two regions are non-overlapping $\theta_l < \theta_h$.*

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

4.4 Hierarchy

Similar to the argument made for rigid divisional capital budgets, hierarchies along divisional lines can be seen as an organizational device to restrain internal competition. Delegation and hierarchy, by reducing the intensity of internal competition, can improve the quality of communication.[37]

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: winner-picking 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. Choosing the best out of four would always lead to higher value, statistically speaking on average, than choosing the best out of two. This is the winner-picking effect pointed out by Stein (1997). On the other hand, 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 Radner (1992, 1993), Sah and Stiglitz (1986), Bolton and

[37] The notion that delegation and hierarchy can serve as a bonding/commitment device is by no means new to this paper. In fact, the argument is a common one in organizational economics. But I believe the interpretation provided here about delegation and hierarchy restraining internal competition and thereby improving the quality of communication is new.

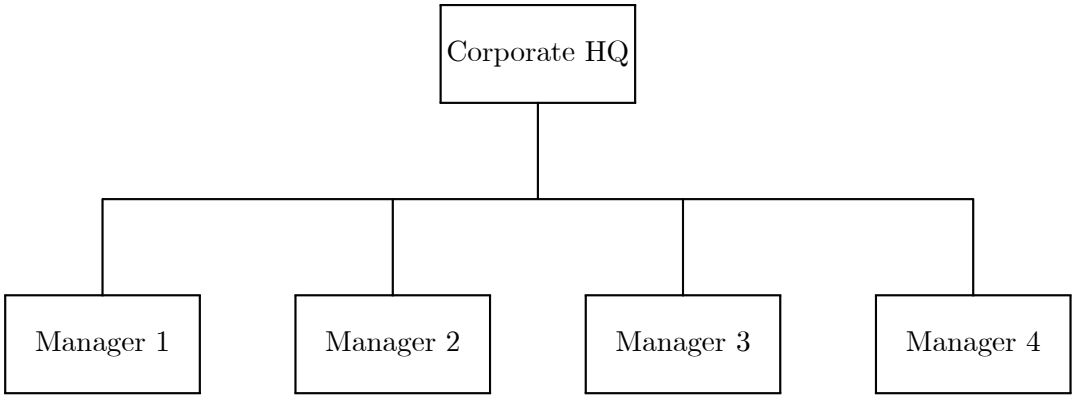

Figure 5: Flat Structure

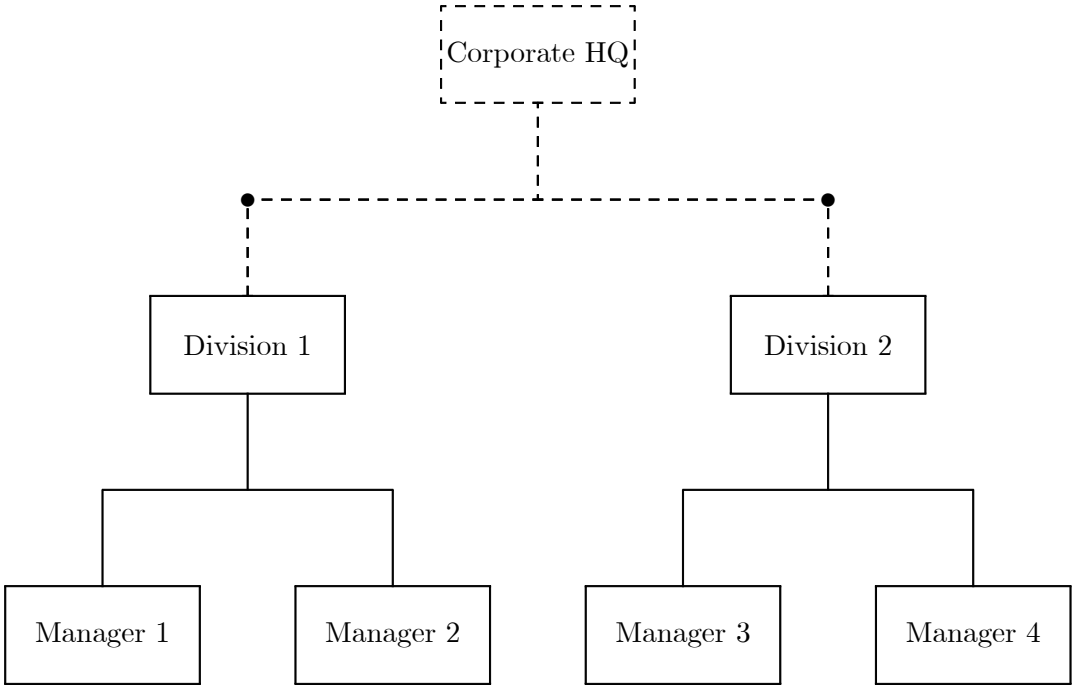

Figure 6: Hierarchical Structure

Dewatripont (1994), and Garicano (2000). The model presented in this paper captures many real-world issues pertaining to incentives, moral hazard and asymmetric information that the operations research focus of this literature leaves out. Yet it is simple enough to generate the kinds of sharp predictions characteristic of the team-theoretic literature.

Finally, one can argue that a bank could do the same without the control rights that come with asset ownership. I do not have a terribly convincing counter argument except to note that the idea of organizing projects along divisional lines in the case of a bank sounds more like having separate banks. For a firm, the situation can be different. It could be that, even though the divisions are more or less autonomous, it makes sense to combine them under one corporate umbrella because they share a critical asset.

5 Testable Implications

In this section, I discuss testable implications of the ideas developed in Propositions 2-5. Most, if not all, can be tested using publicly available data sources such as Compustat firm and segment files which 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. Of course, one would ideally like to have more extensive data on capital budgeting procedures, organizational structure, personnel policies and so forth but such detailed data are not widely available.

Hypothesis 1 *An integrated firm should have a more rigid capital budget than a non-integrated firm.*

Hypothesis 2 *A diversified integrated firm should have a more rigid capital budget than a focused integrated firm.*

Hypothesis 3 *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 3. By restraining internal competition, an integrated firm can improve the quality of communication from managers and achieve higher allocative efficiency. The idea has parallels to the influence cost perspective of Milgrom and Roberts (1988) which suggests that an organization may optimally constrain potential communication channels and use less information to reduce the temptation of managers to engage in costly and wasteful activities to influence decisions. Similarly in my model, 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 job rotation 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 earlier, this may simply be an issue of feasibility than anything else. It is hard to imagine what can be centralized in a firm made up of unrelated businesses. Also it is

hard to imagine that a manager with expertise in one particular business can be rotated easily to a completely unrelated one. Unable to use these organizational remedies effectively, one would expect a diversified integrated firm to use rigidity more than a focused integrated firm. 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. We, human beings, have limited cerebral and sensory capabilities.[38] This imperfection means that our capacity to acquire specialized knowledge is limited. Faced with such a constraint, it would be only optimal to ration that capacity and use it on areas and topics where the returns are the highest. In the case of a corporate headquarters, that area and topic would be the larger segments of the firm to which a significant portion of corporate resources is committed. And as a result, the degree of informational asymmetry would be relatively less for the larger segments than for the smaller segments. Of course, there are other reasons that would make the degree of informational asymmetry higher for the smaller segments. For example, the smaller segments may simply be newer to the firm. Or perhaps they are located further away from corporate headquarters.[39] In either case, the underlying reason for having a rigid divisional capital budget would be the same, namely the lack of specialized knowledge about the smaller segments at higher levels of management.

These hypotheses, however, should not be interpreted negatively for integrated firms. By its very nature, integration brings not only opportunity but also many challenging problems. Any negative interpretation would fail to appreciate the difficulty of providing appropriate incentives in a complex environment.[40]

6 Conclusion

This paper explores the effect of integration on the allocation of resources. I develop an equilibrium model of internal competition for funds in which corporate headquarters relies on communication from specialist managers to allocate resources. Since managers are assumed to have the relevant technical expertise and prefer larger empires, exaggeration arises as a potential problem. The model indicates both a bright side and a dark side to increased integration. On the one hand, increased integration expands the opportunity set and allows more value-enhancing redistribution from bad projects to good projects to take place. On the other hand, increased integration intensifies the internal competition for corporate resources and leads to more exaggeration. As a result, the model predicts an endogenous limit on integration that balances the marginal benefit from having

[38] Simon (1955), Jensen and Meckling (1992).

[39] In fact it would very interesting to test the effect of distance if the data were available. In addition, it would be interesting to investigate how distance as a factor has changed over time. Petersen and Rajan (2000) investigate a similar question and find that the distance between small firms and their lenders have increased with advances in computing and communications.

[40] Holmström (1999), Gibbons (2000).

an expanded opportunity set with the marginal cost from the consequent deterioration in the quality of communication. This aspect of the model more generally points to a theory of the firm based on the efficient allocation of resources.

The model also has a natural interpretation as a bank financing a portfolio of projects which helps to think about financial intermediation more broadly and various differences between a firm and a bank more specifically. In this pursuit, I draw on Holmström's (1999) view of the firm as a subeconomy, and argue that the control rights that come with asset ownership enable a firm to set "the rules of the game" and mitigate negative managerial behavior in ways that a bank cannot. Many organizational processes and structures that we observe in practice indeed come with asset ownership and can be viewed as altering the rules of the game. I show how some of these organizational remedies such as rigidity in capital budgeting, rotating managers, centralization and hierarchies can improve allocative efficiency, and make the firm a better financial intermediary than a bank.

At the end, I provide several implications of the model that can be tested on widely available data. The model predicts the capital budgets of integrated firms to be more rigid than the capital budgets of nonintegrated firms. The model also predicts the effects to be more pronounced in diversified integrated firms that operate in unrelated lines of business. Ozbas (2001) tests some of these predictions.

Finally, there appears to be ample opportunity for productive cross-fertilization between finance and organizational economics. Needless to say, more extensive data on organizational structure and personnel policies would be very useful in discerning the impact that organizational processes and structure have 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.

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A Appendix

A.1 Proof of Propositions

Proof of Proposition 1 (Uniqueness). To show uniqueness, the redundancy of period-2 competition helps to reduce the search for potential equilibria to period-1 strategies. But with three types and three period-1 strategies (pure h, pure l, and mixing), there are still 27 potential equilibria to check.

Noting that there can be no equilibrium in which type-A managers announce l in period 1 further cuts down the number of potential equilibria to nine. To prove this by contradiction, assume that announcing l in period 1 is a best response. Since announcing l reduces period-1 funding with certainty in any equilibrium, 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 equilibria where type-C managers announce h and type-B managers announce h in mixing or pure 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. With six more equilibria eliminated, there are three 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

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

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

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

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) $P\left(g\mid h,R_L\right)>P\left(g\mid l,R_L\right)$, and (ii) $P\left(g\mid h,R_L\right)<P\left(g\mid l,R_L\right)$.

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

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

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

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

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

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

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

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

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

Announcing h clearly dominates announcing l for a type-C manager. Therefore, the conjecture cannot be an equilibrium. The only possible equilibrium left is the equilibrium identified in Proposition 1.■

Proof of Proposition 2. 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

$$\begin{aligned}
P\left(g\mid h,R_H\right) &= 1\\
P\left(g\mid h,R_L\right) &= 0 \text{ (out of equilibrium)}\\
P\left(g\mid l,R_H\right) &= 1 \text{ (out of equilibrium)}\\
P\left(g\mid l,R_L\right) &= \frac{\beta\left(1-\mu\right)}{\beta\left(1-\mu\right)+\left(1-\beta\right)}
\end{aligned}$$

Note that although the posterior $P\left(g\mid l,R_H\right)$ is out of equilibrium, it is not arbitrary. Only type-A managers can deliver R_H in period 1. In addition, to make the conjectured equilibrium Cho-Kreps proof, I fix the posterior belief $P\left(g\mid h,R_L\right)$ be a bad manager with probability one.[41] 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

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

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

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

The difference is

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

Since the contingent portion of the capital budget ν is less than $\left(1-\beta\mu\right)\delta$, 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

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

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

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

The difference is

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

[41] Since a type-B manager can always make a credible speech and claim to be a good manager by promising not to announce h if the posterior was greater than zero.

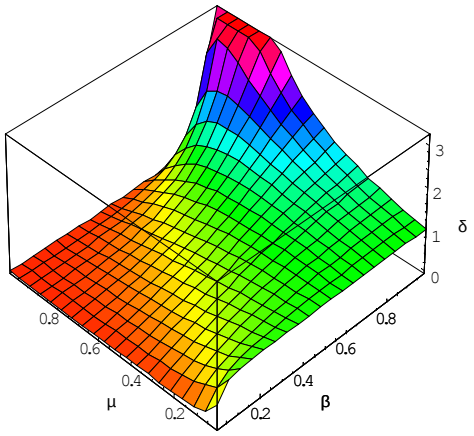


Figure 7: Lower bound δ^* in $\beta - \mu$ space

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 3. Substitute in $(1-\beta\mu)\,\delta$ for ν, the maximum contingent share possible.

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

The difference is positive for

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

Simple algebra shows that $\left(1-\beta\mu\right)^2-\left(1-\beta\right)\left(1-\mu\right)>0$. Therefore, the difference is positive for $\delta>\delta^*$

$$\delta>\frac{\beta\left(1-\mu\right)}{\left(1-\beta\mu\right)^2-\left(1-\beta\right)\left(1-\mu\right)}$$

Rearranging the expression for δ^*

$$\delta^*=\frac{\beta\left(1-\mu\right)}{\beta\left(1-\mu\right)+\left(1-\beta\mu\right)^2-\left(1-\mu\right)}$$

δ^* is less than 1 when $\left(1-\beta\mu\right)^2-\left(1-\mu\right)>0$. Solving for β yields two roots, $\beta>\frac{1+\sqrt{1-\mu}}{\mu}$ and $\beta<\frac{1-\sqrt{1-\mu}}{\mu}$. The first root is not useful since it provides a lower bound for β that is greater than 1.

Analyzing the second root, it can be shown that the expression $\frac{1-\sqrt{1-\mu}}{\mu}$ is increasing in the range $[0,1]$. As μ approaches 1, the upper bound for β approaches 1. However this bound is not good enough since the overall ratio gets unstable at the same time. As μ approaches 0, the upper bound for β is indeterminate. Using L'Hôpital's rule

$$\begin{aligned}\left[\frac{\frac{d}{d\mu}\left(1-\sqrt{1-\mu}\right)}{\frac{d}{d\mu}\left(\mu\right)}\right]_{\mu\to0} &= \left[\frac{1}{2\sqrt{1-\mu}}\right]_{\mu\to0}\\ &= \frac{1}{2}\end{aligned}$$

Therefore, if δ^* is to be less than 1, β and μ cannot be too high at the same time (Figure 7).

■

Proof of Proposition 4. 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-B manager from announcing l in period 1 is

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

Payoff to a type-B 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

$$p<\frac{(1-\beta\mu)\,\delta R_E-R_L}{(1-\beta)\,\delta\left(R_E-R_L\right)}\equiv p_u$$

For this expression to be a proper upper bound on p, a condition stronger than $\delta R_E-R_L>0$ is required (note that the new condition is less onerous when β and μ are not too high).

$$(1-\beta\mu)\,\delta R_E-R_L>0$$

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

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

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

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

For this expression to be a proper lower bound on p,

$$\delta>\frac{R_L}{(1-\beta)\,R_L+\beta\left(1-\mu\right)R_E}\equiv\delta^{**}$$

This condition further ensures that $p_l<p_u$. Finally, δ^{**} is less than 1 when

$$\mu<\frac{R_E-R_L}{R_E}$$

Therefore, if δ^{**} is to be less than 1, μ cannot be too high.■

Proof of Proposition 5

$\boldsymbol{\theta<\theta_l}$. Posterior beliefs and eligibility for period 2 are the same as in Proposition 1. It is important to note that competition in period 2 is no longer value-neutral since $\theta>0$. The firm, if possible, should allocate its period-2 capital budget K equally among managers, who tie for the highest posterior probability of being a good manager, without asking for a statement. I assume that the firm does not have such commitment power.

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

$$(1-\beta)\left[0+\delta K\left(\mu R_H+(1-\mu)\,R_L\right)\right]+\beta\left[\begin{array}{c}\mu\left(0+\frac{1}{2}\delta K\left[\mu R_H+(1-\mu)\,R_L\left(1-\theta\right)\right]\right)\\+\\(1-\mu)\left(\frac{1}{2}KR_L+\frac{1}{2}\delta K\left[\mu R_H+(1-\mu)\,R_L\left(1-\theta\right)\right]\right)\end{array}\right]$$

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

$$(1-\beta)\left[\frac{1}{2}KR_L\left(1-\theta\right)+\frac{1}{2}\delta K\left(\mu R_H\left(1-\theta\right)+(1-\mu)\,R_L\right)\right]+\beta\left[\begin{array}{c}\mu\left(\frac{1}{2}KR_L\left(1-\theta\right)+0\right)\\+\\(1-\mu)\left(KR_L\left(1-\theta\right)+0\right)\end{array}\right]$$

The difference is positive for

$$\theta>\frac{-\delta\mu R_H+\left(1-\delta\left(1-\mu\right)\right)R_L}{\delta\mu\left(1-\beta\right)R_H+\left(1+\beta\left(1-\delta\right)\left(1-\mu\right)\right)R_L}$$

This expression further reduces to

$$\theta > \frac{R_L - \delta\left(\mu R_H + (1-\mu) R_L\right)}{\delta\mu\left(1-\beta\right) R_H + \left(1+\beta\left(1-\delta\right)\left(1-\mu\right)\right) R_L}$$

Since $R_L < \delta\left[\mu R_L + (1-\mu) R_H\right]$ by assumption, the lower bound is less than zero. The condition is satisfied since $0 < \theta < 1$.

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

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

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

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

The difference is

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

Note that $1+\beta\left(1-\delta-\mu\right)>0$. Therefore the difference is positive for

$$\theta < \frac{1-\delta}{1+\beta\left(1-\delta-\mu\right)} \equiv \theta_l$$

Since the numerator $1-\delta>0$, the ratio is positive. Moreover, the denominator is greater than the numerator, leaving the upper bound for θ in the desired range, between 0 and 1.

$\boldsymbol{\theta > \theta_h}$. 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.

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 (or a manager who has stated l and delivered R_H in period 1, which is out of equilibrium)

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

Simplifying the expression yields

$$\theta > \frac{1}{2-\mu} \equiv \theta_h$$

To induce a manager with a bad project in period 2 to tell the true type of his project when facing a manager who has stated l and delivered R_L in period 1 (a type-B or a type-C manager)

$$\begin{aligned}
&\frac{(1-\beta)}{\beta\left(1-\mu\right)+\left(1-\beta\right)}\left[\frac{1}{2}KR_L\right] \\
&+\frac{\beta\left(1-\mu\right)}{\beta\left(1-\mu\right)+\left(1-\beta\right)}\left[\mu\left(0\right)+\left(1-\mu\right)\left(\frac{1}{2}KR_L\right)\right] \\
> \quad &\frac{(1-\beta)}{\beta\left(1-\mu\right)+\left(1-\beta\right)}\left[KR_L\left(1-\theta\right)\right] \\
&+\frac{\beta\left(1-\mu\right)}{\beta\left(1-\mu\right)+\left(1-\beta\right)}\left[\mu\left(\frac{1}{2}KR_L\left(1-\theta\right)\right)+\left(1-\mu\right)\left(KR_L\left(1-\theta\right)\right)\right]
\end{aligned}$$

Simplifying the expression yields

$$\theta > \frac{(1-\beta\mu)}{2\left(1-\beta\mu\right)-\beta\mu\left(1-\mu\right)}$$

Simple algebra shows that

$$\max\{\frac{1}{2-\mu}, \frac{(1-\beta\mu)}{2\left(1-\beta\mu\right)-\beta\mu\left(1-\mu\right)}\} = \frac{1}{2-\mu}$$

Solving the model backwards, payoff to a type-A manager from announcing h in period 1 is

$$(1-\beta)\left[KR_H+\delta K\left(\mu R_H+(1-\mu)\frac{1}{2}R_L\right)\right]+\beta\left[\begin{array}{c}\mu\left(\frac{1}{2}KR_H+u_2\right)\\+\\(1-\mu)\left(KR_H+u_2\right)\end{array}\right]$$

where u_2 is

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

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

$$(1-\beta)\left[\frac{1}{2}KR_H(1-\theta)+\delta K\left(\mu R_H+(1-\mu)\frac{1}{2}R_L\right)\right]+\beta\left[\begin{array}{c}\mu\left(0+u_2\right)\\+\\(1-\mu)\left(\frac{1}{2}KR_H(1-\theta)+u_2\right)\end{array}\right]$$

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

$$(1-\beta)\left[\frac{1}{2}KR_L+\delta K\left(\mu R_H+(1-\mu)\frac{1}{2}R_L\right)\right]+\beta\left[\begin{array}{c}\mu\left(0+u_2\right)\\+\\(1-\mu)\left(\frac{1}{2}KR_L+u_2\right)\end{array}\right]$$

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

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

Ignoring period-2 payoffs to simplify the analysis, the difference is positive for

$$\theta>\frac{1}{2-\beta\mu}$$

Simple algebra shows that

$$\frac{1}{2-\mu}>\frac{1}{2-\beta\mu}$$

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

$$(1-\beta)\left[\frac{1}{2}KR_L+\frac{1}{2}\delta KR_L\right]+\beta\left[\begin{array}{c}\mu\left(0+\delta K\left[\mu\left(0\right)+(1-\mu)\left(\frac{1}{2}R_L\right)\right]\right)\\+\\(1-\mu)\left(\frac{1}{2}KR_L+\delta K\left[\mu\left(0\right)+(1-\mu)\left(\frac{1}{2}R_L\right)\right]\right)\end{array}\right]$$

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

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

The difference is positive for

$$\theta>\frac{1-\delta(1-\beta\mu)}{2-\beta\mu}$$

Again simple algebra shows that

$$\frac{1}{2-\mu}>\frac{1-\delta(1-\beta\mu)}{2-\beta\mu}$$

Non-overlapping. For the two regions to be non-overlapping

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

Simple algebra shows that δ^{***} is less than 1 for all values of β and μ (Figure 8).

■

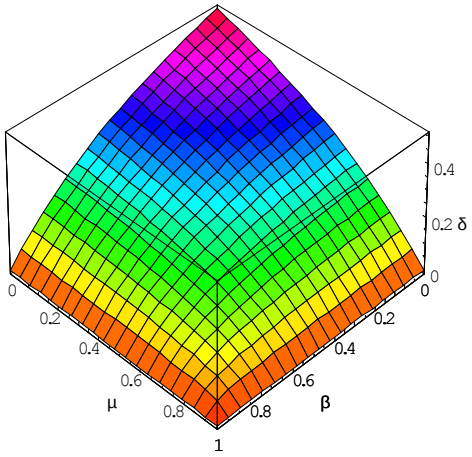


Figure 8: Lower bound δ^{***} in $\beta - \mu$ space

A.2 Three-Manager Competition

I extend the model to three managers. To simplify the analysis without diluting its message, I assume $\delta < \frac{1}{2}$. Let me define constant g as $\frac{\delta R_E}{R_L}$. There are three distinct regions.

Region I: $0 < \beta < \frac{2g-1}{1-\mu+g}$

Region II: $\frac{2g-1}{1-\mu+g} < \beta < \frac{2g-1}{g\mu}$

Region III: $\frac{2g-1}{g\mu} < \beta < 1$

Region I Equilibrium: In period 1, bad managers (type-C) exaggerate and state that they have good projects whereas good managers (type-A and type-B) state their true project types.

Region II Equilibrium: In period 1, bad managers (type-C) exaggerate and state that they have good projects, good managers with good projects (type-A) state their true project types, and good managers with bad projects (type-B) exaggerate with probability α and state their true project types with probability $1-\alpha$.

Region III Equilibrium: In period 1, both bad managers (type-C) and good managers with bad projects (type-B) exaggerate and state that they have good projects whereas good managers with good projects (type-A) state their true project types.

Region I Equilibrium. 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. On the equilibrium path, project proposals 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

$$\begin{aligned} P(g \mid h, R_H) &= 1 \\ P(g \mid h, R_L) &= 0 \\ P(g \mid l, R_H) &= 1 \text{ (out of equilibrium)} \\ P(g \mid l, R_L) &= 1 \end{aligned}$$

Note that although the posterior $P(g \mid l, R_H)$ is out of equilibrium, it is not arbitrary. Only type-A managers can deliver R_H in period 1. These posterior beliefs determine eligibility for period 2. Lemma 1 summarizes the optimal period-2 strategy. Solving the model backwards, payoff to a type-A manager from announcing h in period 1 is

$$(1-\beta)^2\left[\frac{1}{3}KR_H + \delta KR_E\right] + 2\beta(1-\beta)\left[\mu\left(\frac{1}{3}KR_H + \frac{1}{2}\delta KR_E\right) + (1-\mu)\left(\frac{1}{2}KR_H + \frac{1}{2}\delta KR_E\right)\right]$$
$$+\beta^2\left[\mu^2\left(\frac{1}{3}KR_H + \frac{1}{3}\delta KR_E\right) + 2\mu(1-\mu)\left(\frac{1}{2}KR_H + \frac{1}{3}\delta KR_E\right) + (1-\mu)^2\left(KR_H + \frac{1}{3}\delta KR_E\right)\right]$$

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

$$(1-\beta)^2\left[0+\delta KR_E\right]+2\beta(1-\beta)\left[\mu\left(0+\frac{1}{2}\delta KR_E\right)+(1-\mu)\left(0+\frac{1}{2}\delta KR_E\right)\right]$$
$$+\beta^2\left[\mu^2\left(0+\frac{1}{3}\delta KR_E\right)+2\mu(1-\mu)\left(0+\frac{1}{3}\delta KR_E\right)+(1-\mu)^2\left(\frac{1}{3}KR_H+\frac{1}{3}\delta KR_E\right)\right]$$

A type-A manager clearly 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

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

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

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

The difference is

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

In region I where $\beta<\frac{2g-1}{1-\mu+g}$, the difference is positive and announcing l dominates announcing h for a type-B manager. This condition essentially implies that if the chances of facing a type-A manager or a type-B manager are not too high, a type-B manager would choose to protect his reputation for the second period and not exaggerate in period 1.

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

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

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

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

The difference is

$$(1-\beta)^2\left[\frac{1}{3}KR_L-\frac{2}{3}\delta KR_L\right]+2\beta(1-\beta)\left[\mu\left(\frac{1}{3}KR_L-\frac{1}{2}\delta KR_L\right)+(1-\mu)\left(\frac{1}{2}KR_L-\frac{1}{2}\delta KR_L\right)\right]$$
$$+\beta^2\left[\mu^2\left(\frac{1}{3}KR_L-\frac{1}{3}\delta KR_L\right)+2\mu(1-\mu)\left(\frac{1}{2}KR_L-\frac{1}{3}\delta KR_L\right)+(1-\mu)^2\left(\frac{2}{3}KR_L-\frac{1}{3}\delta KR_L\right)\right]$$
$$=\quad \frac{1}{3}KR_L\left[1-2\delta+\beta(1-\mu+\delta)\right]$$

Since $\delta<\frac{1}{2}$, the difference is positive and announcing h dominates announcing l for a type-C manager. Therefore the conjectured BPNE is indeed an equilibrium.

Region II Equilibrium. 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

$$\begin{aligned} P(g \mid h, R_H) &= 1 \\ P(g \mid h, R_L) &= \frac{\alpha\beta(1-\mu)}{\alpha\beta(1-\mu)+(1-\beta)} \\ P(g \mid l, R_H) &= 1 \\ P(g \mid l, R_L) &= 1 \end{aligned}$$

These posterior beliefs determine eligibility for period 2. Lemma 1 summarizes the optimal period-2 strategy. 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

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

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

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

For mixing to be an optimal response, set the two payoffs equal to each other 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, $0<\alpha<1$,

$$\frac{2g-1}{1-\mu+g} < \beta < \frac{2g-1}{g\mu}$$

This is the relevant parameter space, region II. Before proceeding with type-C managers, I need to sort out a few conditions. First, for these boundary conditions to be satisfied, it must be that $\frac{2g-1}{1-\mu+g} < \frac{2g-1}{g\mu}$. $g>1$ satisfies this condition. Second, for β to be a proper probability in region II, $0<\beta<1$, $\frac{2g-1}{g\mu}$ must be greater than 0 and $\frac{2g-1}{1-\mu+g}$ must be less than 1. For $\frac{2g-1}{g\mu}>0$, $g>1$ is again enough. For $\frac{2g-1}{1-\mu+g}<1$, μ must be less than $2-g$. Otherwise, payoff from announcing h would never be as high as payoff from announcing l and type-B managers would never choose to mix. This condition essentially implies that if the chances of facing a type-A manager relative to a type-B manager are too high, it would never pay off to exaggerate in the first period. When $\mu > 2-g$, only region I remains.

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

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

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

$$\begin{array}{l}(1-\beta)^2\left[0+\delta KR_L\right]\\ +2\beta(1-\beta)\left[\mu\left(0+\frac{1}{2}\delta KR_L\right)+(1-\mu)\alpha\left(0+\delta KR_L\right)+(1-\mu)(1-\alpha)\left(0+\frac{1}{2}\delta KR_L\right)\right]\\ +\beta^2\left[\begin{array}{c}\mu^2\left(0+\frac{1}{3}\delta KR_L\right)+2\mu(1-\mu)\alpha\left(0+\frac{1}{2}\delta KR_L\right)\\ +2\mu(1-\mu)(1-\alpha)\left(0+\frac{1}{3}\delta KR_L\right)+(1-\mu)^2\alpha^2\left(0+\delta KR_L\right)\\ +(1-\mu)^2 2\alpha(1-\alpha)\left(0+\frac{1}{2}\delta KR_L\right)+(1-\mu)^2(1-\alpha)^2\left(\frac{1}{3}KR_L+\frac{1}{3}\delta KR_L\right)\end{array}\right]\end{array}$$

The difference is

$$\begin{array}{rl}&(1-\beta)^2\left[\frac{1}{3}KR_L-\frac{2}{3}\delta KR_L\right]\\ &+2\beta(1-\beta)\left[\mu\left(\frac{1}{3}KR_L-\frac{1}{2}\delta KR_L\right)+(1-\mu)\alpha\left(\frac{1}{3}KR_L-\frac{2}{3}\delta KR_L\right)+(1-\mu)(1-\alpha)\left(\frac{1}{2}KR_L-\frac{1}{2}\delta KR_L\right)\right]\\ &+\beta^2\left[\begin{array}{c}\mu^2\left(\frac{1}{3}KR_L-\frac{1}{3}\delta KR_L\right)+2\mu(1-\mu)\alpha\left(\frac{1}{3}KR_L-\frac{1}{2}\delta KR_L\right)\\ +2\mu(1-\mu)(1-\alpha)\left(\frac{1}{2}KR_L-\frac{1}{3}\delta KR_L\right)+(1-\mu)^2\alpha^2\left(\frac{1}{3}KR_L-\frac{2}{3}\delta KR_L\right)\\ +(1-\mu)^2 2\alpha(1-\alpha)\left(\frac{1}{2}KR_L-\frac{1}{2}\delta KR_L\right)+(1-\mu)^2(1-\alpha)^2\left(\frac{2}{3}KR_L-\frac{1}{3}\delta KR_L\right)\end{array}\right]\\ =&\frac{1}{3}KR_L\left(1-2\delta+\beta\left((1-\alpha)(1-\mu)+\delta\left(1-\alpha(1-\mu)\right)\right)\right)\end{array}$$

Further substituting in α, the difference is positive[42]

$$\frac{1}{3}\frac{K(g-\delta)(3-\beta\mu)}{(1+g)}>0$$

Therefore the conjectured BPNE is indeed an equilibrium.

Region III Equilibrium. Given the conjectured BPNE, only both type-B managers and type-C managers fail to deliver 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

$$\begin{array}{rcl}P(g\mid h,R_H)&=&1\\ P(g\mid h,R_L)&=&\frac{\beta(1-\mu)}{\beta(1-\mu)+(1-\beta)}\\ P(g\mid l,R_H)&=&1\\ P(g\mid l,R_L)&=&1\text{ (out of equilibrium)}\end{array}$$

Since a manager stating l and delivering R_L in period 1 is an out of equilibrium outcome, I need to fix the posterior belief. To make the conjectured equilibrium Cho-Kreps proof, I fix the posterior belief following such an outcome to be a good manager with probability one. These posterior beliefs determine eligibility for period 2. Lemma 1 summarizes the optimal period-2 strategy. 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 h in period 1 is

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

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

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

[42] This should come as no surprise. By construction, a type-B manager has a more valuable reputation to protect than a type-C manager. Therefore whenever a type-B manager is just indifferent between protecting his reputation and exaggerating, a type-C manager will choose to exaggerate.

The difference is

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

In region III where $\beta>\frac{2g-1}{g\mu}$, the difference is positive and announcing h dominates announcing l for a type-B manager.

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

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

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

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

The difference is

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

In region III where $\beta>\frac{2g-1}{g\mu}$, the difference is positive and announcing h dominates announcing l for a type-C manager. Therefore the conjectured BPNE is indeed an equilibrium.

A.3 Allocative Efficiency

Full expressions, which are omitted in the text, are provided here. Allocative efficiency of two stand-alone firms is given by

$$\begin{aligned}
A_{2S} &= (1-\beta)^2\left[\frac{1}{2}KR_L+\frac{1}{2}KR_L+\frac{1}{2}\delta KR_L+\frac{1}{2}\delta KR_L\right]\\
&\quad+2\beta(1-\beta)\left[\begin{array}{c}\mu\left(\frac{1}{2}KR_L+\frac{1}{2}KR_H+\frac{1}{2}\delta KR_L+\frac{1}{2}\delta KR_E\right)\\+\\(1-\mu)\left(\frac{1}{2}KR_L+\frac{1}{2}KR_L+\frac{1}{2}\delta KR_L+\frac{1}{2}\delta KR_E\right)\end{array}\right]\\
&\quad+\beta^2\left[\begin{array}{c}\mu^2\left(\frac{1}{2}KR_H+\frac{1}{2}KR_H+\frac{1}{2}\delta KR_E+\frac{1}{2}\delta KR_E\right)\\+\\2\mu(1-\mu)\left(\frac{1}{2}KR_H+\frac{1}{2}KR_L+\frac{1}{2}\delta KR_E+\frac{1}{2}\delta KR_E\right)\\+\\(1-\mu)^2\left(\frac{1}{2}KR_L+\frac{1}{2}KR_L+\frac{1}{2}\delta KR_E+\frac{1}{2}\delta KR_E\right)\end{array}\right]\\
&= K(1+\delta)(R_L+\beta\mu(R_H-R_L))
\end{aligned}$$

Allocative efficiency under first-best integration is given by

$$\begin{aligned}
A_{2I}^{FB} &= (1-\beta)^2[KR_L+\delta KR_L]+2\beta(1-\beta)[\mu(KR_H+\delta KR_E)+(1-\mu)(KR_L+\delta KR_E)]\\
&\quad+\beta^2\left[\begin{array}{c}\mu^2\left(KR_H+\delta K\left[\mu(2-\mu)R_H+(1-\mu)^2R_L\right]\right)\\+\\2\mu(1-\mu)\left(KR_H+\delta K\left[\mu(2-\mu)R_H+(1-\mu)^2R_L\right]\right)\\+\\(1-\mu)^2\left(KR_L+\delta K\left[\mu(2-\mu)R_H+(1-\mu)^2R_L\right]\right)\end{array}\right]
\end{aligned}$$

The difference between A_{2I}^{FB} and A_{2S} is given by

$$\begin{aligned} A_{2I}^{FB} - A_{2S} &= 2\beta(1-\beta)\left[\mu\left(\frac{1}{2}K(R_H-R_L)+\frac{1}{2}\delta\mu K(R_H-R_L)\right)+(1-\mu)\left(\frac{1}{2}\delta\mu K(R_H-R_L)\right)\right] \\ &\quad +\beta^2\left[\begin{array}{c}\mu^2(\delta\mu(1-\mu)K(R_H-R_L)) \\ + \\ 2\mu(1-\mu)\left(\frac{1}{2}K(R_H-R_L)+\delta\mu(1-\mu)K(R_H-R_L)\right) \\ + \\ (1-\mu)^2(\delta\mu(1-\mu)K(R_H-R_L))\end{array}\right] \\ &= (1+\delta)\left[\beta(1-\beta)\mu+\beta^2\mu(1-\mu)\right]K(R_H-R_L)>0 \end{aligned}$$

Allocative efficiency under second-best integration is given by

$$\begin{aligned} A_{2I}^{SB} &= (1-\beta)^2[KR_L+\delta KR_L] \\ &\quad +2\beta(1-\beta)\left[\mu\left(\frac{1}{2}KR_L+\frac{1}{2}KR_H+\delta KE[R]\right)+(1-\mu)(KR_L+\delta KE[R])\right] \\ &\quad +\beta^2\left[\mu^2(KR_H+\delta KE[R])+2\mu(1-\mu)(KR_H+\delta KE[R])+(1-\mu)^2(KR_L+\delta KE[R])\right] \end{aligned}$$

The difference between A_{2I}^{SB} and A_{2I}^{FB} is given by

$$\begin{aligned} A_{2I}^{SB} - A_{2I}^{FB} &= -2\beta(1-\beta)\left[\mu\left(\frac{1}{2}K(R_H-R_L)\right)\right]-\beta^2[\delta\mu(1-\mu)K(R_H-R_L)] \\ &= -\left[\beta(1-\beta)\mu+\delta\beta^2\mu(1-\mu)\right]K(R_H-R_L)<0 \end{aligned}$$

The difference between A_{2I}^{SB} and A_{2S} is given by

$$\begin{aligned} A_{2I}^{SB} - A_{2S} &= 2\beta(1-\beta)\left[\mu\left(\frac{1}{2}\delta K(R_E-R_L)\right)+(1-\mu)\left(\frac{1}{2}\delta K(R_E-R_L)\right)\right] \\ &\quad +\beta^2\left[2\mu(1-\mu)\left(\frac{1}{2}K(R_H-R_L)\right)\right] \\ &= \left[\beta^2\mu(1-\mu)+\delta\beta(1-\beta)\mu\right]K(R_H-R_L)>0 \end{aligned}$$

Allocative efficiency for three managers in the mixing region (region II) is given by

$$\begin{aligned} A_{3I}^{SB} &= (1-\beta)^3[KR_L+\delta KR_L] \\ &\quad +3\beta(1-\beta)^2\left[\mu\left[\frac{2}{3}KR_L+\frac{1}{3}KR_H+\delta KR_E\right]+(1-\mu)\left[\begin{array}{c}\alpha\left(KR_L+\delta\left(\frac{2}{3}KR_L+\frac{1}{3}KR_E\right)\right) \\ +(1-\alpha)(KR_L+\delta KR_E)\end{array}\right]\right] \\ &\quad +3\beta^2(1-\beta)\left[\begin{array}{c}\mu^2\left[\frac{1}{3}KR_L+\frac{2}{3}KR_H+\delta KR_E\right] \\ + \\ 2\mu(1-\mu)\left[\alpha\left(\frac{2}{3}KR_L+\frac{1}{3}KR_H+\delta KR_E\right)+(1-\alpha)\left(\frac{1}{2}KR_L+\frac{1}{2}KR_H+\delta KR_E\right)\right] \\ + \\ (1-\mu)^2\left[\begin{array}{c}\alpha^2\left(KR_L+\delta\left(\frac{1}{3}KR_L+\frac{2}{3}KR_E\right)\right) \\ +2\alpha(1-\alpha)(KR_L+\delta KR_E)+(1-\alpha)^2(KR_L+\delta KR_E)\end{array}\right]\end{array}\right] \\ &\quad +\beta^3\left[\begin{array}{c}\mu^3[KR_H+\delta KR_E] \\ + \\ 3\mu^2(1-\mu)\left[\alpha\left(\frac{1}{3}KR_L+\frac{2}{3}KR_H+\delta KR_E\right)+(1-\alpha)(KR_H+\delta KR_E)\right] \\ + \\ 3\mu(1-\mu)^2\left[\begin{array}{c}\alpha^2\left(\frac{2}{3}KR_L+\frac{1}{3}KR_H+\delta KR_E\right) \\ +2\alpha(1-\alpha)\left(\frac{1}{2}KR_L+\frac{1}{2}KR_H+\delta KR_E\right)+(1-\alpha)^2(KR_H+\delta KR_E)\end{array}\right] \\ + \\ (1-\mu)^3[KR_L+\delta KR_E]\end{array}\right] \end{aligned}$$

Allocative efficiency under the rigid scheme is given by

$$\begin{aligned}
A_{2I}^{RS} &= (1-\beta)^2 \left[\nu\left(KR_L\right)+(1-\nu)\left(KR_L\right)\right] \\
&+2\beta(1-\beta)\left[\begin{array}{c}\mu\left(\nu\left[KR_H\right]+(1-\nu)\left[\frac{1}{2}KR_H+\frac{1}{2}KR_L\right]\right)\\ + \\ (1-\mu)\left(\nu\left[KR_L\right]+(1-\nu)\left[KR_L\right]\right)\end{array}\right] \\
&+\beta^2\left[\begin{array}{c}\mu^2\left(\nu\left[KR_H\right]+(1-\nu)\left[KR_H\right]\right)\\ + \\ 2\mu(1-\mu)\left(\nu\left[KR_H\right]+(1-\nu)\left[\frac{1}{2}KR_H+\frac{1}{2}KR_L\right]\right)\\ + \\ (1-\mu)^2\left(\nu\left[KR_L\right]+(1-\nu)\left[KR_L\right]\right)\end{array}\right] \\
&+\delta\left[\begin{array}{c}(1-\beta)^2\left(KR_L\right)\\ + \\ 2\beta(1-\beta)\left(\mu\left[KR_E\right]+(1-\mu)\left[\frac{1}{2}KR_E+\frac{1}{2}KR_L\right]\right)\\ + \\ +\beta^2\left(\mu^2\left[KR_E\right]+2\mu(1-\mu)\left[KR_E\right]+(1-\mu)^2\left[KR_E\right]\right)\end{array}\right]
\end{aligned}$$

A.4 n-Manager Competition

I analyze the nature of equilibria where type-B managers choose to exaggerate with probability α. As argued in the previous section, whenever type-B managers are just indifferent between exaggerating and not exaggerating, type-C managers will choose to exaggerate. Also as argued in the previous sections, type-A managers have nothing to benefit from announcing l so they always announce h.

In what follows, subscripts i, j, and k denote

$$\begin{aligned}
i &= \text{number of type-A or type-B agents out of } n-1 \text{ competing agents} \\
j &= \text{number of type-B agents out of } i \\
k &= \text{number of type-B agents announcing } h \text{ out of } j
\end{aligned}$$

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

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

where

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

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

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

where

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

Without loss of generality, normalize $u\left(i,j,k,l\right)$ and $u\left(i,j,k,h\right)$ by KR_L. Then

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

and

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

To find α, set the two payoffs equal to each other. The result is a polynomial of order $n-2$.

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

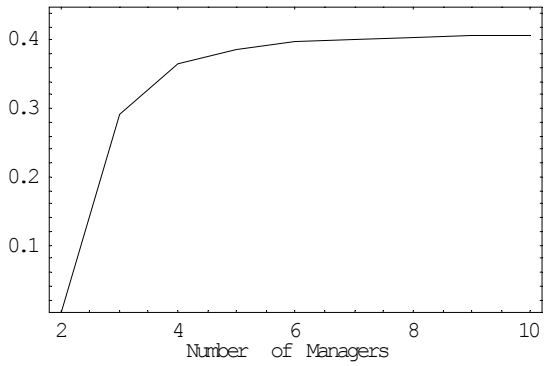
Polynomial coefficients are given by

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

The polynomial has $n-2$ roots, some of them real, some of them imaginary. Numerical analysis shows that the real roots increase as n increases.

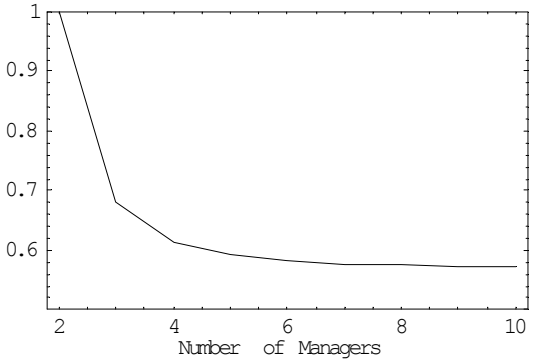
$$\alpha'(n) > 0$$

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



Mixing Probability α

In addition, the next graph shows how the space of parameters for β, where the mixing equilibrium arises, expands with n.



Mixing Parameter Space for β

A.5 Incentive Contracts

In this section, I formalize the idea that incentive contracts necessary to achieve truthful reporting can be very expensive, even with only two managers. 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 in my model the only profitable deviation for a manager 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.

Solving the model backwards, the payment necessary in period 2 to induce truthful reporting by a manager, who has a bad project and is facing another manager with a posterior probability p of being good, is

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

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

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

Note that the payment necessary to induce truthful reporting by 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

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

Substituting in w_1 and w_2 yields

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

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