Essays in Organizational Economics

by

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Abstract

This thesis consists of three theoretical essays that examine the role of organizational architecture in facilitating organizational adaptation to a changing environment.

Chapter 1 develops a model of coordinated adaptation where an organization needs to respond to incoming information about its environment while at the same time retaining coordination between its activities. It analyzes how the allocation of decision rights inside the organization impacts the quality of decision-making and the accuracy of information transmission when information is both soft and distributed inside the organization. The results show that, contrary to the common intuition, the performance differential between centralized and decentralized decision-making is non-monotone in the importance of coordination. Further, both of these common structures are dominated by asymmetric structures in sufficiently asymmetric environments. Finally, if the incentive conflicts between the participants can be made sufficiently small, centralized decision-making is always dominated by decentralized decision-making.

Chapter 2 extends the model developed in Chapter 1 to account for the endogeneity of incoming information and the use of monetary incentives to manage incentive conflicts inside the organization. Focusing on the distinction between centralized and decentralized decision-making, the chapter examines how monetary incentives and the allocation of decision rights can be used to together to motivate information acquisition, support accurate communication and to guide decision-making. The results illustrate the robustness of the conclusions of Chapter 1 to the introduction of monetary incentives. In particular, centralization of decision-making authority is preferred only when coordination is sufficiently important and incentive alignment is too costly in terms of the compromised quality of incoming information.

Chapter 3 analyzes a simplified two-party decision-making problem with a single decision and examines how environmental uncertainty, quality of available performance measures and interim access to information influence the joint determination of the allocation of authority, use of performance pay and direct controls. It uses the results from the model to cast light on (i) the conflicting empirical evidence on the risk-incentives trade-off found in work on executive compensation and franchising, (ii) complementarities in organizational design and (iii) the determinants of the choice to delegate.

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Contents

Chapter 1

Governing Adaptation

Abstract

To remain competitive, an organization needs to continuously respond to incoming information about its environment while at the same time retaining coordination between its activities. We analyze how the allocation of decision rights within an organizational hierarchy influences the organization's ability to solve such problems of coordinated adaptation when decision-relevant information is both soft and distributed inside the organization. By modeling the organizational participants as strategic actors, we endogenize both the equilibrium decisions and the quality of information, as driven by the allocation of decision rights and the relative importance of coordination. The results show that, contrary to the common intuition, the performance differential between centralized and decentralized decision-making is non-monotone in the importance of coordination. Further, both of these common structures are dominated by asymmetric structures in sufficiently asymmetric environments. Finally, if the incentive conflicts between the participants can be made sufficiently small, centralized decision-making is always dominated by decentralized decision-making.

1.1 Introduction

To remain competitive, an organization needs to continuously respond to incoming information about its environment while at the same time retaining coordination between its activities. As an example, consider the problem of product development and positioning faced by a multi-product firm. To reap the benefits of specialization, each product is managed by a dedicated division, headed by a division manager. In the course of their duties, each division manager learns information about her customers, technological developments and market conditions. Now, a unilateral response to such information, say, in terms of new product offerings, can clearly be profitable, but additional benefits can be realized by coordinating the responses of the various divisions. First, cost economies can be realized by coordinating manufacturing, marketing and distribution. Second, if the products are complements, then ensuring that the related products work well together increases the customers' valuation of the products. Third, if the products are substitutes, then coordination is needed to ensure that the products are sufficiently *far* apart to avoid unnecessary cannibalization. Fourth, even if the products are independent, coordinating the product offerings can help the firm to maintain or generate brand value. Thus, while unilateral adaptation can be profitable, coordinated adaptation is typically even more valuable.

Achieving such coordinated adaptation poses an organizational challenge because three factors interact. First, specialization (by technology, region, customer group, or the like) means that decision-relevant information is distributed inside the organization, rather than being directly accessible to any single potential decision-maker. Second, much of that information is "soft," rather than communicable as hard facts. Third, different members of the organization are likely to have conflicting preferences over the possible courses of action. The distributed nature of information necessitates the transmission of information from the informed agents to the decision-maker(s). Misalignment of preferences between the informed agents and the decision-maker(s) generates the problem of strategic communication, which in turn is amplified by the prominence of soft information. Similarly, any misalignment of the preferences of the decision-maker(s) with the organizational objectives will lead to suboptimal decisions, even conditional on the information available.

Returning to our example, the optimal positioning of each product will depend on information held by all division managers (distributed information). Communicating one's opinion about customer preferences may be relatively easy, whereas providing verifiable information is significantly harder (soft information). Finally, the division managers are likely to prefer, even at the expense of overall firm profitability, product offerings that are particularly profitable for their own division, because of both private benefits and existing compensation structures (conflicting preferences).

This paper constructs a model of such problems of coordinated adaptation and analyzes how the importance of coordination among the organization's activities impacts the relative performance of different governance structures. We consider an organization in which two activities need to balance responding to local conditions and being coordinated with each other. Control of the activities can be allocated among two privately informed but biased local agents (division managers) and an uninformed but unbiased central manager (headquarters). We analyze four distinct governance structures. Under *decentralized authority*, each local agent retains the decision right over his own activity, while under *centralized authority*, both decision rights are allocated to the central manager. These two governance structures accord well with what are commonly discussed as decentralized and centralized decision-making, respectively. In addition to these symmetric structures, we also analyze the solution under *partial centralization*, where one of the decision rights is allocated to the central manager, while the other remains in the hands of a local agent, and *directional authority*, where both decision rights are allocated to one of the local agents.

Under any governance structure, the local agents first learn their local conditions, after which they communicate with the decision-maker(s), followed by decision-making. By considering strategic behavior by the organizational participants, we endogenize both the quality of decision-making, conditional on the information available to the decision-maker(s), and the accuracy of information transmission, as influenced by the allocation of decision rights and the underlying environment. Motivated by the importance of soft information, communication is modeled as a cheap-talk game. While we build on the seminal work of Crawford and Sobel (1982), in our framework, the degree of incentive conflict between the sender and the receiver (and so the quality of communication) arises endogenously from the allocation of decision rights and the relative importance of coordination.

We show how all four governance structures can be characterized by a single solution that takes as its primitives the allocation of decision rights and the pairwise incentive conflicts between the organizational participants. A key feature of the solution is the linking of the value and quality of information transmission with the equilibrium decisions, which allows us to analyze the expected performance of each governance structure simply in terms of the quality of decision-making and the value and quality of communication. The focus of the analysis is then on understanding how these two dimensions of performance are influenced by the relative importance of coordination for each of the two activities under each governance structure.

The results offer three qualifications to the common intuition that centralized decision-making is needed when coordination is sufficiently important and, in consequence, suggest that the term "importance of coordination" is too coarse for deriving organizational implications.

First, coordination poses an organizational challenge only when it needs to balance conflicting demands for adaptation. This observation is highlighted by the result that while centralized authority does dominate decentralized authority whenever coordination is sufficiently important to either activity, the performance differential itself is non-monotone, with the two solutions converging both when coordination becomes unimportant and when coordination becomes the overriding concern. When coordination becomes unimportant, the vertical conflict (between a local agent and the manager) is reduced and the local agents become increasingly able to communicate accurately with the manager, thus eliminating the initial informational advantage of decentralized authority. Alternatively, when coordination becomes the primary concern for at least one of the activities, the horizontal conflict (between the two local agents) is reduced and the local agents become increasingly able to coordinate their behavior under decentralized authority, thus eliminating the decisional advantage of centralized authority.

Second, one needs to account for potentially asymmetric interdependencies between activities, because such asymmetries impact the relative value of accurate communication and decision-making for the two divisions. This observation is highlighted by the result that both centralized and decentralized authority are dominated by one or both of the asymmetric governance structures in sufficiently asymmetric environments. Partial centralization can be optimal under two conditions: centralizing the activity with lower importance of coordination can be used to improve decision-making relative to decentralized authority while compromising the overall adaptiveness less than under centralized authority; alternatively, centralizing the activity with higher importance of coordination can be used to facilitate communication by *increasing* the bias in the equilibrium decisions. And directional authority can be opimal when one activity cares primarily about coordination, in which case both decision rights are allocated to the agent with *lower* importance of coordination to eliminate any residual coordination failures, even if this improvement is achieved at the cost of even more biased decisions.

Third, one needs to account for the distribution of the costs and benefits of coordination among the organizational participants themselves (as separate from the underlying environment), because this distribution influences the participants' alignment of interests both with each other and with the organizational objectives. This observation is highlighted by the result that incentive alignment and centralization are substitutes: while both centralized and decentralized authority benefit from increased incentive alignment, with both benefiting from more accurate communication and decentralized authority enjoying the added advantage of improved decision-making, the rate of improvement is higher under decentralized authority. Indeed, centralized authority is eliminated as an equilibrium outcome strictly before perfect incentive alignment is achieved.

The remainder of this chapter is organized as follows. Section 2 reviews the related literature and section 3 describes the model. Section 4 derives the solution under decentralized authority. Drawing on the general solution presented in Appendix A, section 5 repeats the analysis for the alternative governance structures, focusing on how the solutions differ from the solution under decentralized authority. The results are then brought together in section 6 for comparative institutional analysis. Section 7 discusses some extensions, including the impact of incentive alignment on the relative performance of the analyzed governance structures. Section 8 concludes.

1.2 Related literature

In viewing the organizational problem as one of coordinated adaptation under distributed information, the paper is intellectually indebted to the analysis of decision-making, authority and adaptation by, among others, Barnard (1938), Simon (1947), Cyert and March (1963) and Williamson (1975).[1] However, these descriptive theories are significantly broader in scope and blend in their discussion incentive conflicts, bounded rationality and technological considerations. In contrast, our analysis focuses purely on the impact that incentive conflicts among the organizational participants have on decision-making and communication in organizations and thus on the choice of governance structure.

Methodologically, we build on the seminal work of Crawford and Sobel (1982) (henceforth CS) on cheap talk. We maintain the assumption that the actors are unable to commit to a decision rule ex ante, but instead of examining information transmission from an informed agent with a known, fixed preference bias to an uninformed principal, we analyze a setting where the preference bias is random and where the use of a "principal" is a governance choice. In allowing the possibility of full agreement between the sender and the receiver(s), the communication equilibrium is analogous to Stein (1989) and Melumad and Shibano (1991). In our focus on multiple senders, we are closer to Battaglini (2002), but instead of each sender observing full, multidimensional information, the agents in our model observe only partial and independent information, making truth-telling impossible. Further, since we allow the agents to communicate also with each other, our model distiguishes between vertical and horizontal communication.

A number of recent papers are closely related to ours in their focus on organizational design and, in particular, on the roles of private information and communication in influencing the optimal allocation of decision rights. Dessein (2002) analyzes the CS setting and illustrates how delegation of the decision right is often preferred over the communication equilibrium because

[1] And similar considerations within the modern capabilities literature, especially Langlois and Robertson (1993,1995).

the cost of inaccurate information caused by strategic communication is often higher than the cost of biased decision-making. However, by focusing on a single decision, the model remains silent on issues of coordination. Alonso (2006) illustrates how sharing control of complementary decisions improves communication between an informed agent and an uninformed principal. However, the model does not allow for distributed information, which is central to our model.

Dessein and Santos (2006) examine a team-theoretic model that focuses on the limitations that the need for coordinated adaptation imposes on task specialization. However, by taking a team-theoretic approach with a fixed quality of communication, the model has no explicit role for authority.[2] In contrast, our model is about how different allocations of authority influence the organization's ability to achieve coordinated adaptation, given the degree of specialization.

Athey and Roberts (2001), Dessein, Garicano and Gertner (2005) and Friebel and Raith (2006) provide complementary perspectives on organizational design.[3] Athey and Roberts (2001) examine an incentive provision problem where two agents need to be induced to provide productive effort and make good project choices. By allocating the right to choose projects to a third party, the inherent multitasking problem can be relaxed. Dessein, Garicano and Gertner (2005) examine how the optimal allocation of a synergy implementation decision among a functional manager (who learns the value of potential synergies) and two product managers (who learn the cost of synergy implementation in terms of compromised local adaptation) depends on the value of synergies, the value of local adaptation and the importance of productive effort exerted by the agents. Friebel and Raith (2006) examine a resource allocation problem, where two local agents exert effort to generate high-quality projects and the amount of resources available to them can be determined either ex ante (decentralization) or ex post by a central agent (centralization). In all three models, the basic tension is between strong local incentives to induce effort and balanced global incentives to induce truthful communication and/or good decisions. However, none of these models contain multiple, interdependent decisions and thus do not capture the inherent give-and-take process of strategic decision-making that is at the heart of our model.

Finally, Alonso, Dessein and Matouschek (2006) (henceforth ADM) have independently developed a model that is very similar to ours but analyze only the case of symmetric importance of coordination. Our results generalize the framework to allow for asymmetric importance of coordination and the general solution provides a unified treatment of the four governance structures. In consequence, we focus more on the impact that asymmetries in the importance of coordination have on the choice of governance structure, while the focus in ADM is on impact of the degree of incentive alignment. Further, the explicit separation of the importance of coordination to the two activities allows us to gain a more detailed understanding of how the two activities interact, both in the decision-making and in the communication stages. Chapter 2 of this thesis extends the present framework to account for endogeous incentive alignment and active information acquisition.

[2]Team-theoretic models have been used to examine organizational structures and hierarchies from various different angles: information processing (e.g. Marshak and Radner (1972), Bolton and Dewatripont (1994)), problem-solving (e.g. Garicano (2000)), screening for interdependencies (Harris and Raviv (2002)), asset utilization (Hart and Moore (2005)) and coordination and experimentation (Qian, Ronald and Xu (2006)).

[3]See also Aghion and Tirole (1997) and Hart and Holmström (2002).

1.3 The model

1.3.1 Payoffs, actors and feasible governance structures

We examine the problem of coordinating the decision-making processes of two activities, i and j. The ex post loss incurred in the performance of activity i (and borne by agent i) is given by

$$L_i = (1 - r_i)(\theta_i - d_i)^2 + r_i (d_j - d_i)^2,$$

where d_i and d_j stand for the decisions chosen for activities i and j, and $\theta_i \sim U\left[-\overline{\theta}_i, \overline{\theta}_i\right]$ indexes the locally optimal decision, with θ_i and θ_j independently distributed.[4] The exogenous variable of interest in the analysis is $r_i \in (0, 1)$, which captures the degree of interdependence of activity i on activity j and so the relative importance of coordination to activity i. We will refer to r_i as the degree of *dependency* of activity i.[5] We will refer to $(\theta_i - d_i)^2$ as the *adaptation component* and to $(d_j - d_i)^2$ as the *coordination component* of the loss L_i.

Associated with each activity is a local agent (i and j, respectively). Only agent i has direct access to information about θ_i and his ex post loss is given by L_i. In addition to the local agents, there exists a central agent whom we will call the manager (indexed by M). The manager has no direct access to information about either θ_i or θ_j and her objective is to minimize $L_i + L_j$.

Four observations are worth making regarding the payoff structure. First, while we measure coordination by the decisions being close together, being "close" can conceptually mean both being sufficiently close (to realize functional complementarities) and being sufficiently far apart (to avoid cannibalization). Second, there is no additional focal point for coordination. Instead, the hypothetical ideal point is given simply by the joint realization of θ_i and θ_j. This approach is used to capture the idea that especially with demand-side interdependencies, to realize the benefits of coordination, the amount of coordination typically matters more than the focal point for coordination. Note that this argument is not saying that the focal point of coordination does not matter for the *overall* payoffs. What it is saying is that the ideal point of coordination is determined by the private information held by the local agents rather than by any outside considerations.[6] Third, the local agents do benefit directly from coordination. However, they don't internalize the costs and benefits of coordination to the other agent and it is this externality that leads the local agents to disagree on both the focal point and the degree of coordination and that generates the problems of strategic communication and decision-making. Fourth, to keep the intuition behind the results simple, we will discuss the results in detail only under the assumption of maximal degree of incentive conflict (agent i cares only about L_i). We return to the role of incentive alignment in section 7.3.

Within this framework, we analyze four distinct governance structures, which are summarized in figure 1-1. Letting $\mathbf{d}^k$ denote the set of decision rights allocated to an agent, with

[4] Since minimizing loss is equivalent to maximizing profit, this loss formulation is identical to an ex post profit formulation of $\Pi_i = K_i - (1 - r_i)(\theta_i - d_i)^2 - r_i (d_i - d_j)^2$, as long as K_i is sufficiently large so that the activity is worth undertaking. To simplify the notation, we focus on the loss formulation.

[5] The setting where the weights are not constrained to add up to one is discussed in Appendix B.

[6] For example, a brand can be built around product i or product j. The ideal location and the strength of the brand is likely to depend more on the consumers' valuations of different types of product i and product j (realized θ_i and θ_j) than any outside considerations.

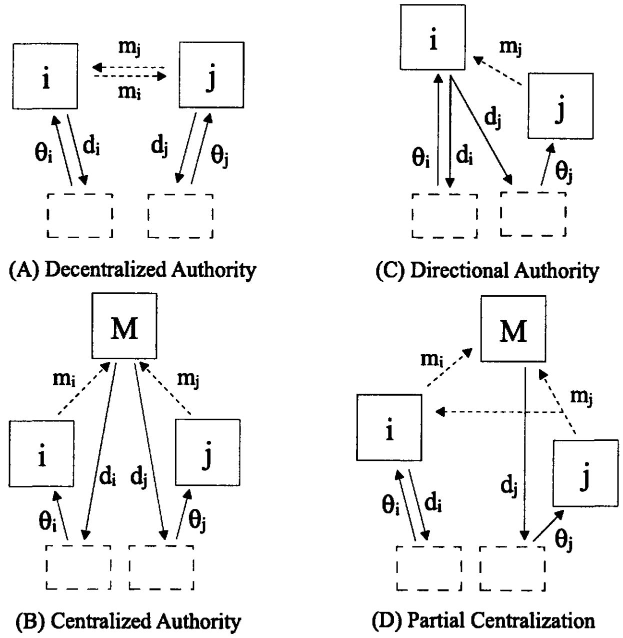


Figure 1-1: Alternative governance structures

$k \in \{i, j, M\}$, the alternatives are: *decentralized authority*, where each local agent decides how their activity is to be performed ($\mathbf{d}^i = \{d_i\}, \mathbf{d}^j = \{d_j\}, \mathbf{d}^M = \{\varnothing\}$); *centralized authority*, where both decision rights are allocated to the manager ($\mathbf{d}^i = \{\varnothing\}, \mathbf{d}^j = \{\varnothing\}, \mathbf{d}^M = \{d_i, d_j\}$); *partial centralization*, where one decision right is centralized while the other is left local ($\mathbf{d}^i = \{d_i\}, \mathbf{d}^j = \{\varnothing\}, \mathbf{d}^M = \{d_j\}$); and *directional authority*, where both decision rights are allocated to one of the local agents ($\mathbf{d}^i = \{d_i, d_j\}, \mathbf{d}^j = \{\varnothing\}, \mathbf{d}^M = \{\varnothing\}$).[7][8] These governance structures are indexed by $g \in \{dec, cent, part(j), dir(i)\}$. In the case of partial centralization, j refers to the centralized activity, while in the case of directional authority, i refers to the local agent gaining control over both activities.

[7]These four governance structures span the set of single-agent, unconditional decision-making structures that can arise in equilibrium. Governance structures where agent i would control d_j without also controlling d_i are never optimal in our model.

[8]This somewhat unorthodox terminology is adapted because under partial centralization, decision-making is decentralized in the sense that the two decisions are made by two different actors, and under directional authority, decision-making is centralized in the sense that the two decisions are made by the same agent. Since these solutions are qualitatively different from centralized and decentralized authority, we cannot simply talk about differences between centralized and decentralized decision-making.

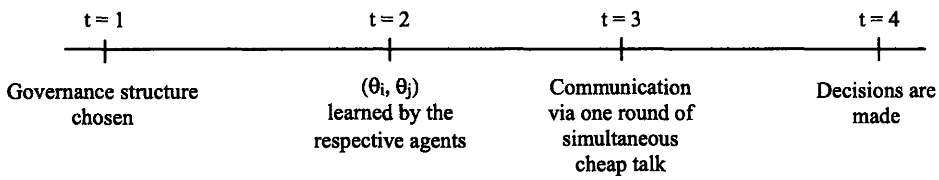


Figure 1-2: Timing of events

1.3.2 Timing of events

The timing of events and the actions available to the agents are summarized in figure 1-2. At $t = 4$, decisions are made by the actors controlling the decision rights in the chosen governance structure. Let m_i and m_j be the messages sent by the local agents (regarding the realization of θ_i and θ_j, respectively) at $t = 3$ to the decision-maker(s). Then, the local agent i solves

$$\min_{\mathbf{d}^i} E\left(L_i|\theta_i, m_i, m_j\right),$$

where $\mathbf{d}^i$ is the (potentially empty) set of decision-rights held by agent i under a given governance structure. Similarly, the manager solves

$$\min_{\mathbf{d}^M} E\left(L_i + L_j|m_i, m_j\right),$$

where $\mathbf{d}^M$ is the (potentially empty) set of decision-rights held by the manager under a given governance structure.[9]

At $t = 3$, communication takes place, which is modeled as one round of simultaneous cheap talk.[10] Foreseeing how equilibrium decisions are formed at $t = 4$ and how they are influenced by additional information, the local agents strategically send non-verifiable messages to the decision-maker(s) in an attempt to induce a more favorable equilibrium outcome. No interim contracting on the decisions or renegotiation of the governance structure is allowed. At $t = 2$, the local conditions θ_i and θ_j are learned by the respective local agents.

For each governance structure, we solve for the Perfect Bayesian Equilibrium of this game: in each stage, the actions of the agents need to be optimal given their beliefs and those beliefs need to be correct in equilibrium. At $t = 1$, the governance structure is chosen to minimize the

[9] Results allowing for the possibility of sequential decision-making are available from the author on request. While sequential decision-making can under some environments be used to improve the outcome under both decentralized authority and partial centralization, the qualitative results regarding the relative performance of the different governance structures are not strongly affected. The main difference is that sequential decision-making under decentralized authority always dominates directional authority.

[10] Results allowing for the possibility of sequential communication are available from the author on request. Sequential communication is not preferred over simultaneous communication unless the variances are extremely asymmetric, in which case sequential decision-making would do even better. Further, the intended first-mover prefers to talk first over talking simultaneously only when sequential communication performs worse, making beneficial sequential communication not incentive-compatible.

total expected loss $E(L_i+L_j)$. We follow the incomplete contracting tradition in assuming that no state- or message-contingent contracts on either decisions or decision rights are available at $t=1$.

1.4 Decentralized authority

We will begin the analysis by deriving the solution under decentralized authority, where each local agent retains control over his activity. We first solve for the equilibrium decisions given the information available to the agents. Having the equilibrium decisions, we then solve for the highest sustainable quality of communication, which is directly dependent on the equilibrium decisions. Having the equilibrium decisions and the quality of communication, we will then analyze the expected performance of decentralized authority relative to the first-best outcome (decisions that minimize $E\left(L_i+L_j\right)$ under perfect information). Section 5 repeats this exercise for the alternative governance structures. The comparative analysis of the governance structures is summarized in section 6. Throughout sections 4 and 5, we analyze $E\left(L_i^g+L_j^g\right)$ under the assumption that $\overline{\theta}_i=\overline{\theta}_j$. The impact of asymmetric variances is discussed in section 6.1.

1.4.1 Equilibrium decisions

At the decision-making stage, the information available to agent i consists of (i) the realization of his local state θ_i, (ii) message m_j received from agent j, used by agent i to form beliefs over θ_j (denoted $E_i\theta_j$), and (iii) message m_i sent to agent j, used by agent j to form beliefs over the realization of θ_i ($E_j\theta_i$). Given this information, agent i solves

$$\min_{d_i} E_i\left(\left(1-r_i\right)\left(\theta_i-d_i\right)^2+r_i\left(d_j-d_i\right)^2\right).$$

Taking the first-order conditions and rearranging gives the reaction functions for the two decisions:

$$d_i=\left(1-r_i\right)\theta_i+r_iE_id_j \qquad \text{and} \qquad d_j=\left(1-r_j\right)\theta_j+r_jE_jd_i.$$

Solving the reaction functions for the equilibrium decisions yields the following proposition:

Proposition 1 ***Equilibrium decisions under decentralized authority:***

$d_i^{dec}=\left(1-r_i\right)\theta_i+\frac{(1-r_j)r_i}{(1-r_ir_j)}E_i\theta_j+\frac{(1-r_i)r_ir_j}{(1-r_ir_j)}E_j\theta_i.$

Proof. Special case of proposition 9. ■

Note that the equilibrium decisions take the form $d_i^{dec} = a_{i1}\theta_i + a_{i2}E_i\theta_j + a_{i3}E_j\theta_i$ (with $a_{i1} + a_{i2} + a_{i3} = 1$). Indeed, this structure of the solution is the same under all analyzed governance structures, but with structure-specific coefficients a_{i1}^g, a_{i2}^g, and a_{i3}^g. Also, observe that $E_i\theta_j$ and $E_j\theta_i$ will be based solely on the messages m_j and m_i exchanged at $t = 3$, and as a result the quality of decisions will depend on the accuracy of communication. However, before analyzing the accuracy of communication that the agents can sustain in equilibrium, let us first consider briefly how the equilibrium responses of d_i and d_j to information about θ_i are determined, to better understand the role of communication under decentralized authority.

Having observed θ_i and absent any communication (so that $E_id_j = E_jd_i = 0$), agent i's decision would be given by $d_i = (1 - r_i)\,\theta_i$. We will refer to the first coefficient of proposition 1, $a_{i1} = (1 - r_i)$, as the *rate of direct adaptation.* By communicating information about the realization of θ_i, agent i is able to improve both the coordination between the decisions *and* the amount of adaptation he is able to achieve. Suppose agent i has sent a message m_i to agent j, inducing a belief $E_j\theta_i$. Because agent j puts weight r_j on coordination, he will accommodate the decision that he expects agent i to make. This accommodation, by improving the coordination between the decisions, allows agent i to further increase the amount adaptation, and so forth. Solving this iterative process gives then the coefficients a_{j2}, which we will refer to as the *rate of accommodation,* and a_{i3}, which we will refer to as the *rate of induced adaptation.* The sum $a_{i1} + a_{i3} = a_{i1+i3}$ will be called simply the *rate of adaptation.* An equivalent process over the beliefs over θ_j determines the weights a_{j1}, a_{i2} and a_{j3}.

Because of the strategic interaction between the decisions, the decisions will in expectation lie somewhere between agent i's preferred decisions $d_i = d_j = \theta_i$ and agent j's preferred decisions $d_i = d_j = \theta_j$. However, how far the equilibrium decisions are from each agent's ideal point depends on how much weight each agent places on coordination and, as a result, on the rates of accommodation. As r_i increases, any adaptation achieved by agent i becomes increasingly dependent on accommodation by agent j. As a result, agent j is able to decrease his rate of accommodation a_{j2} and so move the equilibrium decisions in his favor. Similarly, as r_j increases, the increased dependency of agent j increases his rate of accommodation a_{j2}, allowing agent i to move the equilibrium decisions towards his ideal decisions. Finally, along the diagonal $r_i = r_j = r$, each agent becomes increasingly dependent on the accommodation granted by the other, but at the same time each agent becomes more accommodating: $a_{i2} = a_{j2}$ is increasing in r.

Not only do a_{i2} and a_{j2} play a large role in the determination of the equilibrium decisions, but as we will see below, as a measure of the incentive conflict between the two agents, these coefficients are the sole determinants of the quality of communication by the two agents under decentralized authority.

1.4.2 Equilibrium communication

As discussed above, agent i sends a message m_i about the realization of θ_i to achieve accommodation by d_j, which in turn allows i to achieve more adaptation. The discussion also made apparent the problem that the non-verifiability of information generates in the communication stage. In the decision-making stage, agent i would like to have $d_i = d_j = \theta_i$ and so achieve both perfect adaptation and perfect coordination. On the other hand, agent j's expected response to a message m_i is given by $a_{j2}E_j(\theta_i|m_i)$, where the rate of accommodation a_{j2} is strictly below one for all $r_j < 1$. As a result, if agent j expects agent i to tell the truth, agent i will exaggerate the realized θ_i to induce a higher level of accommodation by agent j, making fully informative communication impossible.

However, as shown by Crawford and Sobel (1982), partially informative communication can still potentially be achieved. This partially informative communication is achieved by partitioning the state-space so that any message m_i reveals only that θ_i belongs to some interval. Intuitively, such partitioning discretizes the response of the recipient so that the sender can be made to choose between an under-response from a lower message and an over-response from a higher message.

From this logic it is clear that for a partition to be incentive-compatible, it needs to be that when the realized state falls on the boundary between two elements (intervals) of the partition, the agent is indifferent between saying that the state belongs to either one of the intervals. That is, it needs to be that

$$E_iL_i\left(\theta_i^M, d_i(., E_j^L\theta_i), d_j(., E_j^L\theta_i)\right) = E_iL_i\left(\theta_i^M, d_i(., E_j^H\theta_i), d_j(., E_j^H\theta_i)\right).$$

Solving this indifference condition gives us the difference equation that defines the family of incentive-compatible partitions:

$$|\theta_{i,k} - \theta_{i,k-1}| - |\theta_{i,k-1} - \theta_{i,k-2}| = \tfrac{4}{\varphi_i^{dec}}|\theta_{i,k-1} - E_i\theta_j|,$$

where $\theta_{i,k}$ are the cutoffs of the partition, with k increasing away from the expected preference intersection $\theta_i = E_i\theta_j$, and

$$\varphi_i^{dec} = \tfrac{a_{j2}}{1-a_{j2}} = \tfrac{r_j(1-r_i)}{(1-r_j)},$$

which uniquely determines the rate at which the size of the intervals needs to grow to counter the increasing incentives for i to exaggerate the realized θ_i. In the case of simultaneous talk, $E_i\theta_j = 0$ before the messages are sent, which we will maintain from now on.

While φ_i^{dec} defines the relative size of two adjacent intervals, it does not yet define the absolute size of the intervals. Solving for the most informative partition, which minimizes the absolute size of the intervals given φ_i^{dec}, gives the following proposition:

Proposition 2 ***Equilibrium quality of communication:***

The cutoffs of the finest incentive-compatible partition are characterized by

$|\theta_{i,n}| = \alpha\left(\varphi_i^{dec}\right)^{|n|}\overline{\theta_i}$ *with* $n \in \{-\infty, ..., -1, 1, ...\infty\}$, *where*

$\alpha\left(\varphi_i^{dec}\right) = \frac{\varphi_i^{dec}}{\left(1+\sqrt{1+\varphi_i^{dec}}\right)^2} \in (0,1)$ *and* $\varphi_i^{dec} = \frac{a_{j2}}{1-a_{j2}} = \frac{r_j(1-r_i)}{(1-r_j)} \in (0,\infty)$.

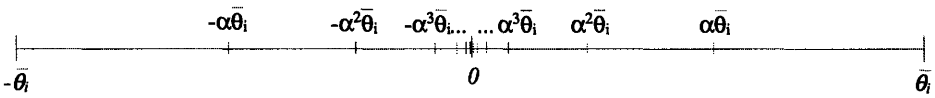


Figure 1-3: Structure of the most informative partition

Proof. Special case of proposition 10. ■

This solution is illustrated in figure 1-3. Note that truth-telling is possible at the point of expected preference intersection: the expected response of the recipient matches the ideal response of the sender. The rate at which the accuracy of messages decreases in $|\theta_i|$ is in turn uniquely determined by φ_i, which we will refer to as the *quality of communication* (by agent i about θ_i). As $\alpha\left(\varphi_i^{dec}\right) \to 1$, communication becomes fully informative, while $\alpha\left(\varphi_i^{dec}\right) \to 0$ implies binomial communication, which is always possible in the present setting due to the partial alignment of interests (i.e. the sender is always able to say whether his realized state is above or below the expected preference intersection).

The quality of communication by agent i is in turn solely determined by the rate of accommodation by the recipient, a_{j2}. This result should be no surprise since, as discussed in section 4.1, it is the rate of accommodation that measures under decentralized authority the degree of conflict between the sender's preferred outcome and the recipient's equilibrium response. The higher the rate of accommodation, the smaller the incentive conflict and the higher the quality of communication that can be sustained. As the recipient becomes perfectly accommodating ($a_{j2} \to 1$), communication becomes perfect. Thus, in addition to influencing the equilibrium decisions, the relative importance of coordination to the two agents (and the resulting rates of accommodation) influence the ability of the agents to share their private information. Indeed, it is exactly *because* the equilibrium decisions vary with the importance of coordination that the quality of communication by each agent varies as well.

Figure 1-4 plots the quality of communication by agent i as a function r_i and r_j. Paralleling the rate of accommodation by agent j, the quality of communication by agent i is increasing in r_j, decreasing in r_i and increasing along the diagonal $r_i = r_j$. Thus, not only does an increase in r_i tilt the equilibrium decisions in favor of agent j, but it also compromises the ability of agent i to share his private information. Communication by agent i is accurate only when he expects the equilibrium decisions to be close to his ideal decisions $d_i = d_j = \theta_i$.

1.4.3 Expected losses

Having derived the equilibrium decisions and the equilibrium quality of communication, we can solve for the expected loss for each activity:

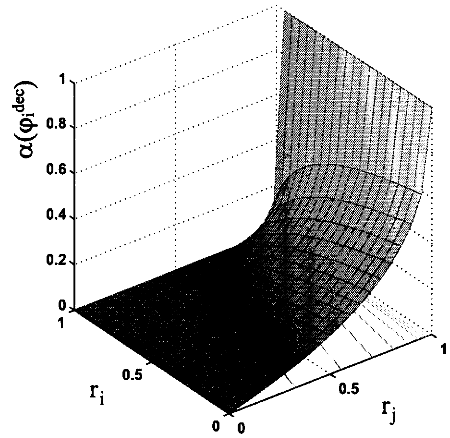


Figure 1-4: Quality of communication by agent i under decentralized authority

Proposition 3 ***Expected Losses under Decentralized Authority:***

$EL_i^{dec} = \Lambda_i^{dec}\left(\overline{\theta}_i^2 + \overline{\theta}_j^2\right) + \Gamma_{i-i}^{dec} V(\varphi_i^{dec})\overline{\theta}_i^2 + \Gamma_{i-j}^{dec} V(\varphi_j^{dec})\overline{\theta}_j^2$, *where*

$\Lambda_i^{dec} = \frac{(1-r_i)r_i(1-r_j)^2}{3(1-r_ir_j)^2}$, $\Gamma_{i-i}^{dec} = \frac{r_i(1-r_i)}{3} - \Lambda_i^{dec}$, $\Gamma_{i-j}^{dec} = \frac{r_i(1-r_j)^2}{3} - \Lambda_i^{dec}$ *and*

$V\left(\varphi_i^{dec}\right)\overline{\theta}_i^2 = \frac{1}{4+3\varphi_i^{dec}}\overline{\theta}_i^2 = 3E\left(\theta_i - E_j\theta_i\right)^2.$

Proof. Special case of proposition 11. ■

We can thus write the expected loss to each activity as being composed of two components. First, the expected loss under perfect information is given by $\Lambda_i^{dec}\left(\overline{\theta}_i^2 + \overline{\theta}_j^2\right)$. Note that Λ_i^{dec} is decreasing in r_j. The more accommodating agent j is, the more the equilibrium decisions favor activity i. Also, $\Lambda_i^{dec} \to 0$ both when $r_i \to 0$ and when $r_i \to 1$. When coordination is unimportant, adaptation to local conditions is only mildly constrained. When coordination is very important, most gains are realized simply by accommodating what agent j is going to do.

Second, the additional expected loss due to strategic communication is given by $\Gamma_i^{dec} V(\varphi_i^{dec})\overline{\theta}_i^2 + \Gamma_j^{dec} V(\varphi_j^{dec})\overline{\theta}_j^2$. Note that the cost of strategic communication is composed of two components. First, φ_i^{dec} measures the quality of communication, as derived above. Second, Γ_i^{dec} measures the *value* of communication. This separation highlights the fact that accurate communication is valuable only if it translates into an improvement in decision-making. In the case of decentralized authority, the value of communication is determined by the cost of *strategic uncertainty* that the agents face over each other's actions. For example, when r_i is very low, agent i's decision is not constrained by accommodation by agent j and neither does he care about coordination. Thus, value of accurate communication about either state is low to agent i. Conversely, when r_i is large and $r_i >> r_j$, then accurate m_j is very valuable to agent i since it allows him to predict what agent j is going to do, while the value of accurate m_i is low since while agent i is highly dependent on accommodation by agent j, at the same time agent j will be very unaccommodating.[11]

To better understand how the expected total loss $E\left(L_i^{dec} + L_j^{dec}\right)$ varies with the environment, define the *relative loss due to biased decisions* by

$$\frac{E\left(L_i^{dec}+L_j^{dec}|\alpha(.)=1\right)-E\left(L_i^{FB}+L_j^{FB}\right)}{E\left(L_i^{FB}+L_j^{FB}\right)}$$

(*i.e.*, the percentage increase in the expected total loss over the first-best outcome when decentralized decision-making is substituted for optimal decisions under perfect information). Similarly, define the *relative loss due to strategic communication* by

$$\frac{E\left(L_i^{dec}+L_j^{dec}|\alpha\left(\varphi^{dec}\right)\right)-E\left(L_i^{dec}+L_j^{dec}|\alpha(.)=1\right)}{E\left(L_i^{FB}+L_j^{FB}\right)}$$

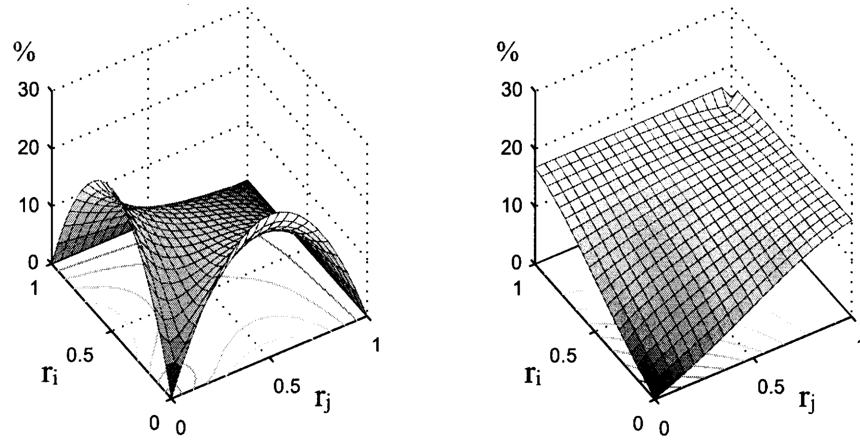
(*i.e.*, the percentage increase in the expected total loss over the first-best outcome when strategic communication is substituted for perfect information under decentralized decision-making). Note that because the expected loss under the first-best outcome is also bound away from zero due to the technological trade-off between adaptation and coordination, any losses must be measured in relation to this standard. The additional normalization by $E\left(L_i^{FB} + L_j^{FB}\right)$ is used to highlight differences in the limit behavior when the absolute loss converges to zero. Thus, it is worth noting that while the discussion below is framed in terms of relative loss, the absolute expected loss does converge to zero both when $r_i, r_j \to 0$ and when r_i and/or $r_j \to 1$. The results are summarized in figure 1-5 and we will discuss each panel separately.

Relative loss due to biased decisions

Panel (i) of figure 1-5 plots the relative loss due to biased decisions. First, observe that the equilibrium decisions converge to first-best both when r_i and $r_j \to 0$, and when r_i and/or $r_j \to 1$. In the first case, each agent is able to make the individually optimal decision as no interdependencies are present. In the second case, as long as at least one agent cares only about coordination, it is optimal to coordinate around the activity that places a positive value on adaptation. Thus, decision-making itself significantly compromises the performance of decentralized authority only when at least one agent faces an intermediate value for coordination and neither agent is extremely dependent on coordination.

The nature and cost of these biases, however, depend on the degree of asymmetry between the agents. Because each agent undervalues coordination, the decisions are in expectation too far apart. When the importance of coordination is relatively symmetric, this translates

[11] $\Gamma_{i-i}^{dec} + \Gamma_{j-i}^{dec} > 0$, so that more accurate communication is always beneficial in terms of the total expected loss. However, it is possible that $\Gamma_{j-i}^{dec} < 0$. The complications that can arise in this case are discussed in section 7.1.



(i) Relative loss due to biased decisions

(ii) Relative loss due to strategic communication

Figure 1-5: Expected performance of decentralized authority

to a situation where each agent undertakes an excessive amount of adaptation. However, as discussed in section 4.1, when the importance of coordination is asymmetric, the less dependent agent is able to pull both decisions in his favor. While this outcome benefits the less dependent agent, it is extremely damaging to the more dependent agent: not only are the decisions under-coordinated, but they are now coordinated around agent i's preferred outcome. In essence, a division that places only a little value on coordination will naturally make choices that are closely tailored to match its local needs, independent of what the other division is doing. As a result, the division that does benefit from coordination is forced to use as the basis for coordination decisions that are highly unsuitable to its local needs, which in turn significantly compromises any possibilities for valuable adaptation.

Relative loss due to strategic communication

Panel (ii) of figure 1-5 plots the relative loss due to biased decisions. Unlike the relative loss due to biased decisions, the relative loss due to strategic communication is almost everywhere increasing in the importance of coordination to either agent, in contrast with the quality of communication discussed in section 4.2. This result follows from our earlier observation that accurate communication is not valuable in itself. It is valuable only to the extent that it improves decision-making. Thus, when both agents face a low importance of coordination, while communication is very inaccurate, it is also unimportant because each agent has direct access to their local information and adaptation is primarily direct (independent of accommodation). Horizontal communication is needed only to improve coordination and to achieve the resulting improvement in adaptation. It is only when coordination becomes more valuable that the inaccuracies in communication start taking their toll. Indeed, while the quality of communication is also increasing in the importance of coordination, it is not increasing fast enough to compensate for the increased relative cost of such coordination failures.

1.5 Alternative governance structures

As shown in Appendix A, the technical structure of the solution under the alternative governance structures is the same as under decentralized authority. In particular, the equilibrium decisions under governance structure g take the form

$$d_i^m = a_{i1}^g E_m\theta_i + a_{i2}^g E_m E_n \theta_j + a_{i3}^g E_n E_m \theta_i,$$

where m and n are the agents controlling the decision right for activities i and j, respectively, with $a_{i1}^g + a_{i2}^g + a_{i3}^g = 1$. Similarly, the indifference condition defining the communication equilibrium under governance structure g takes the form

$$|\theta_{i,k} - \theta_{i,k-1}| - |\theta_{i,k-1} - \theta_{i,k-2}| = \tfrac{4}{\varphi_i^g} |\theta_{k-1}|,$$

and thus the most informative partition is characterized by

$$|\theta_i^n| = \alpha(\varphi_i^g)^{|n|}\,\overline{\theta_i}, \text{ where } \alpha(\varphi_i^g) = \frac{\varphi_i^g}{\left(1+\sqrt{1+\varphi_i^g}\right)^2} \in (0,1).$$

As a result, we will present only the constants φ_i^g. Finally, we can write the expected loss to activity i under governance structure g as

$$EL_i^g = \Lambda_i^g\left(\overline{\theta}_i^2 + \overline{\theta}_j^2\right) + \Gamma_{i-i}^g V(\varphi_i^g)\overline{\theta}_i^2 + \Gamma_{i-j}^g V(\varphi_j^g)\overline{\theta}_j^2.$$

Since the algebraic expressions of the constants $\Lambda_i^g, \Gamma_{i-i}^g$ and Γ_{i-j}^g contain little additional economic intuition, they are presented only in the appendix with proposition 11.

While the structure of the solution is similar across the governance structures, the solutions themselves exhibit significant differences in their expected performance $E\left(L_i^g + L_j^g\right)$. These differences arise for four interrelated reasons. First, the differences in the objective function(s) of the decision-maker(s) across the governance structures translate into systematic differences in the equilibrium decisions. Second, these differences in equilibrium decisions translate into differences in the equilibrium quality of communication by the two local agents. Third, whether agent i retains control of his activity or not directly impacts his qualitative motives for communication and thus his equilibrium quality of communication. Fourth, the differences in equilibrium decisions and the motives for communication translate into differences in the *value* of communication.

Because each governance structure provides a qualitatively different combination of equilibrium decisions and quality and value of communication, the relative performance of each governance structure varies systematically with the underlying environment. In consequence, each governance structure arises as the preferred (second-best) governance structure under specific environmental conditions. In the remainder of the section, we will analyze the equilibrium outcomes under the alternative governance structures of centralized authority, partial centralization and directional authority, focusing on the reasons for and conditions under which each of them can arise as the preferred governance structure. The results of sections 4 and 5 are then brought together in section 6, where figure 1-10 presents the mapping from (r_i, r_j) to the preferred governance structure.

1.5.1 Centralized authority

The outcome under centralized authority is summarized in the following proposition:

Proposition 4 ***Equilibrium under centralized authority:***

The equilibrium decisions under centralized authority are given by

$$d_i^{cent} = \frac{\left(1-r_i^2\right)E_M\theta_i+(r_i+r_j)(1-r_j)E_M\theta_j}{(1+r_i)(1+r_j)-(r_i+r_j)^2}$$

and the quality of communication is determined by

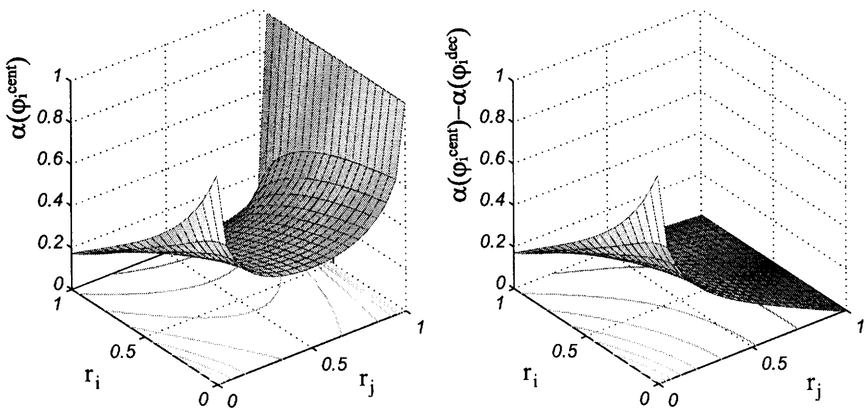
$$\varphi_i^{cent} = \frac{(1-r_i)\left(a_{i1+i3}^{cent}\right)^2+r_i\left(a_{i1+i3}^{cent}-a_{j2}^{cent}\right)^2}{(1-r_i)a_{i1+i3}^{cent}\left(1-a_{i1+i3}^{cent}\right)-r_i\left(a_{i1+i3}^{cent}-a_{j2}^{cent}\right)^2} = \frac{(1-r_i)(1+r_i)^2+r_i(1-r_j)^2}{(1-r_j)\left(r_j+2r_ir_j+r_i^2\right)}.$$

Proof. Special case of propositions 9 and 10. ■

The decisions are, by assumption, optimal conditional on the information available to the manager. The manager, however, has to rely solely on information communicated to her by the local agents and as a result the coefficients of direct and induced accommodation are pooled together in the equilibrium decisions. This difference in the information structure, in turn, alters the incentives for communication.

Recall that under decentralized authority, agent i communicated to induce accommodation by agent j, which both improved coordination and allowed agent i to achieve more adaptation. As a result, the quality of communication was uniquely determined by the rate of accommodation a_{j2}^{dec}. Under centralized authority, sending a message m_i induces adaptation by the manager (with d_i) at the rate a_{i1+i3}^{cent} and accommodation (with d_j) at the rate a_{j2}^{cent}. This change in the qualitative motives for communication generates two primary differences compared to decentralized authority.

First, from the perspective of the adaptation component, it is the rate of adaptation a_{i1+i3}^{cent} instead of the rate of accommodation a_{j2}^{cent} that measures the degree of incentive conflict between the sender (agent i) and the receiver (manager). Intuitively, in the case of decentralized authority, the ability of agent i to achieve adaptation was constrained by the amount of accommodation by agent j. In the case of centralized authority, it is constrained because the agent no



(i) Quality of communication by agent i

(ii) Improvement over decentralized authority

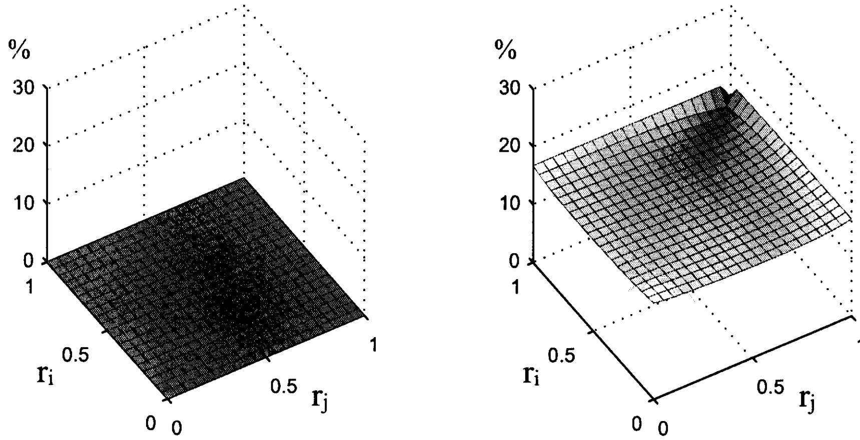
Figure 1-6: Quality of communication by agent i under centralized authority

longer controls the decision and so has to persuade the manager to undertake any adaptation to θ_i.

Second, the coordination component further limits the incentives to exaggerate under centralized authority. This is because $a^{cent}_{i1+i3} - a^{cent}_{j2} > 0$, so that the decisions diverge in $|m_i|$. The constraining influence of the coordination component on agent i's incentive to exaggerate is strongest when r_i is intermediate and r_j is low to intermediate, so that the decisions do diverge significantly with the messages sent *and* the sender cares about it. For low r_i, agent i doesn't care about coordination, while when either r_i or r_j is large, the two decisions remain quite close together, independent of $|m_i|$.

These differences in the motives for communication are reflected in the quality of communication by agent i, summarized in figure 1-6. In particular, we can see that while the quality of communication under centralized authority is always higher than under decentralized authority, this difference is decreasing in the importance of coordination to either agent. In particular, the quality of communication is *decreasing* in $r_i = r_j$ under centralized authority while it is increasing in $r_i = r_j$ under decentralized authority. Under centralized authority, as the importance of coordination increases, the manager becomes less adaptive. This reduction in a^{cent}_{i1+i3} increases the incentive conflict between the manager and agent i and thus worsens the quality of communication. In contrast, under decentralized authority, as the importance of coordination increases, the local agents become increasingly accommodating. This increase in a^{cent}_{j2} in turn leads to an increase the quality of communication. Indeed, the two solutions converge as $r_j = r_i \to 1$.

Figure 1-7 decomposes the expected total loss $E\left(L^{cent}_i + L^{cent}_j\right)$ into the relative loss due to biased decisions and the relative loss due to strategic communication. By assumption, the relative loss due to biased decisions is zero. Also, since the manager controls both decisions, there is no strategic uncertainty in the decision-making stage. However, any inaccuracies in communication now translate directly into *fundamental uncertainty* about the realized states



(i) Relative loss due to biased decisions

(ii) Relative loss due to strategic communication

Figure 1-7: Expected performance of centralized authority

of the world in the decision-making stage: $E\left(\theta_i - E_M\theta_i|m_i\right)^2 > 0$ whenever $\alpha\left(\varphi_i^{cent}\right) < 1$. As a result, while the quality of communication by both local agents is higher under centralized authority, the value of more accurate communication about either state is higher as well. In terms of the expected losses, we can see this by noting that

$$\left(\Gamma_{i-i}^{cent} + \Gamma_{j-i}^{cent}\right) V\left(\varphi_i^*\right) > \left(\Gamma_{i-i}^{dec} + \Gamma_{j-i}^{dec}\right) V\left(\varphi_i^*\right) \ \ \forall r_i, r_j < 1.$$

That is, the net cost of fundamental uncertainty under centralized authority is always higher than the net cost of the *same* level of strategic uncertainty under decentralized authority. This result is reflected in panel (ii), which shows that, despite the higher quality of communication, the relative loss due to strategic communication is almost everywhere higher than under decentralized authority. Even if the quality of communication by both agents tends to perfect as $r_i, r_j \to 0$, it is not increasing fast enough to compensate for the increasing value of communication.

As a result, decentralized authority dominates centralized authority whenever the importance of coordination is sufficiently low to both activities. Conversely, centralized authority dominates decentralized authority whenever the importance of coordination is sufficiently high to either activity. However, this advantage derives solely from the elimination of the bias in the equilibrium decisions. As a consequence, the relative advantage of decentralized authority is largest when at least one activity faces an intermediate value for coordination.

1.5.2 Partial centralization

Under partial centralization, only one of the decisions is centralized. Thus, we need to look separately at the outcomes for the agent retaining control and for the agent losing control. We will discuss the case where activity j is centralized.

Proposition 5 ***Equilibrium under partial centralization (of j):***

The equilibrium decisions are given by

$$d_i^{part(j)} = (1-r_i)\,\theta_i + \frac{r_i(1-r_j)E_iE_M\theta_j + r_i(r_i+r_j)(1-r_i)E_M\theta_i}{(1+r_i)-r_i(r_j+r_i)} \text{ and}$$

$$d_j^{part(j)} = \frac{(1-r_j)E_M\theta_j + (r_j+r_i)(1-r_i)E_M\theta_i}{(1+r_i)-r_i(r_j+r_i)}.$$

The quality of communication by the agent retaining control is given by

$$\varphi_i^{part(j)} = \frac{a_{j2}^{part(j)}}{1-a_{j2}^{part(j)}} = \frac{(r_i+r_j)(1-r_i)}{(1-r_j)},$$

while the quality of communication by the agent losing control is given by

$$\varphi_j^{part(j)} = \frac{(1-r_j)\left(a_{j1+j3}^{part(j)}\right)^2 + r_j\left(a_{j1+j3}^{part(j)} - a_{i2}^{part(j)}\right)^2}{(1-r_j)\left(a_{j1+j3}^{part(j)}\right)\left(1-a_{j1+j3}^{part(j)}\right) - r_j\left(a_{j1+j3}^{part(j)} - a_{i2}^{part(j)}\right)^2} = \frac{1-2r_ir_j+r_i^2r_j}{(1-r_i)r_i(1+r_j)}.$$

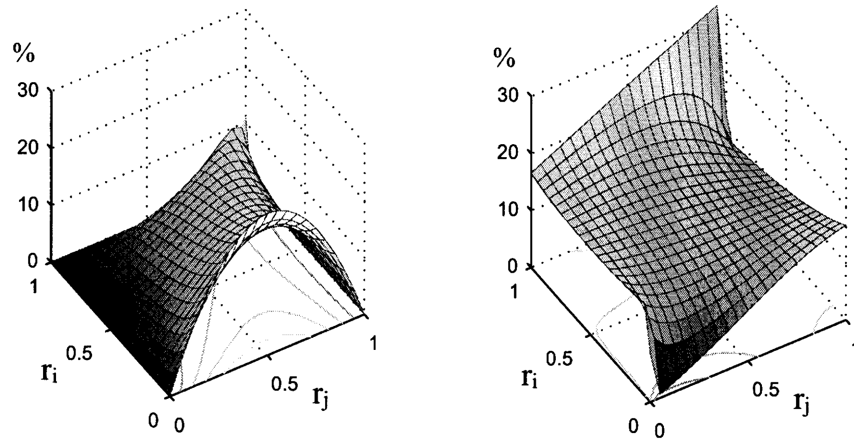
Proof. Special case of propositions 9 and 10. ■

Figure 1-8 decomposes the expected total loss $E\left(L_i^{part(j)} + L_j^{part(j)}\right)$ into the relative loss due to biased decisions and the relative loss due to strategic communication. Consider first the relative loss due to biased decisions. Since agent i undervalues coordination, the equilibrium decisions remain under-coordinated. Also, the equilibrium decisions are always biased in favor of the agent retaining control. To see this result, note that agent i places a weight r_i on coordination while the manager places a weight $r_i + r_j$ on coordination. In consequence, the manager is relatively more accommodating, which in turn allows agent i to pull the equilibrium decisions in his favor.

From the perspective of expected performance, the most important result is that as $r_j \to 0$, the equilibrium decisions under partial centralization converge to optimal decisions. Because the biases in decision-making arise from the local agents not internalizing the value of coordination to the opponent, as $r_j \to 0$, d_i becomes optimal conditional on d_j. Thus, to achieve appropriate decision-making at the limit, it is sufficient to centralize d_j. In general, centralizing the less dependent activity can be used to improve decision-making relative to the decentralized outcome, given a sufficient initial asymmetry.[12] Equivalently, centralizing the more dependent activity will bias the equilibrium decisions even further in favor of the less dependent activity, leading to an even higher relative loss due to biased decisions than decentralized authority.

Describing the relative loss due to strategic communication in detail is somewhat harder because of the asymmetric position of the agents. However, for our purposes, it is sufficient to

[12] Because centralization causes a discrete change in the valuation of coordination by the decision-maker and so in the equilibrium rate of accommodation, the initial asymmetry needs to be sufficiently large as not to tilt the bias in the opposite direction following centralization.



(i) Relative loss due to biased decisions

(ii) Relative loss due to strategic communication

Figure 1-8: Expected performance of partial centralization (of j)

understand when the loss is particularly low. Let us first consider the motives for communication by the two agents. Note that the problem faced by agent i (retaining control) is analogous to the problem he faces under decentralized authority, in that he sends m_i to induce accommodation, but now by the manager. Since the manager is more accommodating than agent j, the quality of communication by agent i is always higher than under decentralized authority. Further, the quality of communication can also be better than under centralized authority. This happens when r_j is large, so that the rate of accommodation is large and the constraining effect of the coordination component under centralized authority would be small.

Similarly, the problem faced by agent j (losing control) is analogous to the problem he faces under centralized authority, in that he sends m_j to induce both adaptation by d_j and accommodation by d_i. The differences are two-fold. First, because of the constraining role played by the agent retaining control, the manager is less responsive to j's messages, increasing the incentive conflict between the manager and agent j. Second, because of the reduced coordination between the decisions, the constraint on exaggeration provided by the coordination component is stronger. As a consequence, the quality of communication by agent j under partial centralization can either dominate his quality of communication under both decentralized and centralized authority, or be dominated by both. It dominates both when r_j is large, so that the amount of adaptation or accommodation achieved by agent j would approach zero under all governance structures and the stronger constraint provided by the coordination component dominates the outcome. In consequence, centralizing a highly dependent activity can improve the quality of communication by both agents.

In terms of the total expected loss, partial centralization dominates both symmetric governance structures under two different conditions. First, as mentioned above, centralizing activity j when r_j is low is sufficient to eliminate most of the bias in the equilibrium decisions under decentralized authority. At the same time, *not* centralizing activity i prevents the introduction of unnecessary fundamental uncertainty into the decision-making process. Because of this containment of the loss due to strategic communication, partial centralization performs better than both centralized and decentralized authority when r_j is small enough and r_i is large enough.

Second, centralizing activity j when r_j is *large* enough will also yield a lower expected total loss than centralized or decentralized authority. Recall that when r_j is large, the primary source of loss under both decentralized and centralized authority is strategic communication. Under decentralized authority, it is the strategic uncertainty faced by agent j in the decision-making stage and, under centralized authority, it is the fundamental uncertainty faced by the manager over θ_i – both caused by inaccurate m_i. Now, as discussed above, centralizing only activity j will increase the bias in equilibrium decisions relative to decentralized authority. But it is exactly this increase in the bias that improves the quality of communication by agent i, reducing the loss due to strategic communication. Further, the quality of communication by agent j is also better or only slightly compromised relative to centralized authority. When r_j is large enough, this improvement in communication dominates the loss caused by the increased bias in the decisions.

1.5.3 Directional authority

Under directional authority, one of the local agents controls both decisions. Assuming that both decisions are allocated to agent i, the following proposition summarizes the outcome:

Proposition 6 ***Equilibrium under directional authority (by i):***

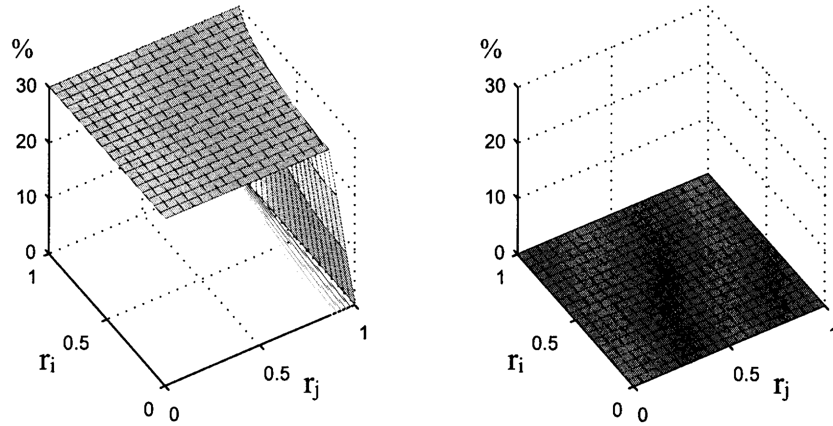
The equilibrium decisions are given by

$$d_i^{dir(i)} = d_j^{dir(i)} = \theta_i,$$

while the quality of communication is indeterminate, as all information sent by agent j is ignored by agent i.

Proof. Special case of propositions 9 and 10. ■

Figure 1-9 decomposes the expected total loss $E\left(L_i^{dir(i)} + L_j^{dir(i)}\right)$ into the relative loss due to biased decisions and the relative loss due to strategic communication. Recall that agent i aims at minimizing only L_i. As a result, if given control of both decisions, he will set both decisions as to optimize his local performance and ignores any messages sent to him by agent j. Thus, the decisions are both highly biased and excessively coordinated unless r_j is very high.[13] However, there is no loss due to strategic communication, as no adaptation to θ_j is attempted. In the region of very high r_j, this avoidance of informational losses dominates losses caused by biased decisions, and as a result directional authority arises as the preferred governance



(i) Relative loss due to biased decisions

(ii) Relative loss due to strategic communication

Figure 1-9: Expected performance of directional authority (by i)

structure. Indeed, as $r_j \to 1$, full efficiency is achieved under directional authority while all other governance structures continue to suffer a first-order loss due to strategic communication.

It might be surprising that we are granting authority to the *less* dependent agent. However, the result is immediate when we recall that coordination in the model is achieved by accommodating adaptation, and so the focal point of coordination should reflect the relative importance of adaptation. As $r_j \to 1$, only adaptation to θ_i matters, and as a result it is more efficient to allow agent i to control both decisions than to rely on strategic communication as the coordination device.

1.6 Relative performance

Figure 1-10 summarizes the mapping from the relative dependency of the two activities to the second-best governance structure. Having already discussed the reasons for the performance differentials through sections 4 and 5, we will now provide only a short summary of the results. Decentralized authority is the preferred governance structure only when both activities face a low importance of coordination. The equilibrium decisions are only mildly biased and communication, while inaccurate, is also unimportant since each agent has direct access to local information. Centralized authority is the preferred governance structure when the importance of coordination is intermediate to high and not too asymmetric. The advantage of centralized authority is in eliminating any biases in equilibrium decisions and thus performs best relative to the other governance structures in the region of intermediate importance of coordination. As r_i and/or $r_j \to 1$, the solutions under centralized and decentralized authority converge.

[13] We have capped the relative loss due to biased decisions at 30% to keep the figures comparable.

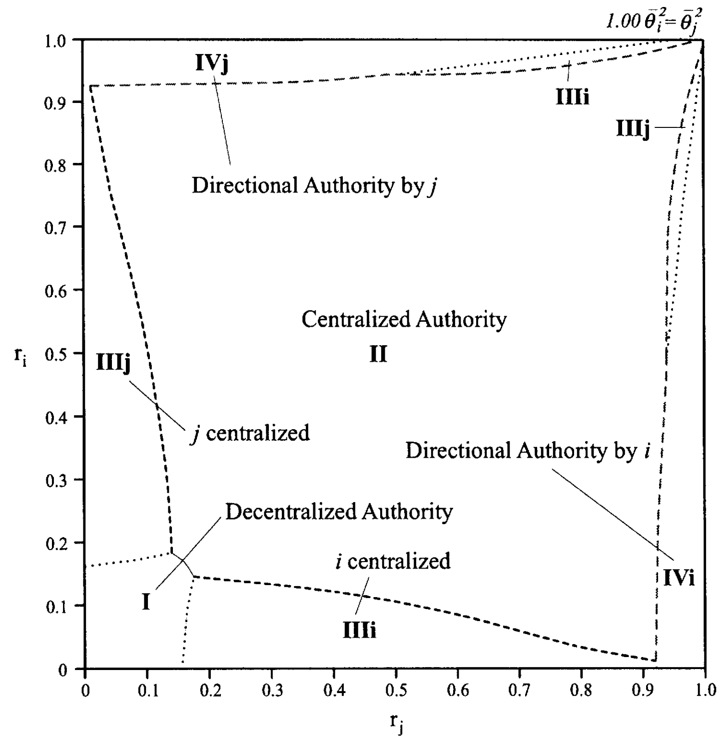


Figure 1-10: Choice of governance structure

While centralized authority dominates decentralized authority in all regions but low importance of coordination, centralized authority is in turn dominated by at least one of the asymmetric governance structures when the activities face a sufficiently asymmetric importance of coordination. First, centralizing only the less dependent activity can be used to improve decision-making relative to decentralized authority while limiting losses due to strategic communication relative to centralized authority. Second, centralizing only the more dependent activity can be used to worsen decision-making relative to decentralized authority to generate a communication outcome that dominates both centralized and decentralized authority. Third, directional authority by the less dependent agent can dominate all three alternatives when the other activity is highly dependent as it fully avoids losses due to strategic communication.

1.6.1 Asymmetric variances

So far, we have discussed the results only in the setting of symmetric overall importance of adaptation, as measured by the relative variance of the two states. The case of asymmetric variances is straightforward: if $\overline{\theta}_i$ increases, the likelihood of control of any activity by agent i increases, and the likelihood of control of d_j by the manager increases. These results follow for two reasons. First, as illustrated in the previous sections, the relative quality of communication is independent of $\overline{\theta}_i$. As a consequence, the absolute quality of communication is decreasing in $\overline{\theta}_i$, making any garbling of information more damaging. Second, any biases in decision-making going against activity i become more damaging in expectation. As a consequence, the choice of governance structure becomes skewed in agent i's favor when $\overline{\theta}_i > \overline{\theta}_j$.[14].

1.7 Some caveats and extensions

In this section, we will consider three extensions to the baseline model analyzed in sections 4-6. First, we show that, contrary to most cheap talk models, the most informative communication equilibrium is not always preferred by all the participants and discuss the implications of this result for organizational performance. Second, we extend the results to account for imperfect local information. Third, we extend the results to allow for the possibility of incentive alignment through pay-for-performance.

Three significant assumptions, however, remain unexamined: the absence of interim contracting on decisions, the absence of interim reallocation of decision rights and the absence of potential problems of implementation when the decision-maker and the implementer are two separate agents.[15] For interim contracting on decisions, while the informational asymmetries in the interim stage are likely to prevent efficient bargaining over the decisions, the degree to which bargaining could improve the performance of the different governance structures remains unexamined. Similarly, the relative performance of the governance structures differs in $|\theta_i - \theta_j|$, which generates the possibility of both selective intervention and conditional delegation. Enriching the analysis to account for these additional behavioral alternatives appears a promising avenue for future research.

Problems of implementation, on the other hand, have been extensively discussed. Ensuring compliance typically involves (i) costly monitoring by the decision-maker, (ii) an efficiency wage based on compliance and/or (iii) an increase in global (with a corresponding decrease in local) incentives faced by the implementer. However, two aspects of the present framework make further analysis of the implementation problem of potential interest. First, the degree of incentive conflict and so the gains from non-compliance depend on the importance of coordination, thus making the cost of ensuring compliance environment-specific. Second, centralized authority can actually benefit from implementation problems. This result follows because the fourth margin that the manager will use to ensure compliance is to bias the decisions in favor of the implementer, thus decreasing the attractiveness of non-compliance. The initial bias will have only a second-order impact on the quality of decisions but will have a first-order impact on the quality of communication.

[14] Detailed results are available from the author on request.

[15] Results extending the analysis to account for (i) sequential communication and decision-making, (ii) option of costly but verifiable communication, (iii) noisy communication and (iv) pay-for-performance to motivate productive effort are available from the author on request. Chapter 2 analyzes endogenous information acquisition.

1.7.1 Incentives to talk and listen

In the analysis we focused on the most informative incentive-compatible communication equilibrium. From the perspective of the firm, this is the desired outcome. As a result, the manager always wants to receive any incoming messages. Also, the sender prefers as accurate communication as possible. However, when the local agent retains control of his activity (decentralization or partial centralization), he might prefer not to listen to incoming messages. This result is summarized in the following proposition:

Proposition 7 ***Incentives to Listen:***

Under decentralized authority, agent i would prefer not to listen to incoming messages when

$r_j \geq \overline{r}_j = \frac{1-\sqrt{1-r_i}}{r_i}$.

Under partial centralization (of j), agent i would prefer not to listen to incoming messages when

$r_j \geq \overline{r}'_j = \frac{(1+r_i)\left(1-\sqrt{(1-r_i)}\right)}{r_i} - r_i$.

Further, $\overline{r}'_j \leq \overline{r}_j$.

Proof. See Appendix C. ■

This results arises from the strategic interaction between the decisions. While listening to informative messages helps to reduce coordination failures, this reduction is achieved through the process of accommodation. Because accommodation induces additional adaptation, the cost of accommodation can exceed the gains from improved coordination. By not listening, the agent commits not to accommodate, which in turn limits the amount of adaptation undertaken by the sender. As a result, communication can break down if coordination is sufficiently important to the sender relative to the receiver, in which case the rate of induced adaptation (and thus the cost of accommodation) is large relative to the rate of direct adaptation (and thus the cost of coordination failure resulting from not listening). For the same reason, the agent retaining control under partial centralization is more likely to prefer not to listen compared to decentralized authority, as the manager puts more weight on coordination.

Note that the selection of the babbling equilibrium relies on the ability of the receiver to commit to not listening. If the sender sends an informative message that he expects to be read, then the induced component of adaptation will be present in his decision and it is better for the receiver to read the message and accommodate. Similarly, if the sender sends an informative message that he expects not to be read, then the receiver would prefer to read the message because responding to the information helps to improve coordination without the added cost of accommodation generated by the component of induced adaptation. However, if the agents are able to take ex ante actions that will lead to inability to understand any messages, a situation of *strategic ignorance* can arise where one or both directions of communication are fully uninformative and the relative performance of the governance structure is significantly compromised.[16]

1.7.2 Noisy information

The results presented in the analysis are robust to noisy information. In particular, if agent i observes a signal s_i that is equal to θ_i with probability p_i but is a random draw from $U[-\overline{\theta}_i, \overline{\theta}_i]$ with probability $(1-p_i)$, the expected loss under governance structure g is given by the following proposition:

Proposition 8 ***Expected loss under noisy information:***

$$EL_i^g = \Lambda_i^g \left(\left(p_i\overline{\theta}_i\right)^2 + \left(p_j\overline{\theta}_j\right)^2 \right) + \Gamma_{i-i}^g V\left(\varphi_i^g\right)\left(p_i\overline{\theta}_i\right)^2 + \Gamma_{i-j}^g V\left(\varphi_j^g\right)\left(p_j\overline{\theta}_j\right)^2$$
$$+ \tfrac{(1-r_i)}{3}\left(1-p_i^2\right)\overline{\theta}_i^2.$$

Proof. See Appendix C ∎

The model is thus equivalent to a perfect-information model with the states distributed on $U[-\widetilde{\overline{\theta}}_i, \widetilde{\overline{\theta}}_i]$, where $\widetilde{\overline{\theta}}_i = p_i\overline{\theta}_i$, plus a common additional loss reflecting the quality of primary information. Intuitively, because all the participants are rational, they discount information in the same way. Conflict exists only over how that information should translate into final decisions. As a result, the relative incentive conflict between the actors is unchanged when the primary information is noisy. This is no longer the case if the communication process itself is noisy, as that does affect the degree of incentive conflict between the agents. Also, if p_i are endogenous, differences across the governance structures arise because of the differing incentives to acquire information.

1.7.3 Incentive alignment

Even if interim recontracting were not possible, payoff sharing can potentially be used to improve the outcome under any governance structure. We will outline here the case where the degree of incentive alignment is exogenously limited. Endogenous degree of incentive alignment is analyzed in Chapter 2.

Consider a situation where agent i retains a share s_i of the payoff to activity i and gains a share $1-s_j$ of the payoff to activity j. That is, agent i's objective function becomes $U_i = s_iL_i + (1-s_j)L_j$. The role of incentive alignment in communication and decision-making is immediate. As $s_i \to 1-s_j$, the interests of the local agents become perfectly aligned both

[16] Note that, as in all cheap talk models, the babbling equilibrium always exists. What this result states is that, unlike in most cheap talk models, the most informative partition need not be pareto-superior.

with each other and with the overall goal of profit-maximization and so the first-best solution is achieved under all governance structures.

The rates of convergence, however, do differ across governance structures, leading to a systematic relationship between the degree of incentive alignment and the choice of governance structure. The pattern that emerges is straightforward. As the degree of incentive alignment increases, the relative attractiveness of both centralized authority and partial centralization of the less dependent activity decreases, with both being eliminated as the preferred governance structure strictly before perfect incentive alignment is achieved. Conversely, the relative attractiveness of decentralized and directional authority increases in the degree of incentive alignment. Thus, managerial control to improve decision making and incentive alignment are substitutes. Finally, the relative attractiveness of partial centralization of the more dependent activity is non-monotone in the degree of incentive alignment, being initially increasing but eventually decreasing in the degree of incentive alignment. In the limit of perfect alignment, the choice of governance structure is made between decentralized and directional authority.[17]

These results are illustrated in figure 1-11 and they follow from two interrelated reasons. First, as analyzed in sections 4-6, the governance structures differ systematically in the quality of decision-making and the value and quality of communication. Second, incentive alignment impacts decision-making and communication at different rates. In particular, the rate of improvement in decision-making is decreasing in the degree of incentive alignment, while the rate of improvement in the accuracy of communication is *increasing* in the degree of incentive alignment. As a result, the returns to incentive alignment come initially in terms of improvements in decision-making and later in terms of improvements in communication.

Consequently, both decentralized and directional authority, whose primary shortcoming is biased decision-making, gain ground from centralized authority and partial centralization of the less dependent activity when incentive alignment is increased. After a sufficient degree of incentive alignment is achieved, most of the remaining relative loss is due to inaccurate communication. Because both centralized authority and partial centralization of the less dependent activity depend more heavily on accurate communication than decentralized or directional authority, they are eliminated as the preferred governance structure strictly before perfect incentive alignment is achieved.

The logic for the non-monotone relationship between incentive alignment and the use of partial centralization of the more dependent activity is similar. Recall that centralization of the more dependent activity was used to improve communication by *increasing* the bias in the equilibrium decisions relative to decentralized authority. Thus, the initial gains from incentive alignment make partial centralization of the more dependent activity more attractive vis-à-vis centralized and decentralized authority. However, as the degree of incentive alignment increases further, the remaining inaccuracies in communication become the dominant concern. In consequence, it becomes more attractive to leave both decisions at the local level, by using either decentralized or directional authority – the two governance structures that rely the least on accurate communication.[18]

[17]This conclusion is thus highly analogous to Dessein (2002), who shows that in the CS framework, delegation is always preferred over the cheap-talk solution when the bias between the agent and the principal is sufficiently small.

[18]Note that the logic behind these results was already implicitly present in two of our earlier results. First, when $r_i, r_j \to 0$, the quality of decision-making under decentralized authority improved faster than the quality of

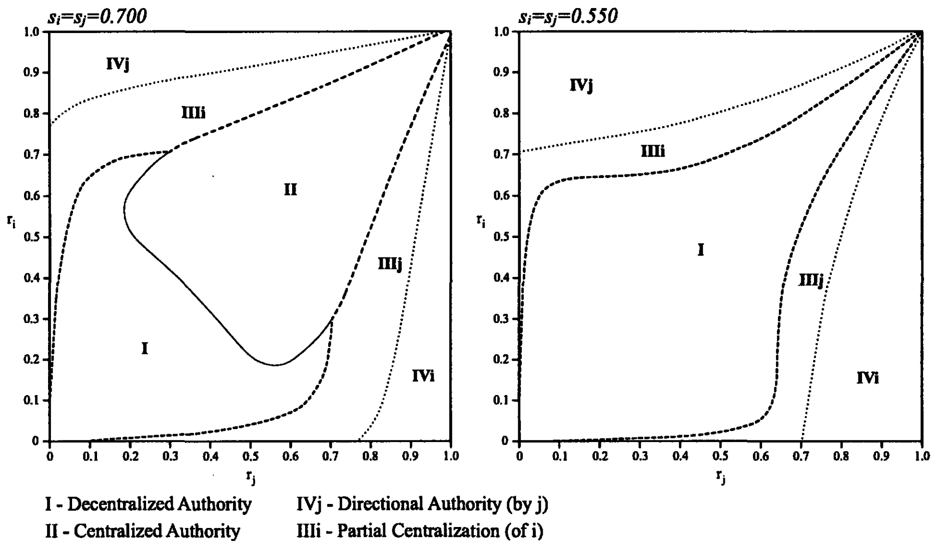


Figure 1-11: Exogenous degree of incentive alignment and the choice of governance structure

1.8 Conclusion

We have investigated how the allocation of decision rights inside an organization can be used to influence decision-making and communication among strategic agents when decisions need to balance coordination and adaptation and when information is both soft and distributed.

Decentralized authority, where each local agent retains control over his activity, is the preferred method of organization when coordination is sufficiently unimportant to both parties. The equilibrium decisions are then only mildly biased and communication, while inaccurate, is also unimportant because each local agent has direct access to his local information.

Centralized authority, where both decision rights are allocated to the central manager, is the preferred method of organization when the importance of coordination is intermediate to high and not too asymmetric. By making socially optimal decisions, the manager is able to eliminate the biases in the equilibrium decisions under decentralized authority. However, because the manager needs to rely solely on information communicated to him by the local agents, the quality of adaptation remains limited. The advantage of centralized authority is largest in the region of intermediate importance of coordination, where the under-coordination problem under decentralized authority is particularly damaging. As the importance of coordination grows further, the local agents become increasingly willing to coordinate their decisions under

communication under centralized authority, making decentralized authority the preferred governance structure for the region of low importance of coordination. Second, when $r_j \to 1$, it was better to choose directional authority by agent i to avoid the limit losses due to inaccurate communication that were present under all the other governance structures. The only difference is that in these cases, the incentive alignment arose through the underlying environment, not explicit payoff-sharing.

decentralized authority and as a result the decisional advantage of centralized authority is eroded.

Partial centralization, where one of the decisions is centralized while the other is left under local control, is the preferred governance structure under two very different asymmetric environments. First, centralizing only the less dependent activity is sufficient to eliminate most of the bias in the equilibrium decisions under decentralized authority, while not centralizing the more dependent activity limits the total informational losses relative to centralized authority. Second, centralizing only the more dependent activity helps to improve the information flows between the agents by increasing the bias in the equilibrium decisions, a gain which outweighs the cost of increased bias when the dependent activity is sufficiently dependent.

An alternative solution in the case of high dependency of one activity is to simply allocate both decision rights to the less dependent agent (directional authority). Even if the agent gaining control will make very biased decisions relative to the alternative governance structures, the allocation does eliminate all strategic uncertainty from the decision-making process. When the agent losing control cares primarily about coordination, the resulting gains from the full elimination of strategic uncertainty will outweigh the further increase in the bias of the equilibrium decisions.

Finally, we illustrated how managerial control to improve decision-making and incentive alignment and are substitutes. This result followed from two observations. First, the quality of decision-making improved faster in the degree of incentive alignment than the quality of communication. Second, the governance structures relying on managerial control (centralized authority and partial centralization) were more dependent on accurate communication than the governance structures relying on local control (decentralized and directional authority).

Taken together, these results suggest that the term "importance of coordination" is too coarse for deriving clean organizational implications. First, coordination poses an organizational challenge only when it needs to balance conflicting needs for adaptation. Second, one needs to account for asymmetric interdependencies between activities as they may warrant asymmetric solutions. Finally, one needs to account for the distibution of the costs and benefits of coordination among the organizational participants, since the degree of incentive alignment impacts the relative performance of the different governance structures at differing rates. However, once these three qualifiers are accounted for, a consistent relationship emerges between the underlying environment and the preferred governance structure.

1.9 Appendix A: The general solution

We will derive here the general solution to the framework analyzed. We will first derive the equilibrium decisions, then the equilibrium quality of communication and finally the expected losses.

1.9.1 Equilibrium decisions

In the final stage of the game, the actors holding the decision rights choose decisions that maximize their payoffs conditional on their current information. Let m and n denote the identity of the decision-maker for activities i and j, respectively, and let ω_m denote the set of information held by agent m when deciding. Also, let $E_m(.)$ denote $E\left(.|\omega_m\right)$ and $\left(\beta_i^m, \beta_j^m\right)$ denote the weights that agent m places on activities i and j, respectively. Then, m solves:

$$\min_{d_i} E_m \left[\begin{array}{c} \beta_i^m \left(\left(1-r_i\right)\left(\theta_i - d_i\right)^2 + r_i \left(d_j - d_i\right)^2 \right) \\ +\beta_j^m \left(\left(1-r_j\right)\left(\theta_j - d_j\right)^2 + r_j \left(d_j - d_i\right)^2 \right) \end{array} \right],$$

and symmetrically for n. For example, under centralized authority, $\beta_i^m = \beta_j^m = 1$, and under decentralized authority, $\beta_i^m = s_i, \beta_j^m = \left(1 - s_j\right)$, where s_i is the share of L_i retained by agent i and $\left(1 - s_j\right)$ the share of L_j gained by agent i. The first-order conditions are then

$$d_i^m = \frac{\beta_i^m (1-r_i) E_m\theta_i + \left(\beta_i^m r_i + \beta_j^m r_j\right) E_m d_j}{\beta_i^m + \beta_j^m r_j} \qquad d_j^n = \frac{\beta_j^n (1-r_j) E_n\theta_j + \left(\beta_j^n r_j + \beta_i^n r_i\right) E_n d_i}{\beta_j^n + \beta_i^n r_i}.$$

Define for notational simplicity

$$a_1 = \frac{\beta_i^m (1-r_i)}{\beta_i^m + \beta_j^m r_j}, \quad a_2 = \frac{\beta_i^m r_i + \beta_j^m r_j}{\beta_i^m + \beta_j^m r_j}, \quad b_1 = \frac{\beta_j^n (1-r_j)}{\beta_j^n + \beta_i^n r_i} \quad \text{and} \quad b_2 = \frac{\beta_j^n r_j + \beta_i^n r_i}{\beta_j^n + \beta_i^n r_i},$$

which are simply the weights placed on adaptation and coordination by the decision-maker(s). The first-order conditions simplify to

$$d_i^m = a_1 E_m\theta_i + a_2 E_m d_j \qquad \text{and} \qquad d_j^n = b_1 E_n\theta_j + b_2 E_n d_i,$$

and the equilibrium decisions are then given by the intersection of the two reaction functions and summarized in the following proposition:

Proposition 9 ***Equilibrium Decisions:***

Let m and n be the identity of the decision-maker for activities i and j, respectively. Then,

$$d_i^m = \frac{a_1(1-b_2a_2)E_m\theta_i + a_2b_1E_mE_n\theta_j + a_2b_2a_1E_nE_m\theta_i}{1-b_2a_2} = a_{i1}^g E_m\theta_i + a_{i2}^g E_mE_n\theta_j + a_{i3}^g E_nE_m\theta_i.$$

Proof. See Appendix C ■

The logic behind the coefficients is the same as the one discussed in section 4. Absent any coordination, adaptation by decision-maker m is limited to a_1. Coordination and the associated improvement in adaptation is achieved by mutual accommodation. The more decision-maker m cares about coordination and the more decision-maker n cares about adaptation, the more m ends up accommodating: $a_2 b_1$. Equivalently, the more accommodation m is able to get from n, and the more he or she is dependent on it, the more adaptation is achieved through the induced component: $a_2 b_2 a_1$. The equilibrium biases are in turn determined by the underlying importance of coordination for each of the two activities and the divisional biases (if any) of the decision-maker(s). The less weight decision-maker m places on coordination, the more favorable decisions he is able to induce. The equilibrium decisions converge to first-best when $\beta_i^m \to \beta_j^m$ and $\beta_j^n \to \beta_i^n$.

1.9.2 Equilibrium communication

In the communication stage, the agents send non-verifiable messages about their local conditions to the decision-maker(s). Given the equilibrium decisions from above and letting β_i and β_j denote the weights placed by agent i on L_i and L_j, respectively, the indifference condition for agent i is given by

$$\begin{aligned} &E_i\left(\beta_i L_i\left(d_i(.,m^L), d_j(.,m^L)\right) + \beta_j L_j\left(., d_i(.,m^L), d_j(.,m^L)\right)|\widetilde{\theta}, m^L\right) \\ &\quad = E_i\left(\beta_i L_i\left(d_i(.,m^H), d_j(.,m^H)\right) + \beta_j L_j\left(., d_i(.,m^H), d_j(.,m^H)\right)|\widetilde{\theta}, m^H\right). \end{aligned}$$

Rearranging the indifference condition and solving the difference equation yields the following proposition:

Proposition 10 ***Equilibrium quality of communication:*** *Under any governance structure, we can write the indifference condition defining the family of incentive-compatible partitions as*

$$|\theta_{i,k} - \theta_{i,k-1}| - |\theta_{i,k-1} - \theta_{i,k-2}| = \tfrac{4}{\varphi_i(r_i,r_j,s_i,s_j,g)}\,|\theta_{i,k-1} - E_i\theta_j|,$$

with g indexing the governance structure and k increasing away from the expected preference intersection ($\theta_i = E_i\theta_j$). The constant $\varphi_i(.)$ is given by

$$\begin{aligned} &\varphi_i\left(r_i, r_j, s_i, s_j, g\right) \\ &= \tfrac{a_1\left[\beta_i(1-r_i)(1-I_{m=i}(1-b_2a_2))^2 + \left(\beta_i r_i + \beta_j r_j\right)(b_1 - I_{m=i}(1-b_2a_2))^2 + \beta_j(1-r_j)b_2^2\right]}{\left[\beta_i(1-r_i)a_2b_1(1-I_{m=i}(1-b_2a_2)) - \left(\beta_i r_i + \beta_j r_j\right)a_1(b_1 - I_{m=i}(1-b_2a_2))b_1 - \beta_j(1-r_j)b_2^2 a_1\right]} \in (0,\infty), \end{aligned}$$

where $I_{m=i} \in \{1,0\}$ is an indicator function for whether the sender (agent i) retains control over his own activity (d_i). The cutoffs of the finest incentive-compatible partition are then given by

$$\theta_{i,n} - E_i\theta_j = \alpha(\varphi_i)^n \left(\overline{\theta} - E_i\theta_j\right) \text{ for } \theta_{i,n} > E_i\theta_j \ (n \in \{1, ..., \infty\}),$$
$$\theta_{i,n} - E_i\theta_j = -\alpha(\varphi_i)^{|n|} \left(\overline{\theta} + E_i\theta_j\right) \text{ for } \theta_{i,n} < E_i\theta_j \ (n \in \{-\infty, ..., -1\}),$$

$$\text{where } \alpha(\varphi_i) = \frac{\varphi_i}{\left(1+\sqrt{1+\varphi_i}\right)^2} \in (0,1),$$

with $|n| = 1$ *indexing the furthest interior cutoff and* $|n| \to \infty$ *implying* $\theta_{|n|} \to E_i\theta_j$.

Proof. See Appendix C ■

While the equation for φ_i appears complex, the intuition behind the equation is straightforward. Note that both the numerator and the denominator are comprised of three components. The first component captures how much weight agent i places on his own adaptation, coupled with how much a marginal exaggeration would improve the outcome through the equilibrium decisions. This component is always positive in the denominator so that the bigger the weight on adaptation, the greater the incentive to exaggerate, other things constant.

The second component is the overall weight put on coordination by the agent. In the case of $I_{m=i} = 1$, the denominator is negative, while in the case of $I_{m=i} = 0$, it is positive. Thus, in the case of the agent retaining control, the accuracy of communication is decreasing in the weight placed by the agent on coordination. This result follows because in this case, exaggeration allows the agent both to improve coordination (because successful exaggeration would induce a larger response by the other agent) and to achieve additional adaptation (because the agent would trade some of the gains in coordination for additional adaptation). In contrast, in the case where the agent doesn't control the decision, the two decisions are diverging in $|m_i|$ and thus damaging the coordination component.

Finally, the third component gives the weight placed by the agent on adaptation by the other division. This component is always negative in the numerator and thus the quality of communication is increasing in the weight placed on the other division's adaptation. Intuitively, since any successful exaggeration worsens adaptation by the other division, this constrains the incentives to exaggerate. As the incentives of the agent become perfectly aligned with the equilibrium decisions, $\varphi_i \to \infty$ and communication becomes perfectly informative.

1.9.3 Expected losses

Having derived the equilibrium decisions and the resulting quality of communication, the expected losses follow from a simple substitution of these solutions into the payoff functions. However, to illustrate the impact of communication, let us look at the outcomes componentwise. For the adaptation component, we have that

$$E(\theta_i - d_i)^2 = \frac{a_2^2}{(1-b_2a_2)^2}\left((b_1)^2 \overset{(A)}{E(E_m\theta_i)^2} + b_2a_1(b_2a_1 + 2b_1) \overset{(B)}{E(E_m\theta_i - E_nE_m\theta_i)^2}\right)$$

$$+ E\overset{(C)}{Var_m\theta_i} + \frac{1}{(1-b_2a_2)^2}(a_2b_1)^2 \overset{(D)}{E\left(E_mE_n\theta_j\right)^2}.$$

Here, (A) captures the baseline loss caused by the limit on adaptation imposed by the need to coordinate decisions, as given by the equilibrium decisions. (C) captures the interim uncertainty over the appropriate course of action faced by the decision-maker, constituting the *fundamental uncertainty* over θ_i remaining at this stage and is thus present only when agent i is not allowed to decide d_i and communication is inaccurate. (B) captures the cost of the fact that when communication is inaccurate, even if agent i would make the decision, the induced component of adaptation is based on an inaccurate message. Finally, (D) gives the cost of accommodating d_j in terms of compromised adaptation. The size of these components follows directly from the equilibrium decisions.

In a similar fashion, we can write the coordination component as

$$E\left(d_j - d_i\right)^2 = \frac{1}{(1-b_2a_2)^2}\left(b_1a_1\right)^2 \left(\overset{(A)}{E\left(E_mE_n\theta_j\right)^2 + E\left(E_nE_m\theta_i\right)^2}\right)$$
$$+ b_1^2\overset{(B)}{E\left(E_n\theta_j - E_mE_n\theta_j\right)^2} + a_1^2\overset{(C)}{E\left(E_m\theta_i - E_nE_m\theta_i\right)^2}.$$

Here, (A) captures the baseline divergence in decisions, caused by the need for adaptation. Parts (B) and (C) capture the *strategic uncertainty* remaining in the interim stage, caused by the inaccurate communication and the associated incomplete ability to predict exactly what the opponent is going to do.

To bring the two together in a simple form, we can rearrange $(\theta_i - d_i)^2$ based on the common knowledge components, which gives

$$Var_m\theta_i + a_2^2\left(E_m\theta_i - E_nE_m\theta_i\right)^2 + \frac{(a_2b_1)^2}{(1-b_2a_2)^2}\left(\left(E_nE_m\theta_i\right)^2 + \left(E_mE_n\theta_j\right)^2\right).$$

Then, adding up $(1-r_i)(\theta_i - d_i)^2 + r_i(d_j - d_i)^2$ gives us

$$\frac{b_1^2\left((1-r_i)a_2^2 + r_ia_1^2\right)}{(1-b_2a_2)^2}\left(\left(E_nE_m\theta_i\right)^2 + \left(E_mE_n\theta_j\right)^2\right) + (1-r_i)\,Var_m\theta_i$$
$$+ \left((1-r_i)\,a_2^2 + r_ia_1^2\right)\left(E_m\theta_i - E_nE_m\theta_i\right)^2 + r_ib_1^2\left(E_n\theta_j - E_mE_n\theta_j\right)^2.$$

Now, whether any of the three last terms are present in any given situation depends on the identity of the decision-maker(s) and the underlying accuracy of information. For example, under perfect primary information and decentralized authority, $Var_m\theta_i = 0$, but the beliefs of the two agents will be different, so that the last two coefficients will be positive. Similarly, under centralized authority, $Var_m\theta_i > 0$, but the last two terms are not present because the manager knows what he knows. What remains is to solve the expectations, which then gives the following proposition:

Proposition 11 ***Expected Losses:***

In the case of simultaneous communication, we can write the expected loss to activity i as

$$EL_i = \Lambda_i^g \left(A(\varphi_i) \overline{\theta}_i^2 + A(\varphi_j) \overline{\theta}_j^2 \right) + \Lambda_{i-i}^g B(\varphi_i) \overline{\theta}_i^2 + \Lambda_{i-j}^g B(\varphi_j) \overline{\theta}_j^2,$$

where Λ_k^g is shorthand for $\Lambda_k(r_i, r_j, s_i, s_j, g)$, constants that depend only on the underlying environment, the amount of payoff sharing present and the governance structure chosen, and

$$A(x) \equiv \frac{(1-\alpha(x))(1+\alpha(x))^2}{4\left(1-\alpha(x)^3\right)}, \qquad B(x) \equiv \frac{(1-\alpha(x))^3}{12\left(1-\alpha(x)^3\right)}.$$

Proof. See Appendix C ■

Corollary 12 *An alternative way to write the expected loss to activity i is:*

$$EL_i = \Lambda_i^g \left(\overline{\theta}_i^2 + \overline{\theta}_j^2 \right) + \Gamma_{i-i}^g V(\varphi_i^g) \overline{\theta}_i^2 + \Gamma_{i-j}^g V\left(\varphi_j^g\right) \overline{\theta}_j^2,$$

where $\Gamma_{i-i}^g = \frac{\Lambda_{i-i}^g}{3} - \Lambda_i^g$, $\Gamma_{i-j}^g = \frac{\Lambda_{i-j}^g}{3} - \Lambda_i^g$ and $V(\varphi_i^g) = 3B(\varphi_i^g) = \frac{1}{4+3\alpha(x)}$

In the case of $s_i = s_j = 1$, the coefficients are:

$\Lambda_i^{dec} = \frac{(1-r_i)r_i(1-r_j)^2}{3(1-r_ir_j)^2}$	$\Lambda_{i-i}^{dec} = \frac{r_i(1-r_i)}{3}$	$\Lambda_{i-j}^{dec} = \frac{r_i(1-r_j)^2}{3}$
$\Lambda_i^{cent} = \frac{(1-r_i)(1-r_j)^2\left(r_i+2r_ir_j+r_j^2\right)}{3\left((1+r_i)(1+r_j)-(r_i+r_j)^2\right)^2}$	$\Lambda_{i-i}^{cent} = \frac{(1-r_i)}{3}$	$\Lambda_{i-j}^{cent} = 0$
$\Lambda_i^{part(j)} = \frac{(1-r_i)r_i(1-r_j)^2}{3(1-r_ir_j+r_i(1-r_i))^2}$	$\Lambda_{i-i}^{part(j)} = \frac{r_i(1-r_i)}{3}$	$\Lambda_{i-j}^{part(j)} = 0$
$\Lambda_j^{part(j)} = \frac{(1-r_i)^2(1-r_j)\left(r_j+2r_ir_j+r_i^2\right)}{3(1-r_ir_j+r_i(1-r_i))^2}$	$\Lambda_{j-j}^{part(j)} = \frac{(1-r_j)}{3}$	$\Lambda_{j-i}^{part(j)} = \frac{r_j(1-r_i)^2}{3}$
$\Lambda_i^{dir(i)} = 0$	$\Lambda_{i-i}^{dir(i)} = 0$	$\Lambda_{i-j}^{dir(i)} = 0$
$\Lambda_j^{dir(i)} = \frac{(1-r_j)}{3}$	$\Lambda_{j-j}^{dir(i)} = 0$	$\Lambda_{j-i}^{dir(i)} = 0$

1.10 Appendix B: An alternative loss formulation

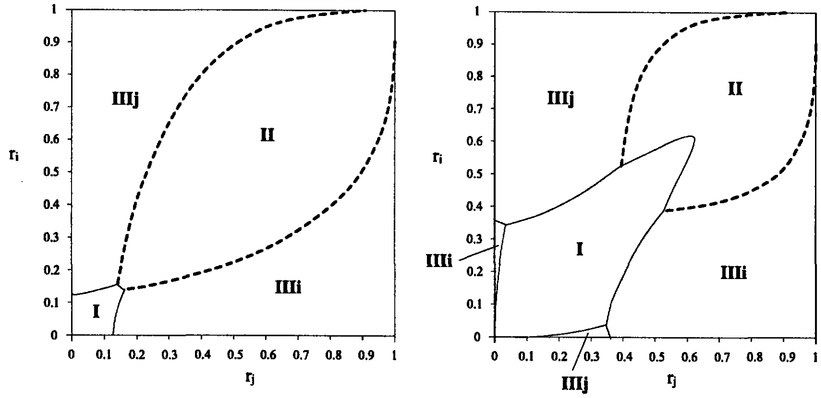
In the analysis we focused on a loss formulation

$$L_i = (1-r_i)(\theta_i - d_i)^2 + r_i(d_j - d_i)^2.$$

An alternative formulation has

$$L_i = \alpha_i (\theta_i - d_i)^2 + \beta_i (d_j - d_i)^2 = \kappa_i \left[(1-r_i)(\theta_i - d_i)^2 + r_i(d_j - d_i)^2 \right],$$

where $\kappa_i = \alpha_i + \beta_i$. This loss formulation is analyzed for the general case in Chapter 2 and for the symmetric case in Alonso, Dessein and Matouschek (2006), so we will only outline the key differences here. The solution itself follows Appendix A after substituting the weights β_i' with



(i) maximal incentive conflict *(ii) intermediate incentive conflict*

Figure 1-12: Choice of governance structure under alternative loss formulation

$\beta_i'\kappa_i$ in both the decision-making and communication stages and then scaling the final expected loss with κ_i.

In the case of symmetric divisions, the two formulations are equivalent because the levels cancel each other out in both the decision-making and communication stages. In the case of asymmetric divisions, however, there is a significant difference. The reason for this that when $r_i \to 1$, adaptation becomes fully unimportant in the formulation of the present model, while if $\beta_i \to \infty$, adaptation to θ_i remains valuable. Indeed, if α_i and α_j remain unchanged, the focal point of coordination remains unchanged and an increase in β_i only increases the optimal *amount* of coordination. In other words, the focal point of coordination is driven by the relative importance of adaptation (α_i, α_j) while the amount of coordination (and hence how close together the decisions are around this focal point of coordination) is given by (β_i, β_j). For example, if $\alpha_i = \alpha_j$ and $\beta_i \to \infty$, then the first-best decisions are simply $d_i^{FB} = d_j^{FB} = \frac{1}{2}\theta_i + \frac{1}{2}\theta_j$.

The equilibrium decision dynamics, however, remain the same. In particular, under decentralization, as $\beta_i \to \infty$, $d_i^{dec}, d_j^{dec} \to \theta_j$ since the extra weight placed on coordination by agent i weakens his strategic position in the decision-making stage and thus makes the outcome worse for him. In consequence, the decisions keep on diverging away from the first-best. As a result, when coordination becomes extremely important to one of the parties, communication never becomes the primary issue. Instead, biased decision-making remains the overriding concern. Consequently, directional authority never arises as the preferred governance structure under this formulation unless we introduce asymmetries in α_i or $\overline{\theta}_i$. Also, partial centralization of the more dependent activity is no longer observed unless some incentive alignment is feasible. Instead, partial centralization of the less dependent activity is used in the asymmetric settings to balance decision-making while limiting the costs of inaccurate communication. Figure 1-12 plots the outcome under two different levels of incentive conflict under the assumption of $\alpha_i = \alpha_j$ and $\overline{\theta}_i = \overline{\theta}_j$.

The logic behind the impact of incentive alignment on the choice of governance structure remains unchanged, even if the initial condition is changed. The use of centralized authority and partial centralization of the less dependent activity is decreasing in the degree of incentive alignment, while the use of decentralized authority is increasing. Partial centralization of the more dependent activity is temporarily introduced to facilitate communication but is eventually replaced by decentralized authority. In the limit, only decentralized authority survives. The only difference to the original formulation is that directional authority is never observed for reasons already discussed above.

1.11 Appendix C: Proofs and derivations

Proposition 7

Recall that

$$EL_i = \Lambda_i^g \left(\overline{\theta}_i^2 + \overline{\theta}_j^2\right) + \Gamma_{i-i}^g V\left(\varphi_i^g\right)\overline{\theta}_i^2 + \Gamma_{i-j}^g V\left(\varphi_j^g\right)\overline{\theta}_j^2.$$

Thus, increased accuracy of communication is damaging to activity i iff $\Gamma_{i-j}^g < 0$. For decentralized authority, we have

$$\Gamma_{i-j}^g = \tfrac{r_i(1-r_j)^2}{3} - \tfrac{(1-r_i)r_i(1-r_j)^2}{3(1-r_ir_j)^2}.$$

Rearranging gives

$$\Gamma_{i-j}^g < 0 \qquad \textit{iff} \qquad r_j \geq \overline{r}_j = \tfrac{1-\sqrt{1-r_i}}{r_i}.$$

The condition for partial centralization follows equivalently.

Proposition 8

Recall from A.2 that the expected loss under any governance structure simplifies to

$$\begin{aligned}\tfrac{b_1^2\left((1-r_i)a_2^2+r_ia_1^2\right)}{(1-b_2a_2)^2}\left((E_nE_m\theta_i)^2 + (E_mE_n\theta_j)^2\right) + (1-r_i)\,Var_m\theta_i \\ + \left((1-r_i)\,a_2^2 + r_ia_1^2\right)(E_m\theta_i - E_nE_m\theta_i)^2 + r_ib_1^2\,(E_n\theta_j - E_mE_n\theta_j)^2.\end{aligned}$$

First, note that given the signal s_i, agent i's belief about the realized θ_i is given by p_is_i. In consequence, agent i's belief about the realization of θ_i is distributed $U\left[-p_i\overline{\theta}_i, p_i\overline{\theta}_i\right]$, while the receiver's belief upon receiving a message m_i is given by $p_iE\left(s_i|m_i\right)$. Because $p_i's$ cancel each other out in the degree of incentive conflict, the communication solution presented goes directly through and can be defined either in the space of signals or in the space of beliefs. The only component that directly depends on the quality of primary information is $Var_m\theta_i$. When $m = i$,

$$E\left(\theta_i - E_i\theta_i\right)^2 = p_iE\left(\theta_i - p_i\theta_i\right)^2 + (1-p_i)\,E\left(\theta_i - p_ix_i\right)^2 = \left(1-p_i^2\right)\tfrac{\overline{\theta}_i^2}{3}.$$

When $m \neq i$,

$$E\left(\theta_i - E_m\theta_i\right)^2 = E\left(\theta_i - p_iE_ms_i\right)^2 = p_iE\left(\theta_i - p_iE_m\theta_i\right)^2 + (1-p_i)\,E\left(\theta_i - p_iE_mx_i\right)^2.$$

Now, note first that $E\left(\theta_i - p_iE_mx_i\right)^2 = E\theta_i^2 + p_i^2E\left(E_mx_i\right)^2$. Second, note that

$$E\left(\theta_i - p_iE_m\theta_i\right)^2 = E\left(\theta_i - E_m\theta_i\right)^2 + (1-p_i)^2\,E\left(E_m\theta_i\right)^2$$

Adding the two components together and adding and subtracting $p_i^2E\left(\theta_i - E_m\theta_i\right)^2$ gives

$$p_i\left(E\left(\theta_i - E_m\theta_i\right)^2 + (1-p_i)^2E\left(E_m\theta_i\right)^2\right) + (1-p_i)\left(E\theta_i^2 + p_i^2E\left(E_mx_i\right)^2\right)$$
$$+p_i^2E\left(\theta_i - E_m\theta_i\right)^2 - p_i^2E\left(\theta_i - E_m\theta_i\right)^2$$

$$\left(1-p_i^2\right)E\theta_i^2 + (1-p_i)\,p_i^2E\left(E_mx_i\right)^2 - p_i^2\left(1-p_i\right)E\left(E_m\theta_i\right)^2 + p_i^2E\left(\theta_i - E_m\theta_i\right)^2$$

and noting that $E\left(E_mx_i\right)^2 = E\left(E_m\theta_i\right)^2$, this simplifies to

$$E\left(p_i\theta_i - p_iE_m\theta_i\right)^2 + \left(1-p_i^2\right)\tfrac{\overline{\theta}_i^2}{3}.$$

First component is equivalent to the fundamental uncertainty that would be present if the state was distributed on $U\left[-p_i\overline{\theta}_i, p_i\overline{\theta}_i\right]$ and the second component gives the additional loss due to inaccurate primary information. The equivalence is thus established.

Proposition 9

The first-order conditions are given by

$$d_i^m = a_1E_m\theta_i + a_2E_md_j \qquad \textit{and} \qquad d_j^n = b_1E_n\theta_j + b_2E_nd_i,$$

where

$$E_md_j = b_1E_mE_n\theta_j + b_2E_mE_nd_i \qquad \textit{and} \qquad E_nd_i = a_1E_nE_m\theta_i + a_2E_nE_md_j.$$

Note that since E_nd_i and E_md_j are based solely on the messages m_i, m_j sent, "what you think that I know" and so all higher-order beliefs (which are equal) are common knowledge.[19] Thus, we can write by repeated substitution

$$d_i^m = a_1E_m\theta_i + a_2\left(b_1E_mE_n\theta_j + b_2\left(a_1E_nE_m\theta_i + a_2\left(b_1E_mE_n\theta_j + b_2\left(...\right)\right)\right)\right),$$

which, after rearranging, simplifies to

$$d_i^m = \tfrac{a_1(1-b_2a_2)E_m\theta_i + a_2b_1E_mE_n\theta_j + a_2b_2a_1E_nE_m\theta_i}{1-b_2a_2}.$$

Proposition 10

[19] The solution in the case of an exogenous probability of communication failure is available from the author on request.

The linearity of the solution follows directly from the quadratic form of the payoffs and the linearity of the equilibrium decisions in all information. In particular, we can write the objective function of the sender (agent i) as:

$$\min_{m_i} E_i \left[\begin{array}{c} \beta_i \left((1-r_i)(\theta_i - d_i(.,m_i))^2 + \left(\beta_i r_i + \beta_j r_j\right)(d_i(.,m_i) - d_j(.,m_i))^2 \right) \\ +\beta_j (1-r_j)(\theta_j - d_j(.,m_i))^2 \end{array} \right]$$

where m_i stands for the message sent, and our task is to solve for an incentive-compatible partition of the message space. Let $I_{m=i} \in \{0,1\}$ be an indicator function for whether the sender retains control for his own activity. Then we can write the indifference condition component-wise (dropping constant components):[20]

$$\begin{aligned} \Delta(\theta_i - d_i(.,m_i))^2 = {} & a_1^2 (1 - I_{m=i}(1-b_2 a_2))^2 (\theta_k + \theta_{k-2} - 2\theta_{k-1}) \\ & -2a_1 a_2 b_1 (1 - I_{m=i}(1-b_2 a_2))(\theta_{k-1} - E_i\theta_j) \end{aligned}$$

$$\Delta(\theta_j - d_j(.,m_i))^2 = (b_2 a_1)^2 (\theta_k + \theta_{k-2} - 2\theta_{k-1}) + 2(b_2 a_1)^2 (\theta_{k-1} - E_i\theta_j)$$

$$\begin{aligned} \Delta(d_i(.,m_i) - d_j(.,m_i))^2 = {} & a_1^2 (b_1 - I_{m=i}(1-b_2 a_2))^2 (\theta_k + \theta_{k-2} - 2\theta_{k-1}) \\ & +2a_1^2 (b_1 - I_{m=i}(1-b_2 a_2)) b_1 (\theta_{k-1} - E_i\theta_j) \end{aligned}$$

substituting back and rearranging gives then:

$$\begin{aligned} \theta_k = {} & 2\theta_{k-1} - \theta_{k-2} \\ & +4\frac{\left[\beta_i(1-r_i)a_2 b_1(1-I_{m=i}(1-b_2a_2)) - \left(\beta_i r_i+\beta_j r_j\right)a_1(b_1 - I_{m=i}(1-b_2a_2))b_1 - \beta_j(1-r_j)b_2^2 a_1\right]}{a_1\left[\beta_i(1-r_i)(1-I_{m=i}(1-b_2a_2))^2 + \left(\beta_i r_i+\beta_j r_j\right)(b_1 - I_{m=i}(1-b_2a_2))^2 + \beta_j(1-r_j)b_2^2\right]}(\theta_i - E_i\theta_j) \end{aligned}$$

or

$$\theta_n = 2\theta_{n-1} - \theta_{n-2} + 4\frac{1}{\varphi_i^g}(\theta_{n-1} - E_i\theta_j)$$

The general solution to the difference equation with the above structure is given by:

$$\theta_n - E_i\theta_j = \frac{\varphi}{4\sqrt{1+\varphi}} \left(\left(\frac{\varphi}{(1-\sqrt{1+\varphi})^2} \right)^n - \left(\frac{\varphi}{(1+\sqrt{1+\varphi})^2} \right)^n \right) (\theta_1 - E_i\theta_j)$$

let l and k be the two different cutoffs. Then,

$$\frac{\theta_l - E_i\theta_j}{\theta_k - E_i\theta_j} = \frac{\frac{\varphi}{4\sqrt{1+\varphi}} \left(\left(\frac{\varphi}{(1-\sqrt{1+\varphi})^2} \right)^l - \left(\frac{\varphi}{(1+\sqrt{1+\varphi})^2} \right)^l \right)}{\frac{\varphi}{4\sqrt{1+\varphi}} \left(\left(\frac{\varphi}{(1-\sqrt{1+\varphi})^2} \right)^k - \left(\frac{\varphi}{(1+\sqrt{1+\varphi})^2} \right)^k \right)} = \varphi \frac{(1+\sqrt{1+\varphi})^{2l} - (1-\sqrt{1+\varphi})^{2l}}{(1+\sqrt{1+\varphi})^{2k} - (1-\sqrt{1+\varphi})^{2k}}$$

define $k = n$ and $l = n - x$, where x is the distance between the two cutoffs, with $x = 1$ implying adjacent cutoffs. This substitution allows us to write the equation as

[20] We make the assumption that agent i doesn't have better information about θ_j than the person deciding d_j. In the simultaneous one-round case, there is no prior information and as a result this condition is trivially satisfied

$$\frac{\theta_{n-x}-E_i\theta_j}{\theta_n-E_i\theta_j} = \frac{\left(1+\sqrt{1+\varphi}\right)^{2(n-x)}-\left(1-\sqrt{1+\varphi}\right)^{2(n-x)}}{\varphi^{n-x}} \frac{1}{\frac{\left(\left(1+\sqrt{1+\varphi}\right)^{2n}-\left(1-\sqrt{1+\varphi}\right)^{2n}\right)}{\varphi^{n}}}$$

Now, to solve for the most informative partition (which minimizes the absolute size of the intervals conditional on the relative size of the adjacent intervals being given by φ), we let $n \to \infty$. Observe that:

$$\frac{\left(1-\sqrt{1+\varphi}\right)^{2y}}{\varphi^y} = \frac{\left(2-2\sqrt{1+\varphi}+\varphi\right)^y}{\varphi^y}|_{y\to\infty} \to 0$$

as long as $\varphi > 0$. Therefore, the above rearranges to:

$$\frac{\theta_{n-x}-E_i\theta_j}{\theta_n-E_i\theta_j} = \left(\frac{\varphi}{\left(1+\sqrt{1+\varphi}\right)^2}\right)^x = \alpha\left(\varphi\right)^x$$

Letting $\theta_n = \overline{\theta}$ gives the full characterization of the partition. The solution going backwards $(\theta_n < E_i\theta_j)$ follows similarly.

Proposition 11

To solve the expectations we need to use to communication equilibrium (we continue to let α to stand for α_i to simplify):

(a) probabilities

The probability of $\theta_i \in [\theta_{k-1}, \theta_k]$ is simply:

$$\left(\frac{\overline{\theta}-E_i\theta_j}{2\overline{\theta}}\right)\alpha^{i-1}\left(1-\alpha\right) \qquad \theta_i > E_i\theta_j$$

$$\left(\frac{E_i\theta_j+\overline{\theta}}{2\overline{\theta}}\right)\alpha^{i-1}\left(1-\alpha\right) \qquad \theta_i < E_i\theta_j$$

where $i = 1$ indexes the furthest partition.

(b) cutoffs

The cutoffs are in turn given by:

$$\theta_i = E_i\theta_j + \alpha^i\left(\overline{\theta}_i - E_i\theta_j\right),$$

where $i = 0 \to \theta_i = \overline{\theta}$ and symmetrically downwards

(c) conditional expectations and variances

From the cutoffs it follows immediately that

$$E\theta_i = E_i\theta_j + \tfrac{1}{2}\alpha^{i-1}\left(1+\alpha\right)\left(\overline{\theta} - E_i\theta_j\right) \qquad \theta_i > E_i\theta_j$$

$$E\theta_i = E_i\theta_j - \tfrac{1}{2}\alpha^{i-1}\left(1+\alpha\right)\left(\overline{\theta} + E_i\theta_j\right) \qquad \theta_i < E_i\theta_j$$

(d) ex ante expectations and variances

First, note that since learning is a random walk, $EE\theta_i = 0$. The two components that do matter are $E\left(E_j\theta_i\right)^2$ and $EVar(\theta_i)$

Evaluating $E\left(E_j\theta_i\right)^2$:

$$E\left(E_j\theta_i\right)^2 = \sum_{i=1}^{\infty}\left(\frac{\overline{\theta}-E_i\theta_j}{2\overline{\theta}}\right)\alpha^{i-1}\left(1-\alpha\right)\left(E_i\theta_j+\tfrac{1}{2}\alpha^{i-1}\left(1+\alpha\right)\left(\overline{\theta}-E_i\theta_j\right)\right)^2$$
$$+\sum_{i=1}^{\infty}\left(\frac{\overline{\theta}+E_i\theta_j}{2\overline{\theta}}\right)\alpha^{i-1}\left(1-\alpha\right)\left(E_i\theta_j-\tfrac{1}{2}\alpha^{i-1}\left(1+\alpha\right)\left(\overline{\theta}+E_i\theta_j\right)\right)^2$$

$$E\left(E_j\theta_i\right)^2 = \tfrac{1}{4}\left(\left(1+\tfrac{\alpha(1-\alpha)}{(1-\alpha^3)}\right)\overline{\theta}^2-\left(1-\tfrac{3\alpha(1-\alpha)}{(1-\alpha^3)}\right)\left(E_i\theta_j\right)^2\right)$$

Similarly for $E\left(\theta_i - E_j\theta_i\right)^2$:

$$E\left(\theta_i-E_j\theta_i\right)^2 = \sum_{i=1}^{\infty}\left(\frac{\overline{\theta}-E_i\theta_j}{2\overline{\theta}}\right)\alpha^{i-1}\left(1-\alpha\right)\tfrac{1}{12}\left(\alpha^{i-1}\left(1-\alpha\right)\left(\overline{\theta}-E_i\theta_j\right)\right)^2$$
$$+\sum_{i=1}^{\infty}\left(\frac{\overline{\theta}+E_i\theta_j}{2\overline{\theta}}\right)\alpha^{i-1}\left(1-\alpha\right)\tfrac{1}{12}\left(\alpha^{i-1}\left(1+\alpha\right)\left(\overline{\theta}+E_i\theta_j\right)\right)^2$$

$$EVar_j\theta_i = \tfrac{1}{12}\left(\tfrac{(1-\alpha)^3}{(1-\alpha^3)}\right)\left(\overline{\theta}^2+3\left(E_i\theta_j\right)^2\right)$$

in the case of simultaneous one-round communication, $E_i\theta_j = E_j\theta_i = 0$, and we get the functions $A(x)$ and $B(x)$ of the proposition. Finally, note that $A(x) + B(x) = \frac{1}{3}$ and that

$$B\left(x\right) \equiv \frac{(1-\alpha(x))^3}{12\left(1-\alpha(x)^3\right)} = \frac{\left(1-\frac{x}{\left(2+x+2\sqrt{1+x}\right)}\right)^3}{12\left(1-\left(\frac{x}{\left(2+x+2\sqrt{1+x}\right)}\right)^3\right)} = \frac{\left(2+2\sqrt{1+x}\right)^3}{12\left(\left(2+x+2\sqrt{1+x}\right)^3-x^3\right)}$$
$$= \frac{\left(2+2\sqrt{1+x}\right)^3}{12\left(\left(2+2\sqrt{1+x}\right)^3+3x^2\left(2+2\sqrt{1+x}\right)+3x\left(2+2\sqrt{1+x}\right)^2\right)}$$
$$= \frac{4\left(1+\sqrt{1+x}\right)^2}{12\left(4\left(1+\sqrt{1+x}\right)^2+3x^2+6x\left(1+\sqrt{1+x}\right)\right)}$$
$$= \frac{\left(1+\sqrt{1+x}\right)^2}{3\left(4\left(2+x+2\sqrt{1+x}\right)+3x\left(2+x+2\sqrt{1+x}\right)\right)} = \frac{1}{3(4+3x)}.$$

Then, to simplify notation for the analysis, we define $V\left(x\right) = 3B\left(x\right) = \frac{1}{4+3x}$.

Chapter 2

Motivating Information Acquisition through Organization Design

Abstract

We investigate how monetary incentives and the allocation of decision rights inside an organizational hierarchy can be used together to motivate information acquisition, support accurate communication and guide decision-making. We analyze the differences between a centralized decision-making structure, where local divisions acquire information and communicate it to the headquarters that makes the decisions, and a decentralized decision-making structure, where the local divisions not only acquire information but also retain decision-making authority. Under both governance structures, the basic tension of incentive provision is between providing strong local incentives to motivate information acquisition and balanced global incentives to motivate accurate communication and to guide decision-making. However, because the value of information and the value of incentive alignment depend on the allocation of decision rights, each governance structure arises as the preferred choice under specific conditions. In particular, centralization is preferred only when coordination is sufficiently important and motivating information acquisition is more valuable than incentive alignment.

2.1 Introduction

One reason for the existence of organizations is their ability to coordinate interdependent activities. This idea has been embedded in organization science at least since Chester Barnard, who defined formal organization as "*a system of consciously coordinated activities or forces of two or more persons*" (1938 (1968:73), emphasis in the original). However, organizations exhibit significant heterogeneity both in terms of the degree of interdependence between their activities and in their organizational architecture.

Two key dimensions of organizational architecture are the degree of centralization of decision-making and the monetary incentives provided to the organizational participants. This paper analyses how these two dimensions are simultaneously determined by the degree of interdependence between the organization's activities. In particular, we examine how the allocation of decision rights and the provision of monetary incentives can be simultaneously used to improve the organization's ability to solve problems of coordinated adaptation.

The organization analyzed consists of two (symmetric) divisions, profitability of which depends both on how well the activities of the divisions are aligned with local conditions and on how well the divisions coordinate their activities with each other. The organization is operated by three self-interested agents, with two of the agents running the local divisions and the third agent managing the headquarters. Information about the local conditions faced by each division is only available at the divisional level and has to be actively acquired by the division managers (local agents) at a personal cost. Information is thus local and distributed, and we also assume that the information acquired is soft, in the sense that the agents can talk about the information they (claim to) have acquired, but they cannot verifiably reveal any of this information.

While information acquisition is localized, we assume that decision rights over how the divisions are operated can be reallocated inside the organization. We consider two alternative governance structures. Under centralization, control of both divisions is allocated to the headquarters (manager), while under decentralization, control of the divisions is retained by their respective local agents. After information acquisition, the local agents strategically communicate this information (through cheap talk) to the decision-maker(s), and the decision-maker(s) then choose decisions that maximize their individual payoffs given the information available to them. Finally, while information cannot be acquired at the level of headquarters, the manager is able to improve divisional profits by devoting costly attention to them. Thus, all three participants need to be motivated through monetary incentives to perform their respective roles appropriately.

The basic incentive provision problem under both governance structures is clear. While motivating the manager is relatively straightforward since balanced incentives lead to both good decision-making and good choice of effort provision, the local agents face an inherent multitasking problem. On the one hand, local incentives are needed to induce information acquisition. On the other hand, balanced incentives are needed to induce accurate communication and, in the case of decentralization, good decision-making. The question is then what factors determine the optimal balance between the two and how this balance is influenced by the allocation of decision rights.

The basic conclusion of our analysis is that centralization is preferred only when coordination between the divisions is sufficiently important and aligning the interests of the local agents is too costly in terms of compromised quality of primary information and managerial effort. In particular, centralization is preferred only when the equilibrium strength of local incentives is *stronger* than under decentralization. However, at the same time, the equilibrium strength of incentives under both governance structures is typically decreasing in the importance of coordination. In consequence, our results suggest that the common association of centralization with weak incentives is not necessarily due to centralization requiring weak incentives as such, but instead that both are needed when the organization needs to maintain a sufficient level of coordination among its activities. While the link between the importance of coordination and the level of decision-making was analyzed in Chapter 1 and in is also analyzed in Alonso, Dessein and Matouschek (2006), the endogenization of the inter-divisional conflict and the resulting co-movement of incentives and decision rights is novel.

To establish the intuition behind this result and to present some additional insights, we will discuss the results in three steps. First, we discuss the basic links among information acquisition, communication and decision-making to establish the logic behind the equilibrium strength of incentives. Second, we consider how the value of information and the value of incentive alignment depend on the importance of coordination. Third, we establish the key differences between centralization and decentralization with respect to the value of information and the value of incentive alignment.

The first set of results pertains to the basic links among information acquisition, communication and decision-making (conditional on the importance of coordination). First, the quality of primary information, communication and decision-making are substitutes in terms of the overall organizational performance. After all, it matters very little whether decisions are bad because of bad incentive or bad information, and whether information is bad because it was communicated inaccurately or because the primary information was poor. In consequence, one driver of the choice of inter-divisional conflict is the sensitivity of the agent to incentives to acquire information relative to the marginal benefit from transmitting and using that information better. The more responsive the agent is to incentives to acquire information, the higher the equilibrium inter-divisional conflict is under both governance structures. Second, the lower the equilibrium quality of information, the higher the equilibrium degree of inter-divisional conflict. This result follows from the inherent asymmetry between the value of information and the value of incentive alignment. Information retains positive value even under maximal inter-divisional conflict because some information still gets transmitted and enters the equilibrium decisions. On the other hand, the value of incentive alignment goes to zero as the quality of primary information goes to zero since then there is no information to use. In consequence, the lower the quality of information, the more valuable motivating further information acquisition is relative to incentive alignment. Thus, conditional on the importance of coordination, the key drivers behind the equilibrium degree of inter-divisional conflict are (i) the responsiveness of the agent to incentives to acquire information and (ii) the quality of equilibrium information.

The second set of results pertains to the impact that the need for coordination has on the equilibrium strength of incentives. First, whenever coordination carries positive value, there are free incentives to motivate information acquisition: because the benefits of information acquisition accrue to the division undertaking the acquisition while imposing a negative externality on the other division, full divisional ownership provides excessive incentives to acquire information whenever coordination carries any value. Thus, both governance structures can achieve some incentive alignment without compromising the quality of information and the size of these free incentives is increasing in the importance of coordination. Second, the value of information is typically decreasing in the importance of coordination: the need for coordination limits the amount of adaptation that takes place in equilibrium and thus decreases the value of information. Third, the value of incentive alignment is typically increasing in the importance of coordination: under centralization, increased importance of coordination decreases the quality of communication which needs to be compensated for, while under decentralization, incentive alignment is used to improve both decision-making and communication. As a result of these three forces, the strength of local incentives (and thus the degree of inter-divisional conflict) is typically decreasing in the importance of coordination.

The third set of results pertains to how the value of information and the value of incentive alignment differ across the governance structures and how these differences then translate to differences in the equilibrium strength of incentives, quality of information and thus overall performance. The basic result is that centralization arises as the equilibrium outcome only when (i) coordination is sufficiently important *and* (ii) the equilibrium warrants a sufficient degree of inter-divisional conflict (aligning incentives further is too costly, both in terms of compromised quality of primary information and reduction in managerial effort). When inter-divisional conflict is present, then communication is compromised in the case of centralization while both communication and decision-making are compromised under decentralization. The cost of each compromise depends on the importance of coordination. When coordination is sufficiently unimportant, the cost of inaccurate vertical communication is higher than the cost of biased decisions and inaccurate horizontal communication. Further, whenever centralization is preferred, both the local incentives and the quality of information are higher than they would be under decentralization. In contrast, when the equilibrium inter-divisional conflict is sufficiently low, then decentralization dominates centralization independent of the degree of incentive conflict.

The remainder of the paper is structured as follows. Section 2 reviews the related literature and section 3 describes the model. Section 4 derives the equilibrium outcome under centralization and decentralization and section 5 analyzes the solutions. Section 6 concludes. Appendix A outlines the general solution that accounts for asymmetries across the divisions and Appendix B discusses how asymmetries between the divisions, in terms of importance of adaptation, coordination and environmental volatility, impact both the incentive provision and the allocation of decision rights.

2.2 Related literature

This paper contributes to and is related to the literatures on authority, strategic communication, coordination and incentive provision in organizations. The model builds directly on the framework in Chapter 1 of this thesis and Alonso, Dessein and Matouschek (2006), but instead of considering the outcome conditional on an exogenous degree of incentive alignment between the divisions and an exogenous quality of information, we endogenize both the degree of incentive alignment and the quality of information acquired by the divisions.

In consequence, the paper is more closely related to Friebel and Raith (2006), Dessein, Garicano and Gertner (2006) and Athey and Roberts (2001), each of which looks at the simultaneous determination of incentives and decision-making authority from alternative angles. The paper most closely related to ours is Friebel and Raith (2006), who analyze a model where the divisions need to exert effort to generate good-quality projects and the amount of resources available for implementing the project can be determined either ex ante or interim. The basic trade-off is thus between motivating effort to improve the likelihood of good-quality projects and motivating truthful revelation of that quality to improve resource allocation. While interim resource allocation contains an element of coordination, the underlying problems are qualitatively different. To illustrate, in their model, decentralization is always associated with zero incentive alignment because if interim reallocation of resources is desired, the headquarters is always in a better position to do so. In contrast, in our model, one of the key determinants of the choice of governance structure is the relative degree of equilibrium incentive alignment achieved under the two governance structures. Also, effort to acquire information is qualitatively different from effort to improve the likelihood of good-quality projects.

As in Friebel and Raith (2006), the basic trade-off in Dessein, Garicano and Gertner (2006) (henceforth DGG) is between local incentives to induce effort provision and balanced incentives to induce truthful communication. The organization needs to decide when to implement synergies. A functional manager learns the returns to synergy implementation while two divisional managers learn the cost of implementing those synergies in terms of compromised adaptation. Again, incentive alignment is needed to induce truth-telling by the divisional managers and appropriate synergy implementation decisions, while local incentives are needed to induce productive effort. However, because the productive effort is orthogonal to the synergy implementation decision, the links among value of information, value of incentive alignment and the allocation of decision rights are not analyzed in DGG.

Finally, Athey and Roberts (2001) consider a problem where two agents need to be motivated to exert productive effort. In addition, somebody needs to decide which projects to implement, which impacts the payoffs to both agents. If one of the agents is allowed to make decisions, then he faces a multi-tasking problem analogous to the other papers: local incentives to induce effort and global incentives to induce good project implementation decisions. Introducing a third agent as the decision-maker helps to solve this multi-tasking problem. As in DGG, effort provision and project choice are orthogonal. Further, information about the projects can be made readily available to the manager, so that the use of a third agent is always beneficial unless it carries an additional cost. In contrast, in our model, the problem of strategic communication limits the use of an initially uninformed agent as the decision-maker even if she carries no extra cost.

In addition to these papers, the present paper is more distantly related to number of other papers.

Cheap talk: Communication, both between the local agents and to the headquarters, is modeled as cheap talk. As a result, the model is related to the literature on cheap talk that has followed the seminal article of Crawford and Sobel (1982). However, by considering multiple senders, the setting is closer to Battaglini (2002), but since the agents obtain only partial and independent information, inducing truth-telling is impossible in our setting absent monetary transfers. Also, the possibility of preference alignment between the sender and the receiver makes the payoff structure more related to Stein (1989) and Melumad and Shibano (1991).

Authority, delegation and incentives: The role of decision rights has also been analyzed from other angles. Aghion and Tirole (1997) show how delegation of a project choice decision can be used to motivate an agent to acquire information when the preferences of the principal and the agent are misaligned. Their model, however, takes the degree of incentive alignment as exogenous and the transmission of information is perfect. Chapter 3 examines how contracting difficulties influence the allocation of decision rights and how such difficulties can be used to endogenize the degree of incentive conflict in Aghion and Tirole while leaving a role for delegation that is qualitatively different from monetary incentives. Still, Chapter 3 doesn't explicitly consider the process of communication. Dessein (2002) illustrates how communication difficulties encourage delegation by showing that the cost of biased decisions is typically lower than the costs of garbled information following strategic communication in the setting of Crawford and Sobel (1982). In a setting with multiple decisions, Alonso (2006) shows how sharing control of complementary decisions improves communication between an informed agent and an uninformed principal. With the exception of Chapter 3, the models take the degree of incentive alignment as exogenous. In contrast, the present paper examines how the degree of incentive conflict is determined in equilibrium and how it depends on the current allocation of decision rights.

Hierarchies: Organizational structures have also been analyzed from various other angles, but with the exception of the papers already mentioned, primarily only from a team-theoretic perspective. The paper closest to ours is Dessein and Santos (2006), who examine a team-theoretic model that focuses on the limitations that the need for coordinated adaptation imposes on task specialization. Coordination in their model is, however, constrained only because information transmission is exogenously imperfect. Other perspectives include information processing (e.g. Marshak and Radner, 1972, Bolton and Dewatripont, 1994), problem-solving (e.g. Garicano, 2000), screening for interdependencies (Harris and Raviv, 2002) and coordination and experimentation (Qian, Ronald and Xu, 2006).

2.3 The model

The basic structure of the model parallels closely the frameworks of Chapter 1 and Alonso, Dessein and Matouschek (2006), with the addition of active information acquisition and the resulting endogenization of incentive provision. The organization consists of two divisions, i and j, that need to both respond to their local environments and coordinate with each other. Each division is headed by a division manager (local agents i and j, respectively), who must acquire information about their local conditions for decision-making purposes. In addition to the local agents, there exists headquarters (manager, M), who invests in purely productive effort. If decision-making is decentralized, after information acquisition, the local agents communicate with each other through cheap talk after which they make decisions. If decision-making is centralized, they communicate through cheap talk with the manager, who then makes the decisions.

2.3.1 Payoff structure

Activities: The organization consists of two divisions, i and j. Given the decision d_i of how to run the operations of division i, the ex post profit to activity i is given by:

$$\pi_i = K_i - \alpha_i (\theta_i - d_i)^2 - \beta_i (d_j - d_i)^2 + \gamma_i \ln e_{M-i},$$

where $\theta_i \sim U\left[-\overline{\theta}_i, \overline{\theta}_i\right]$ indexes the locally optimal decision, with θ_i and θ_j independently distributed, and d_j is the decision governing division j. We will refer to $\alpha_i (\theta_i - d_i)^2$ as the *adaptation component* and to $\beta_i (d_j - d_i)^2$ as the *coordination component* of the profit function, together comprising the decision-dependent part of the divisional profit. In addition to the decisions, the profitability of the division depends on the attention devoted to the division by the headquarters, captured by the *effort component*, $\gamma_i \ln e_{M-i}$.

We assume that K_i is large enough so that the organization is worth operating and to simplify notation, since maximizing profit is the same as minimizing loss, we will focus on the loss formulation of

$$L_i = \kappa_i \left((1 - r_i) (\theta_i - d_i)^2 + r_i (d_j - d_i)^2 \right) - \gamma_i \ln e_{M-i},$$

where we have simply normalized the decision-dependent part so that the relative importance of coordination (dependency) of activity i is parameterized by $r_i \in [0, 1]$ while the overall importance of decision-making to the activity is captured by $\kappa_i = (\alpha_i + \beta_i)$. We assume that all monetary costs and benefits of the organization are reflected in the profit and loss accounts of the two divisions, so that the ex post performance of the organization is given simply by $L_i + L_j$.

Local agents: The local agents contribute to the performance of their division by acquiring information about the local conditions to improve the quality of decision-making. In particular, the local agent i acquires a signal t_i of the realized state θ_i that is correct with probability p_i and a random draw from $U\left[-\overline{\theta}_i, \overline{\theta}_i\right]$ with probability $1 - p_i$ at a personal cost of

$$C^{i,g}(p_i) = -(\mu_i + I\nu_i)\left(p_i^2 + \ln\left(1 - p_i^2\right)\right),$$

where μ_i controls the marginal cost of information acquisition, $I \in \{0, 1\}$ is an indicator function for whether the agent is also responsible for making decisions, and ν_i captures the opportunity cost of decision-making.

The behavior of the local agents is managed through a profit-sharing plan. In particular, while we assume that (p_i, θ_i, d_i) are not contractible, the profitability of each division is verifiable. In particular, agent i is offered a linear incentive contract

$$T^i(L_i, L_j) = A_i - s_{i-i}L_i - s_{i-j}L_j,$$

which is used to guide information acquisition, communication and, if given control, decision-making. The ex post utility of agent i is then given by $U^i = T^i(L_i, L_j) - C^{i,g}(p_i)$.

Manager: In contrast to the local agents, the manager is unable to acquire information directly. However, he is able to contribute to the profitability of division i by exerting productive effort at a personal cost

$$C^{M,g}(e_{M-i}, e_{M-j}) = (\mu_M + I\nu_M)\left(\ln(1 - e_{M-i}) + \ln(1 - e_{M-j})\right),$$

where μ_M parameterizes the marginal cost of effort, and paralleling the case of local agents, $I \in \{0, 1\}$ is an indicator function for whether the manager is also responsible for making decisions and ν_M parameterizes the opportunity cost of decision-making for the manager. As with the local agents, the manager also needs to be motivated through a profit-sharing plan. The contract offered to the manager is given by

$$T^M (L_i, L_j) = A_M - s_{M-i}L_i - s_{M-j}L_j,$$

so that the ex post utility of the manager is given by $U^M = T^M (L_i, L_j) - C^{M,g} (e_{M-i}, e_{M-j})$.

Assumptions regarding the payoff structure

Incentives: We assume that while the divisional pie can be divided arbitrarily between the three participants and so used to grow the size of the pie, the pie itself cannot be leveraged (that is, $s_{i-i} + s_{j-i} + s_{M-i} \leq 1$). This assumption is crucial to the analysis and to the relevance of the allocation of decision rights. With the help of a budget-breaker, the first-best could be achieved and the organizational form would become irrelevant. We rationalize this assumption by appealing to the possibility of sabotage, since the budget-breaker would always have an incentive to make the organization fail to avoid making any payments.

We also assume that only the aggregate divisional profit can be measured, without the ability to separately measure their components (adaptation, coordination and effort). While the managerial effort provision problem could be fully solved by such a separation, the information acquisition/decision-making problem would remain (even if attenuated) as long as the adding-up constraint is present. Finally, we are restricting our attention to linear incentives. In general, linear incentives are not optimal in the present setting, but the forces that are going to drive the optimal division of the pie are largely orthogonal to forces that drive the shape of optimal incentive contract.

Effort Structure: We have significantly restricted the roles of the agents to reduce the number of dimensions that need to be analyzed, but these restrictions don't appear to play a significant role in the qualitative nature of the results. For example, in practice we would assume that the local agents can also engage in productive effort. Such productive effort would simply increase the value of strong local incentives, leaving the general comparative statics unchanged.[1] Similarly, the manager is also often in a position to directly acquire some information. This, in turn, would significantly benefit the centralized solution.[2] However, the localization of information acquisition captures the idea that much information is location-specific and understanding that raw information requires specialization (even if codified information can later be transmitted).

[1]The results in the case of only local effort and no information acquisition are available from the author on request.

[2]Similarly, if agent i is able to acquire information about θ_j, this will also typically improve the outcome under decentralization. Sometimes, however, such cross-learning can lead to excessive information acquisition.

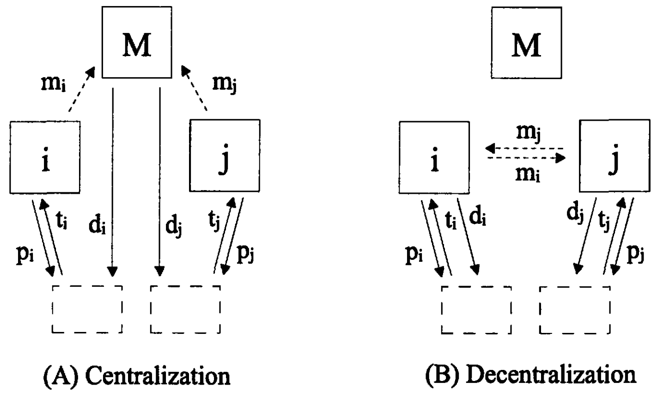


Figure 2-1: Alternative governance structures

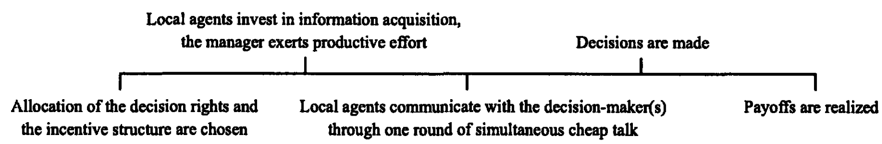


Figure 2-2: Timing of events

2.3.2 Timing of events and the choice of governance structure

We will focus on analyzing two governance structures. Under centralization, both decisions are controlled by the manager. Under decentralization, the decisions are controlled by the respective local agents. These two governance structures are summarized in figure 2-1, depicting the flow of information. The timing of events is further detailed in figure 2-2 and is the same under each governance structure.

First, each local agent invests p_i in information acquisition and the manager exerts productive effort $(e_{M-i}, e_{M-j})$to maximize their respective payoffs.[3] Second, the local agents send non-verifiable messages (m_i, m_j) about their local conditions to the decision-maker(s). In the case of centralization, this communication is vertical (to the manager), while in the case of decentralization it is horizontal (to the other local agent). Third, the decision-maker(s) use the received messages and any additional information they have available to choose a decision that again maximizes their respective payoffs. Fourth, payoffs are realized and shared according to the contract.

The objective in the design stage is to choose an allocation of decision rights (a governance structure $g \in \{dec, cent\}$) and a profit-sharing rule $\{s_i, s_j\}$ that maximizes the expected surplus generated by the game described. That is, letting u be the identity of the decision-maker

[3]The timing of managerial effort is irrelevant to the analysis.

controlling d_i and ω_u^g the information available to the decision-maker u in the decision-making stage under governance structure g, we can write the program as:

$$\min_{g,\{\mathbf{s}_i,\mathbf{s}_j\}} E\left(L_i\left(\mathbf{d}^g, \mathbf{e}_M\right) + L_j\left(\mathbf{d}^g, \mathbf{e}_M\right)\right) + C^M\left(\mathbf{e}_M\right) + C^i\left(p_i\right) + C^j\left(p_j\right)$$

$$\begin{aligned}
\text{s.t.} \quad & d_u^g \in \arg\min_d E\left(s_{u-i}L_i + s_{u-j}L_j|\omega_u^g, g\right), \qquad u \in \{i,j,M\} \\
& m_k^g \in \arg\min_{\{m_k^g\}} E\left(s_{k-i}L_i + s_{k-j}L_j|E\left(d_i^g|m_k^g\right), E\left(d_j^g|m_k^g\right), t_k\right), \qquad k \in \{i,j\} \\
& p_k \in \arg\min_p E\left(s_{k-i}L_i + s_{k-j}L_j|\left(d_i^g|m_k^g\right), E\left(d_j^g|m_k^g\right), \{m_k^g(t_k)\}\right) + C^{k,g}(p), \\
& \qquad k \in \{i,j\} \\
& \mathbf{e}_M \in \arg\min_{e_i,e_j} E\left(s_{M-i}L_i + s_{M-j}L_j\right) + C^{M,g}\left(\mathbf{e}_M\right),
\end{aligned}$$

where the constraints simply require incentive-compatibility in each stage of the game: (i) decisions are individually optimal to the decision-maker(s) given the information available to him or her, (ii) the messages sent are individually optimal to the local agents given the structure of the communication equilibrium and the structure of the equilibrium decisions, (iii) information acquisition by the local agents is individually optimal given its expected final impact on the equilibrium outcome, as given by the communication and decision equilibria, and (iv) the manager exerts an individually optimal level of productive effort. In addition, the beliefs held by the agents at each stage of the game have to naturally be correct in equilibrium.

Assumptions regarding the timing of events

Renegotiation: The most restrictive assumption in the analysis is our assumption that no renegotiation can take place between information acquisition and decision-making. First, renegotiating the sharing rule down to 50/50 after information acquisition would clearly eliminate all incentive conflicts and lead to first-best communication and decision-making. This, however, would then also feed back into the information acquisition stage. In general, some conflict is optimal in equilibrium and so commitment to the sharing rule is desired. Also, such renegotiation, even if possible, is highly unlikely in more fluid problems where decision-making problems overlap with information acquisition problems (so that there is limited fluctuation in the incentive provision problem at hand). More troublesome is the lack of reallocation of the decision rights or contracting on the decisions directly. While the presence of asymmetric and incomplete information is going to hinder efficient bargaining, the question of how much inefficiency would remain remains unanswered. We appeal to the need for a speedy response to rule out such intermediate bargaining.

Simultaneity: In this paper we focus only on the case where one round of simultaneous cheap talk is followed by simultaneous decision-making. Results for the decision and communication stages under the assumption of sequential actions are available from the author on request. In short, sequential decision-making can be used to improve the outcome under decentralization and is sustainable in equilibrium. The impact of sequential decisions on the qualitative trade-off between centralization and decentralization is, however, minimal.[4] Sequential communication is typically worse than simultaneous communication. Under centralization, this is always the case, while under decentralization, this is the case unless the variances are highly asymmetric (in which case alternative governance structures will do better). Continued communication, on the other hand, can benefit both governance structures. We focus on the simple one-round case with the continued appeal to the need for a speedy response.

2.4 Preliminaries

Because of the relatively high dimensionality of the model, we will present the analysis in a number of steps. First, sections 4.1 and 4.2 present the solution under centralization and decentralization under the assumption of symmetric divisions ($\kappa_i = \kappa_j$, $r_i = r_j$ and $\overline{\theta}_i = \overline{\theta}_j$) and discusses the basic trade-offs that are present. The general solution is summarized in Appendix A and was discussed in more detail in Chapter 1. In what follows, we will focus on information acquisition and incentive alignment at the expense of a detailed repetition of communication and decision-making stages.

Comparative analysis of these two solutions, maintaining the assumption of symmetry, is then performed in section 5. Section 5.1 analyzes the true and perceived value of information and the value of incentive alignment to detail the basic trade-offs. Section 5.2 analyzes the equilibrium under no managerial effort. Section 5.3 adds the need for managerial effort and section 5.4 adds the opportunity cost of decision-making. Appendix B extends the analysis to asymmetric divisions and discusses how asymmetric governance structures can be used to improve upon the symmetric structures analyzed in sections 4 and 5.

2.4.1 Solution under centralization

Decisions, communication and decision-dependent losses

Under centralization, the manager controls both decisions. When the divisions are symmetric, the equilibrium sharing rule will be symmetric. Thus, to simplify notation, let $s_M = s_{M-i} = s_{M-j}$ be the share of each division allocated to the manager, $s = s_{i-i} = s_{j-j}$ the share of each division retained by their respective local agents and $\widetilde{s} = s_{i-j} = s_{j-i}$ the share of the other division allocated to the local agents.

The solution follows by backward-induction. In the decision-making stage, the manager's information consists of messages m_i and m_j received from agents i and j, regarding the observed signals t_i and t_j, respectively. Thus, the manager solves

$$\min_{d_i,d_j} s_M E\left(L_i + L_j | m_i, m_j\right).$$

Taking the first-order conditions and solving them yields a decision rule

[4] Main differences arise when the divisions are asymmetric.

$d_i^{cent} = \frac{E_M\theta_i + 2rE_M\theta_j}{1+3r},$

where $E_M\theta_i = p_i E(t_i|m_i)$. When the divisions are symmetric (so that in equilibrium the manager will place an equal weight on each division), the decisions are optimal from the perspective of profit-maximization. However, the manager needs to rely solely on information communicated to her by the local agents. Thus, while the decisions themselves are appropriate given the information reaching the manager, the information itself is endogenous and dependent on the degree of incentive alignment between the manager and the local agents.

In the communication stage, agent i sends a non-verifiable message m_i regarding the realization of t_i to the manager in an attempt to influence her decisions. As long as $s > \widetilde{s}$, the local agent places excessive weight on the profitability of his division and the resulting incentive conflict between the agent and the manager leads to some garbling of information. In the case of centralization, the quality of communication (as determined by the most informative partition equilibrium of the cheap talk game) is parameterized by

$\varphi_i^{cent} = \frac{s+\widetilde{s}r}{r(s-\widetilde{s})} \in [0, \infty),$

which becomes perfect when $r \to 0$ or $s \to \widetilde{s}$ and is monotone decreasing in r and $|s - \widetilde{s}|$ for all $s > \widetilde{s}$. When the decisions face no need for coordination, no incentive conflict is present between the manager and the local agents: the manager simply implements the individually optimal decision for each division. However, when the value of coordination becomes positive, the manager becomes less responsive to local information than the local agents would prefer. In consequence, the quality of communication is decreasing in the dependency of the divisions. The bigger the own-division bias, the bigger the conflict and as a result, the quality of communication is monotone decreasing in the size of the incentive conflict.

Given the equilibrium decisions $\left(d_i^{cent}, d_j^{cent}\right)$, the equilibrium quality of communication by the local agents $\left(\varphi_i^{cent}, \varphi_j^{cent}\right)$ and the quality of primary information (p_i, p_j), we can then solve for the expected decision-dependent component of the expected loss, which is given by

Proposition 13 *The decision-dependent component of the expected loss under centralization can be written as*

$$EL_i^{cent} = \Lambda_i^{cent}\left(\left(p_i\overline{\theta}_i\right)^2 + \left(p_j\overline{\theta}_j\right)^2\right) + \Gamma_{i-i}^{cent}V\left(\varphi_i^{cent}\right)\left(p_i\overline{\theta}_i\right)^2 + \Gamma_{i-j}^{cent}V\left(\varphi_j^{cent}\right)\left(p_j\overline{\theta}_j\right)^2 + \pi_i\left(1-p_i^2\right)\overline{\theta}_i^2,$$

where $\Lambda_i^{cent} = \frac{\pi_i r}{(1+3r)}, \Gamma_{i-i}^{cent} = \pi_i - \Lambda_i^{cent}, \Gamma_{i-j}^{cent} = -\Lambda_i^{cent}, \pi_i = \frac{\kappa(1-r)}{3}$ *and* $V\left(\varphi_i^{cent}\right) = \frac{1}{4+3\varphi_i^{cent}}.$

Thus, division i naturally benefits from more accurate communication by agent i since it allows for more accurate adaptation by the manager. Similarly, division i benefits from the increased quality of primary information acquired by agent i since it also improves decision-making. Intuitively, it matters very little from the perspective of the final outcome whether the manager holds poor information because it got transmitted inaccurately or because the initial information was inaccurate. Only the final accuracy matters. The accuracy of information transmission is in turn measured by $V\left(\varphi_i^{cent}\right)$ and the payoff consequences of communication imperfections are given by Γ_{i-i}^{cent}.

However, division i suffers both from more accurate primary information and from more accurate communication regarding θ_j. This is the key characteristic of the model and results from the fact that coordination in the model is achieved by accommodating the needs of the other division, which is costly because it compromises local adaptation. Intuitively, if division j doesn't know what it should do, division i doesn't need to undertake any accommodation and is thus better off. The presence of this cost of accommodation can provide significant help in motivating information acquisition, as we will see below.

Information acquisition and effort provision

Consider first the managerial problem of effort provision. Since the choice of effort is independent of the decision-dependent part of the loss and there is no cross-substitution of effort, the per-division effort choice problem can be written simply as

$$\max_{e_{M-i}} s_M \gamma_i \ln e_{M-i} + (\mu_M + \nu_M) \ln (1 - e_{M-i}) \to e_{M-i} = \frac{s_M \gamma_i}{s_M \gamma_i + \mu_M + \nu_M}.$$

The local agents, on the other hand, will invest in information acquisition to

$$\min_{p_i} E\left(sL_i + \widetilde{s}L_j\right) + C^i\left(p_i\right),$$

the first-order condition to which is given by

$$\left[s\left(\pi_i - \underbrace{\left(\Lambda_i^{cent} + \Gamma_{i-i}^{cent} V\left(\varphi_i^{cent}\right)\right)}_{(1)}\right) - \widetilde{s}\underbrace{\left(\Lambda_j^{cent} + \Gamma_{j-i}^{cent} V\left(\varphi_i^{cent}\right)\right)}_{(2)} \right] \overline{\theta}_i^2 = \mu_i \frac{p_i^2}{1-p_i^2},$$

where the left-hand side gives the perceived marginal value of information. Part (1) of LHS gives the impact of information acquisition on the loss to activity i. First, the perceived value of information is decreasing in r, since the more important coordination is, the less the decisions will make use of any information about local conditions and thus the less valuable any information is (even when, as stated earlier, α is constant). Second, the perceived value of information is increasing in φ_i^{cent}. The more accurately the information acquired is transmitted to the manager, the more accurately the decisions match local conditions. Thus, while the quality of information and the quality of communication are substitutes from the perspective of overall performance, quality of communication also complements formal incentives in motivating information acquisition. Part (2) gives the cost of improved information imposed on division j through the increased cost of accommodation. Note that as long as $s > \widetilde{s}$, this cost is undervalued relative to improvement in division i's profitability. Thus, misaligned incentives provide free incentives to acquire information. We can see this explicitly by noting that, keeping the quality of communication constant, the profit-maximizing level of effort would be given by

$$\left[\left(\pi_i - \left(\Lambda_i^{cent} + \Gamma_{i-i}^{cent} V\left(\varphi_i^{cent}\right)\right)\right) - \left(\Lambda_j^{cent} + \Gamma_{j-i}^{cent} V\left(\varphi_i^{cent}\right)\right)\right] \overline{\theta}_i^2.$$

Thus, holding the quality of communication constant, (i) setting $s = 1$ and $\widetilde{s} = 0$ provides too strong incentives to acquire information, (ii) setting $s = \widetilde{s} < 1$ provides too weak incentives to acquire information and (iii) the incentives to acquire information are monotone increasing in s and monotone decreasing in $\widetilde{s}$. Thus, there exists an interior incentive strength with $0 \leq \overline{\widetilde{s}}\left(\varphi_i^{cent}\right) < \overline{s}\left(\varphi_i^{cent}\right) \leq 1$ such that, other things constant, the incentives to acquire information are profit-maximizing.

To complete the characterization of the incentive provision problem, note that $s_M = (1 - s - \widetilde{s})$, since there is no point in wasting any incentives. Thus, because the problem faced by the two divisions is symmetric, we can characterize the incentive provision problem as:

Proposition 14 *The optimal choice of* $(s, \widetilde{s})$ *under centralization solves*

$$\min_{s,\widetilde{s}} \left[\pi_i - \left(\pi_i - \left[\left(\Lambda_i^{cent} + \Lambda_j^{cent}\right) + \left(\Gamma_{i-i}^{cent} + \Gamma_{j-i}^{cent}\right) V\left(\varphi_i^{cent}\right)\right]\right) p_i^2\right] \overline{\theta}_i^2$$
$$- \mu\left(p_i^2 + \ln\left(1 - p_i^2\right)\right) - \left[\gamma_i \ln e_{M-i} + \left(\mu_M + \nu_M\right) \ln\left(1 - e_{M-i}\right)\right]$$

$$s.t. \qquad p_i^2 = \frac{\left[s\left(\pi_i - \left(\Lambda_i^{cent} + \Gamma_{i-i}^{cent} V\left(\varphi_i^{cent}\right)\right)\right) - \widetilde{s}\left(\Lambda_j^{cent} + \Gamma_{j-i}^{cent} V\left(\varphi_i^{cent}\right)\right)\right]\overline{\theta}_i^2}{\left[s\left(\pi_i - \left(\Lambda_i^{cent} + \Gamma_{i-i}^{cent} V\left(\varphi_i^{cent}\right)\right)\right) - \widetilde{s}\left(\Lambda_j^{cent} + \Gamma_{j-i}^{cent} V\left(\varphi_i^{cent}\right)\right)\right]\overline{\theta}_i^2 + \mu}$$

$$e_{M-i} = \frac{(1-s-\widetilde{s})\gamma_i}{(1-s-\widetilde{s})\gamma_i + \mu_M + \nu_M}$$

$$\varphi_i^{cent} = \frac{s + \widetilde{s}r}{r(s - \widetilde{s})}$$

If we take the first-order conditions, the solution is characterized by the following corollary:

Corollary 15 *The optimal choice of* $s' \in \{s, \widetilde{s}\}$ *under centralization solves*

$$s' : \underset{(1)}{\left[\frac{\mu p_i^2}{1-p_i^2} - \left(\pi_i - \left[\left(\Lambda_i^{cent} + \Lambda_j^{cent}\right) + \left(\Gamma_{i-i}^{cent} + \Gamma_{j-i}^{cent}\right) V\left(\varphi_i^{cent}\right)\right]\right) \overline{\theta}_i^2\right] \frac{\partial p_i^2}{\partial s'}}$$
$$+ \underset{(2)}{\left(\Gamma_{i-i}^{cent} + \Gamma_{j-i}^{cent}\right) p_i^2 \overline{\theta}_i^2 \frac{\partial V\left(\varphi_i^{cent}\right)}{\partial s'}} - \underset{(3)}{\left[\frac{\gamma_i}{e_{M-i}} - \frac{(\mu_M + \nu_M)}{(1 - e_{M-i})}\right] \frac{\partial e_{M-i}}{\partial s'}} = 0$$

For both s and $\widetilde{s}$, each component has a simple interpretation. The first component is simply the direct impact of incentives on the value and cost of information acquisition, with $\frac{\partial p_i}{\partial s} > 0$ and $\frac{\partial p_i}{\partial \widetilde{s}} < 0$. The solution to this part would give the optimal amount of information acquisition $\left(\overline{\widetilde{s}}\left(\varphi_i^{cent}\right), \overline{s}\left(\varphi_i^{cent}\right)\right)$, conditional on the quality of communication, as discussed above. However, the incentives provided have two additional effects. First, the second component gives the impact the incentives provided have on the quality of communication and its payoff consequences, with $\frac{\partial V\left(\varphi_i^{cent}\right)}{\partial s} > 0$ and $\frac{\partial V\left(\varphi_i^{cent}\right)}{\partial \widetilde{s}} < 0$ as long as $s > \widetilde{s}$. Second, any incentives provided to the local agents decrease the incentives of the manager to exert productive effort, captured by the third component.

2.4.2 Solution under decentralization

Decisions, communication and decision-dependent losses

The solution under decentralization, where each local agent controls their respective decisions, parallels that of under centralization, with two differences. First, in the decision-making stage, agent i knows his signal t_i and his information thus consists of (i) the signal t_i obtained regarding the realization of θ_i, (ii) message m_i sent to agent j regarding the realization of t_i, used by agent j to form beliefs about i's beliefs about θ_i, denoted $E_j E_i \theta_i$ $(= p_i E(\theta_i | m_i))$and (iii) message m_j received from agent j regarding the realization of t_j and used by agent i to form beliefs about j's beliefs about θ_j, denoted by $E_i E_j \theta_j$. Second, if $s > \widetilde{s}$, decision-making will be biased relative to centralization because of the excessive weight placed by agent i on the profitability of division i. Thus, agent i solves

$$\min_{d_i} E\left(sL_i + \widetilde{s}L_j | t_i, m_i, m_j\right)$$

and similarly for agent j. Solving the first-order conditions yields a decision rule of

$$d_i^{dec} = \frac{s(1-r)}{s+\widetilde{s}r} E_i\theta_i + \frac{(s+\widetilde{s})r}{((s+\widetilde{s}r)+r(s+\widetilde{s}))} E_i E_j \theta_j + \frac{(s+\widetilde{s})^2 r^2}{(s+\widetilde{s}r)((s+\widetilde{s}r)+r(s+\widetilde{s}))} E_j E_i \theta_i.$$

As discussed in Chapter 1, conditional on the information available to the agent and independent of the degree of incentive alignment, the equilibrium decisions converge to first-best decisions both when $r \to 0$ and when $r \to 1$. In the first case, no coordination is needed. In the second case, since the payoffs are fully dependent on coordination, the agents become willing to coordinate even absent any explicit incentive alignment. However, whenever $s > \widetilde{s}$ and r is interior, the decisions exhibit too little coordination (and correspondingly, excessive adaptation) from the perspective of profit maximization.

The role of incentive alignment in the decision-making stage is immediate: as $s \to \widetilde{s}$, the quality of decision-making is monotonically improving and converges to profit-maximizing when a balanced sharing rule of $s = \widetilde{s}$ is achieved. Since the initial bias in the decisions is largest in the region of intermediate r, the value of improved incentive alignment (from a decision-making perspective) is correspondingly highest in that region.

In the communication stage, agent i attempts to persuade agent j to accommodate his adaptive needs and thus an incentive conflict leading to garbled communication is again present whenever $s > \widetilde{s}$. In particular, the quality of communication under decentralization is given by

$$\varphi_i^{dec} = \frac{r(s-\widetilde{s})^2 + \widetilde{s}s(1+3r)}{(s+\widetilde{s}r)(s-\widetilde{s})}.$$

Thus, as in the case of centralization, when $s \to \widetilde{s}$, communication becomes perfect as the interests of the two local agents become perfectly aligned. However, in contrast to the case of centralization, the quality of communication is now increasing in r. The reason for this is that while in the case of centralization, the agent is communicating to achieve adaptation by the manager, in the case of decentralization, the agent agent is communicating to achieve accommodation by the other agent. As the importance of coordination increases, the amount of adaptation decreases, thus increasing the incentive conflict between the local agent and the manager, while the amount of accommodation increases, thus decreasing the incentive conflict between the two local agents. Further, it is immediate that $\varphi_i^{dec}(s, \widetilde{s}, r) < \varphi_i^{cent}(s, \widetilde{s}, r)\ \forall s > \widetilde{s}$ and $r < 1$, since the rate of accommodation is always lower than the amount of accommodation, and that $\varphi_i^{dec}(s, \widetilde{s}, r) \to \varphi_i^{cent}(s, \widetilde{s}, r)$ as $r \to 1$, since when the problem becomes one of pure coordination, the rates of adaptation and accommodation converge. However, $\varphi_i^{g}(s, \widetilde{s}, r \to 1) < \infty$ since conflict remains over the focal point of coordination.

Having the equilibrium decisions and the quality of communication, we can then solve for the decision-dependent component of the expected loss, which is given by

Proposition 16 *The decision-dependent component of the expected loss under decentralization can be written as*

$$EL_i^{dec} = \Lambda_i^{dec}\left(\left(p_i\overline{\theta}_i\right)^2 + \left(p_j\overline{\theta}_j\right)^2\right) + \Gamma_{i-i}^{dec}V\left(\varphi_i^{dec}\right)\left(p_i\overline{\theta}_i\right)^2 + \Gamma_{i-j}^{dec}V\left(\varphi_j^{dec}\right)\left(p_j\overline{\theta}_j\right)^2$$
$$+\pi_i\left(1-p_i^2\right)\overline{\theta}_i^2,$$

where $\Lambda_i^{dec} = \frac{\pi_i r(r\widetilde{s}(s+\widetilde{s})+s(s+r\widetilde{s}))}{(s(1+r)+2\widetilde{s}r)^2}$, $\Gamma_{i-i}^{dec} = \frac{\pi_i r(s(s+r\widetilde{s})+r\widetilde{s}(s+\widetilde{s}))}{(s+\widetilde{s}r)^2} - \Lambda_i^{dec}$,

$\Gamma_{i-j}^{dec} = \frac{\pi_i s^2(1-r)r}{(s+\widetilde{s}r)^2} - \Lambda_i^{dec}$, $\pi_i = \frac{\kappa(1-r)}{3}$ *and* $V\left(\varphi_j^{dec}\right) = \frac{1}{4+3\varphi_i^{dec}}$.

The basic features of the loss are the same as under centralization in terms of the impact of p_i, p_j and φ_i^{dec}. There are two primary differences. First, the coefficient Λ_i^g, which reflects the equilibrium decisions, was independent of $(s, \widetilde{s})$ under centralization, while under decentralization it naturally dependent on the degree of incentive alignment. Second, the costs of inaccurate communication are naturally different, with inaccurate communication being always less damaging under decentralization than under centralization. This result reflects the differing purposes of communication. Under centralization, decisions are naturally coordinated but information needs to be transmitted to achieve any adaptation. Under decentralization, the decisions are going to be somewhat adaptive even absent any communication since the local agents have direct access to information, but communication is needed to coordinate the decisions and to improve the amount of adaptation.

Information acquisition and effort provision

The solution to the effort provision problem by the manager is exactly the same as in the case of centralization, with the exception that the opportunity cost of time is now (weakly) lower since the manager no longer needs to make decisions. Similarly, the local agents will invest in information acquisition to satisfy the first-order condition

$$\left[s\left(\pi_i - \left(\Lambda_i^{dec} + \Gamma_{i-i}^{dec}V\left(\varphi_i^{dec}\right)\right)\right) - \widetilde{s}\left(\Lambda_j^{dec} + \Gamma_{j-i}^{dec}\right)\right]\overline{\theta}_i^2 = (\mu+\nu)\frac{p_i^2}{1-p_i^2}.$$

Thus, we can characterize the incentive provision problem as

Proposition 17 *The optimal choice of $(s, \widetilde{s})$ under decentralization solves*

$$\begin{aligned}
\min_{s,\widetilde{s}} & \left[\pi_i - \left(\pi_i - \left[\left(\Lambda_i^{dec} + \Lambda_j^{dec}\right) + \left(\Gamma_{i-i}^{dec} + \Gamma_{j-i}^{dec}\right) V\left(\varphi_i^{dec}\right)\right]\right) p_i^2\right] \overline{\theta}_i^2 \\
& - (\mu + v)\left(p_i^2 + \ln\left(1 - p_i^2\right)\right) - \left[\gamma_i \ln e_{M-i} + (\mu_M) \ln\left(1 - e_{M-i}\right)\right] \\
s.t. \quad & p_i^2 = \frac{\left[s\left(\pi_i - \left(\Lambda_i^{dec} + \Gamma_{i-i}^{dec} V\left(\varphi_i^{dec}\right)\right)\right) - \widetilde{s}\left(\Lambda_j^{dec} + \Gamma_{j-i}^{dec} V\left(\varphi_i^{dec}\right)\right)\right]\overline{\theta}_i^2}{\left[s\left(\pi_i - \left(\Lambda_i^{dec} + \Gamma_{i-i}^{dec} V\left(\varphi_i^{dec}\right)\right)\right) - \widetilde{s}\left(\Lambda_j^{dec} + \Gamma_{j-i}^{dec} V\left(\varphi_i^{dec}\right)\right)\right]\overline{\theta}_i^2 + (\mu + \nu)} \\
& e_{M-i} = \frac{(1 - s - \widetilde{s})\gamma_i}{(1 - s - \widetilde{s})\gamma_i + \mu_M} \\
& \varphi_i^{dec} = \frac{r(s - \widetilde{s})^2 + \widetilde{s}s(1 + 3r)}{(s + \widetilde{s}r)(s - \widetilde{s})}
\end{aligned}$$

Taking the first-order conditions, the optimal choice is characterized by the following corollary

Corollary 18 *The optimal choice of $s' \in \{s, \widetilde{s}\}$ under decentralization solves*

$$\begin{aligned}
s' : & \left[\frac{\mu p_i^2}{1 - p_i^2} - \left(\pi_i - \left[\left(\Lambda_i^{dec} + \Lambda_j^{dec}\right) + \left(\Gamma_{i-i}^{dec} + \Gamma_{j-i}^{cent}\right) V\left(\varphi_i^{dec}\right)\right]\right) \overline{\theta}_i^2\right] \frac{\partial p_i^2}{\partial s'} \\
& + \left[\left(\Gamma_{i-i}^{dec} + \Gamma_{j-i}^{dec}\right) \frac{\partial V\left(\varphi_i^{cent}\right)}{\partial s'} + \left(\frac{\partial\left(\Lambda_i^{dec} + \Lambda_j^{dec}\right)}{\partial s'} + \frac{\partial\left(\Gamma_{i-i}^{dec} + \Gamma_{j-i}^{dec}\right)}{\partial s'} V\left(\varphi_i^{dec}\right)\right)\right] \left(p_i \overline{\theta}_i\right)^2 \\
& - \left[\frac{\gamma_i}{e_{M-i}} - \frac{\mu_M}{(1 - e_{M-i})}\right] \frac{\partial e_{M-i}}{\partial s'} = 0
\end{aligned}$$

The first-order condition is thus very similar to the one under centralization. However, while the solutions are structurally similar, they differ in a variety of places. First, $\Lambda_i^{dec} \neq \Lambda_i^{cent}$, implying that the equilibrium decisions are different under the two governance structures, which in turn impacts the value of information. Second, the value and accuracy of information transmission generally differs across the governance structures: $\left(\Gamma_{i-i}^{dec} + \Gamma_{j-i}^{dec}\right) V\left(\varphi_i^{dec}\right) \neq \left(\Gamma_{i-i}^{cent} + \Gamma_{j-i}^{cent}\right) V\left(\varphi_i^{cent}\right)$. Again, this difference translates into differences in motivation for information acquisition. Third, the first-order condition under decentralization contains a fourth term, which captures how decision-making is impacted by changes in the degree of incentive alignment under decentralization.

2.5 Equilibrium outcomes and relative performance

We will perform the analysis of the equilibrium in several steps. In section 5.1 we will first examine how the two governance structures differ in their perceived and true value of information acquisition, which determines the value and need for providing incentives to motivate information acquisition, and how they differ in their value of incentive alignment, as measured by gains in the quality of communication and, in the case of decentralization, decision-making.

Having discussed the trade-off between local incentives to motivate information acquisition and balanced incentives to motivate communication and decision-making, section 5.2 presents the equilibrium outcome under the assumption of no managerial effort and no opportunity cost of decision-making. We see that the primary benefit of centralization is in alleviating the inherent tension between local and balanced incentives and thus arises as the equilibrium outcome when (i) equilibrium warrants sufficient inter-divisional conflict and (ii) centralization can provide a sufficient improvement in the quality of decision-making. Managerial effort is added in section 5.3. The need to motivate the manager makes providing both local and balanced incentives more costly. In consequence, as managerial effort becomes more important, the equilibrium conflict between the two divisions increases and centralization becomes more likely to be the preferred governance structure.

Finally, section 5.4 adds the opportunity cost of decision-making. Adding to the trade-offs in sections 5.2 and 5.3, we see that when the managerial opportunity cost increases, decentralization becomes the preferred solution also when the importance of coordination is sufficiently high. Conversely, when the local agents' opportunity cost of decision-making increases, centralization becomes the preferred method of organization also when the importance of coordination is sufficiently low.

2.5.1 Value of information and value of incentive alignment

Value of information and local incentives

To isolate the basic trade-offs, we will begin by analyzing the case where effort by the manager carries no value and decision-making involves no opportunity cost. The first set of results pertains to the perceived value of information, conditional on the degree of incentive alignment. Recall from above that we can write the difference in the perceived marginal value of more accurate signals as

$$\widetilde{MV}_{p_i}^{dec} - \widetilde{MV}_{dec}^{cent} = \begin{pmatrix} s\left(\left(\Lambda_i^{cent} + \Gamma_{i-i}^{cent} V\left(\varphi_i^{cent}\right)\right) - \left(\Lambda_i^{dec} + \Gamma_{i-i}^{dec} V\left(\varphi_i^{dec}\right)\right)\right) \\ +(1-s)\left(\left(\Lambda_j^{cent} + \Gamma_{j-i}^{cent} V\left(\varphi_i^{cent}\right)\right) - \left(\Lambda_j^{dec} + \Gamma_{j-i}^{dec} V\left(\varphi_i^{dec}\right)\right)\right) \end{pmatrix} \overline{\theta}_i^2.$$

Similarly, we can write the difference in the true value of information as

$$MV_{p_i}^{dec} - MV_{dec}^{cent} = \begin{pmatrix} \left(\left(\Lambda_i^{cent} + \Gamma_{i-i}^{cent} V\left(\varphi_i^{cent}\right)\right) - \left(\Lambda_i^{dec} + \Gamma_{i-i}^{dec} V\left(\varphi_i^{dec}\right)\right)\right) \\ +\left(\left(\Lambda_j^{cent} + \Gamma_{j-i}^{cent} V\left(\varphi_i^{cent}\right)\right) - \left(\Lambda_j^{dec} + \Gamma_{j-i}^{dec} V\left(\varphi_i^{dec}\right)\right)\right) \end{pmatrix} \overline{\theta}_i^2.$$

Analysis of the differences yields the following proposition:

Proposition 19 ***Perceived and true value of information:***

(i) If communication were non-strategic and perfect, then $\widetilde{MV}_{p_i}^{cent} > \widetilde{MV}_{p_i}^{dec}$ *and* $MV_{p_i}^{cent} > MV_{p_i}^{dec}$ $\forall$ $r \in (0,1)$ *and* $s > 1 - s$.

(ii) If communication were impossible, then $\widetilde{MV}_{p_i}^{cent} < \widetilde{MV}_{p_i}^{dec}$ *and* $MV_{p_i}^{cent} < MV_{p_i}^{dec}$ $\forall$ $r \in (0,1)$ *and* $s > 1 - s$.

(iii) $MV_{p_i}^{g}$ *and* $\widetilde{MV}_{p_i}^{g}$ *are decreasing in* r, $MV_{p_i}^{g}$ *is decreasing in* s *and* $\widetilde{MV}_{p_i}^{g}$ *is increasing in* s. *Further,* $\widetilde{MV}_{p_i}^{g} > MV_{p_i}^{g}$ *when* $s = 1$ *and* $r \in (0,1)$. *Thus, conditional on the quality of information and decision-making, the first-best incentives to acquire information would be given by*

$$\tfrac{1}{2} < \overline{s}^{g}\left(r\right) = \frac{\pi_i - \left(\Lambda_i^g + \Gamma_{i-i}^g V\left(\varphi_i^g\right)\right)}{\left(\pi_i - \left(\Lambda_i^g + \Gamma_{i-i}^g V\left(\varphi_i^g\right)\right) + \left(\Lambda_j^g + \Gamma_{j-i}^g V\left(\varphi_i^g\right)\right)\right)} \leq 1$$

(iv) $MV_{p_i}^{cent} > MV_{p_i}^{dec}$ *if* $r > \overline{r}\left(s\right)$ *and* $s \geq \overline{s} = \frac{17}{28}$. *If* $s < \frac{17}{28}$, $MV_{p_i}^{cent} < MV_{p_i}^{dec}$. *Also,* $\frac{\partial \overline{r}(s)}{\partial s} < 0$.

(v) $\widetilde{MV}_{p_i}^{dec} \geq \widetilde{MV}_{p_i}^{cent}$ *for all* r *if* $s \leq \frac{1}{4}\left(1+\sqrt{7}\right) \approx 0.911$ *and for* $r \leq \widetilde{r}\left(s\right)$ *otherwise. Also,* $\frac{\partial \widetilde{r}(s)}{\partial s} < 0$.

(vi) $MV_{p_i}^{cent} \to MV_{p_i}^{dec}$ *and* $\widetilde{MV}_{p_i}^{dec} \to \widetilde{MV}_{p_i}^{cent}$ *when* $r \to 1, r \to 0$ *or* $s \to 1/2$.

This proposition illustrates the multifaceted nature of the forces that actually go into determining the value of information. Parts (i) and (ii) establish the hypothetical bounds on the value of information. If information transmission was perfect, then centralization would actually provide *stronger* incentives to acquire information than decentralization. In the case of perfect information, the manager would achieve the profit-maximizing outcome while if the agents make decisions, each agent will be worse off unless their incentives are perfectly aligned with those of the firm, thus leading to a lower value of information.[5] Conversely, if information transmission is impossible, then the value of information is always higher under decentralization. In the case of centralization, information that cannot be transmitted carries zero value. In the case of decentralization, the agents are still able to achieve some adaptation and the need to coordinate constrains the decisions enough so that such adaptation carries a positive value relative to no response.

Part (iii) summarizes the overall behavior of the value of information. Both the true and the perceived value of information are decreasing in the importance of coordination. The more important coordination is, the less adaptive the decisions are and thus the lower the value of information (given the absolute value of adaptation). Similarly, the true value of information is increasing in $1 - s$ because it is communicated more accurately and, under decentralization, used better, while the perceived value is decreasing because of the increasing internalization of the cost of accommodation imposed on the other division.

Because the gains to information are disproportionately accruing to the division that acquires the relevant information, there are free incentives to acquire information and there exists an interior $\overline{s}^{g}\left(r\right)$ such that the first-best level of incentives to acquire incentives is provided:

[5] This result highlights the idea that in a broader organizational context, delegation need not improve motivation because other constraints on decision-making might change at the same time. However, it continues to be the case that if agent i gained control of d_i while the manager retained control of d_j, then the incentives of agent i would be unambiguously improved (while the overall firm value would be unambiguously decreased) because the local agent would then be able to induce more favorable decisions without worrying the constraining role of agent j controlling d_j.

some incentive alignment can be achieved without any loss in the efficiency of information acquisition and this alignment is typically increasing in the importance of coordination under both governance structures.[6]

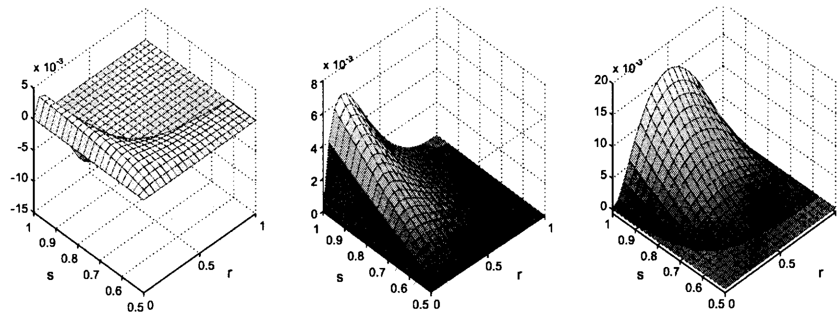
Parts (iv)-(vi) of the proposition summarize the differences in the perceived and true value of information, which are illustrated in figure 2-3. Because these play a key role in the determination of incentives, we will go through them in some more detail. Part (iv) (and panel (i)) state that the true value of information is higher under centralization whenever coordination is sufficiently important and the incentive conflict sufficiently large. Consider first the case of a large incentive conflict. When r is small, then the equilibrium decisions under decentralization are mildly biased while the communication under centralization is mildly garbled. For a sufficiently low r, the cost of garbled communication under centralization is larger than the cost of biased decision-making under decentralization. However, as r increases, the equilibrium decisions under decentralization become increasingly biased, while the value of accurate communication under centralization decreases, making centralization the more efficient means of using information. Even if the decisions under decentralization eventually start improving, the value of information remains higher under centralization until the two converge as $r \to 1$.

On the other hand, as incentive alignment is increased, the value of information under decentralization comes to dominate centralization for all levels of coordination. To understand this result, recall that incentive alignment improves communication under centralization while improving both communication and decision-making under decentralization. Now, communication is always less valuable under decentralization because some adaptation can be achieved even without communication. Second, as shown below in section 5.2, the return to increased incentive alignment is convex in the dimension of communication while being concave in the dimension of decision-making. Thus, as $s \to 1/2$, (i) value of information comes to be driven by the quality of communication and (ii) inaccurate communication is more damaging under centralization. In consequence, information is always more valuable under decentralization.[7] Finally, as we reach the limit, both decision-making and communication become perfect under both governance structures, thus equating the outcomes.

Part (v) (and panel (ii)) in turn states that contrary to the true value of information, the perceived value of information is almost always higher under decentralization. However, as pointed out by part (i), this result is not related to gaining the decision-right itself. Instead, it is driven by the fact that the distribution of costs and benefits, when accounting for the equilibrium quality of communication, is different across the governance structures. In particular, the negative externality imposed by better information is typically higher under decentralization. This result follows for two reasons. First, the equilibrium decisions under decentralization exhibit excessive adaptation. Excessive adaptation, in turn, increases the perceived value of information while increasing the costs of accommodation and coordination failure on the other division. Second, in the case of centralization, the perceived value of information is inherently attenuated by the garbling that occurs in the communication

[6] In particular, $\partial s^{cent}(r)/\partial r < 0\ \forall r$ and $\partial \overline{s}^{dec}(r)/\partial r < 0$ for $r \leq \widetilde{r} < 1$. For sufficiently high r, $\partial \overline{s}^{dec}(r)/\partial r > 0$ because of the improving quality of decision-making under decentralization. Finally, $\overline{s}^{cent}(r) \to \overline{s}^{dec}(r)$ as $r \to 1$.

[7] Indeed, because of the structure of the problem, the boundary $\overline{r}(s)$ is exactly the boundary between centralization and decentralization given a fixed quality of information and an exogenous degree of incentive alignment.



(i) MV^{dec}-MV^{cent}
difference in the true value of information

(ii) $\widetilde{MV}^{dec}$-$\widetilde{MV}^{cent}$
difference in the perceived value of information

(iii) $(\widetilde{MV}^{dec}$-$MV^{dec})$-$(\widetilde{MV}^{cent}$-$MV^{cent})$
difference in the difference between perceived and true value of information

Figure 2-3: Differences in the perceived and true value of information

stage, which is absent in the case of decentralization.[8] In terms of the underlying coefficients, $\widetilde{MV}^{dec} \geq \widetilde{MV}^{cent}$ because $\pi_i - \left(\Lambda_i^{dec} + \Gamma_{i-i}^{dec} V\left(\varphi_i^{dec}\right)\right) > \pi_i - \left(\Lambda_i^{cent} + \Gamma_{i-i}^{cent} V\left(\varphi_i^{cent}\right)\right)$ while $\left(\Lambda_i^{dec} + \Gamma_{i-i}^{dec} V\left(\varphi_i^{dec}\right)\right) > \left(\Lambda_i^{cent} + \Gamma_{i-i}^{cent} V\left(\varphi_i^{cent}\right)\right)$. However, because the equilibrium decisions converge as $r \to 1, r \to 0$ or $s \to 1/2$, so do the perceived values of information.

Value of incentive alignment

The value of incentive alignment, conditional on the quality of information, is roughly the converse of the value of information, conditional on the degree of incentive alignment. To understand this result, note that the value of information is constrained by two effects: (i) biased equilibrium decisions and (ii) garbled communication. High value of information (conditional on the importance of coordination) implies that the bias is low and communication is accurate. Conversely, low value of information implies that the bias is high and/or communication is valuable and inaccurate. Incentive alignment, in turn, generates an improvement in these dimensions. Thus, in broad terms, high value of information implies a low value of incentive alignment and vice versa. The qualifiers are that the quality of primary information naturally affects the overall value of incentive alignment and, on a more nuanced level, the differences in the perceived value of information translate to differences in inherent motivation.

To look at the value of incentive alignment in a little more detail, recall that in the case of centralization, this benefit is measured by

$$MV_s^{cent} = -\left[\left(\Gamma_{i-i}^{cent} + \Gamma_{j-i}^{cent}\right) \frac{\partial V\left(\varphi_i^{cent}\right)}{\partial s}\right] \left(p_i \overline{\theta}_i\right)^2,$$

while in the case of decentralization this benefit is measured by

[8] Exactly the converse holds true under costly communication where, *once the information is generated*, the agent typically has stronger incentives to communicate that information under centralization than under decentralization. Results available from the author on request.

$$MV_s^{dec} = -\left[\left(\Gamma_{i-i}^{dec} + \Gamma_{j-i}^{dec}\right)\frac{\partial V\left(\varphi_i^{cent}\right)}{\partial s} + \left(\frac{\partial\left(\Lambda_i^{dec}+\Lambda_j^{dec}\right)}{\partial s} + \frac{\partial\left(\Gamma_{i-i}^{dec}+\Gamma_{j-i}^{dec}\right)}{\partial s} V\left(\varphi_i^{dec}\right)\right)\right]\left(p_i\overline{\theta}_i\right)^2.$$

Comparing the two components yields the following proposition:

Proposition 20 ***Value of incentive alignment:***

(i) The value of incentive alignment is increasing in the accuracy of primary information.

Holding the accuracy of primary information constant, increasing the alignment of interests is always valuable and:

(ii) $\frac{d}{dr}MV_s^{cent} > 0$ *and* $\frac{d}{dr}MV_s^{dec} \gtreqless 0$.

(iii) $\frac{d}{ds}MV_s^{cent} < 0$ *and* $\frac{d}{ds}MV_s^{dec} \gtreqless 0$.

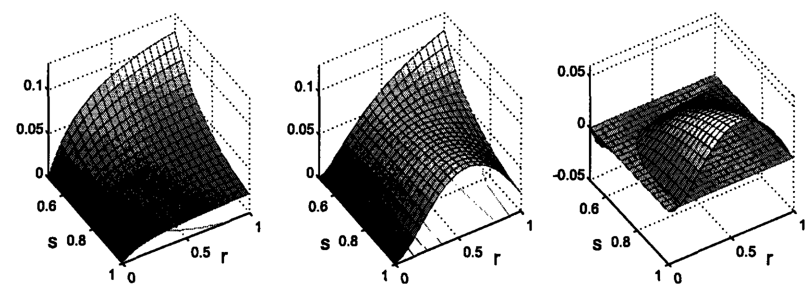
(iv) $MV_s^{dec} \to MV_s^{cent}$ *when* $r \to 0$ *and when* $r \to 1$.

(v) $MV_s^{dec} > MV_s^{cent}$ *whenever* $r > \overline{\overline{r}}(s)$, *with* $\frac{\partial\overline{\overline{r}}(s)}{\partial s} < 0$

Part (i) makes the obvious statement that the value of incentive alignment is increasing in the accuracy of information: the more information there is, the more valuable its accurate transmission is. The remainder of the proposition examines the behavior of the value of incentive alignment under the assumption of constant p_i to better highlight the differences. These results are illustrated in figure 2-4.

Part (ii) notes that the value of incentive alignment is increasing in the importance of coordination under centralization but not necessarily under decentralization. The case of centralization results from two forces. First, the incentive conflict between the agents and the manager is increasing in the importance of coordination, thus worsening the quality of communication. Second, the value of accurate communication goes down since the decisions are inherently coordinated and they become less responsive to local conditions as the importance of coordination increases. The first effect, however, dominates, leading to the increasing value of incentive alignment. This result holds for all degrees of incentive alignment.

The same conclusion doesn't, however, follow under decentralization because incentive alignment now affects both equilibrium decisions and equilibrium communication. Panel (ii) in figure 2-4 illustrates the net effect. To get intuition for the shape the relationship, recall from sections 4.2 and 5.1 that the equilibrium decisions under decentralization are worst at the range of intermediate importance of coordination. In consequence, when s is high, the value of incentive alignment is highest in the region of intermediate r, where the equilibrium decisions experience the largest relative improvement. In contrast, when s is sufficiently low so that the accuracy of communication is the dominating concern, then the monotonicity result holds also under decentralization. In the case of decentralization, the reason why accurate communication becomes more important is somewhat different from the case of centralization. Under decentralization, the value increases because coordination, value of which is increasing, is dependent on communication, and any adaptation is becoming increasingly dependent on accommodation. While



(i) Marginal value of incentive alignment under centralization

(ii) Marginal value of incentive alignment under decentralization

(iii) Difference in marginal values of incentive alignment: (dec-cent)

Figure 2-4: Differences in the value of incentive alignment, given p_i

the quality of communication is increasing, the value of accurate communication is increasing even faster.

Part (iii) makes explicit the role of incentive alignment alluded to in section 5.1. Under centralization, incentive alignment improves only communication, and the quality of communication enjoys increasing returns to scale under both governance structures. Under decentralization, communication improves both decision-making and communication. In contrast to the quality of communication, the returns to incentive alignment in terms of decision-making (conditional on the quality of information) are decreasing in the degree of alignment. In consequence, when s is small, the additional returns from increased alignment of interests are in terms of communication, while the gains in decision-making dominate under decentralization when r is intermediate and s is large.

Finally, part (v) (panel (iii)) states that the value of incentive alignment is higher under decentralization than under centralization whenever r and s are sufficiently large. This result is the converse of part (iv) of proposition 19 and the result of the logic to part (iii) of this proposition: as the degree of alignment becomes sufficiently large, additional gains come primarily in terms of improvements in communication. Since communication is more valuable under centralization, so is incentive alignment.

2.5.2 Equilibrium incentives and relative performance

Before presenting the equilibrium outcome, it is worth briefly summarizing the basic trade-off between local incentives to motivate information acquisition and balanced incentives to encourage accurate communication and improve decision-making. First, the two are complements in the following sense: the value of primary information is increasing in the quality of decision-making and communication and the value of accurate communication and appropriate decision-making is increasing in the quality of information. Second, the two are substitutes in terms of the final outcome: only the final quality of information held by the decision-maker matters in terms of the overall performance. Given these inherent trade-offs between the two, we can, without any further analysis, identify three rough regions in the parameters space as to the relationship between the degree of equilibrium incentive alignment, importance of coordination and the preferred governance structure:

High conflict/low importance of coordination: Decentralization dominates centralization. Given a fixed level of incentives, (i) information is more valuable under decentralization and (ii) more information is acquired under decentralization. Free incentives allow for an increased degree of incentive alignment under decentralization while the higher value of incentive alignment necessitates weaker incentives under centralization. Note that the former is a positive effect (more of both) while the latter is a negative effect (substituting one for the other).

Medium conflict conflict/high importance of coordination: Centralization dominates decentralization. Given a fixed level of incentives, (i) information is more valuable under centralization while (ii) more information is acquired under decentralization. Because of the higher free incentives and higher value of incentive alignment, incentives are weaker under decentralization. In equilibrium, more information is acquired under centralization.

Low conflict/any importance of coordination: Decentralization dominates centralization. Given a fixed level of incentives, (i) information is more valuable under decentralization and (ii) more information is acquired under decentralization. The value of incentive alignment is dominated by improvements in communication and is thus higher for centralization, leading to relatively weaker incentives.

Because of the nuanced variation in the true and perceived value of information, the resulting free incentives and the value of incentive alignment, this categorization is by necessity quite rough. However, it contains the basic logic that carries through the rest of the analysis. The only thing that remains to be determined is how the equilibrium degree of conflict between the divisions is determined. The following proposition makes these trade-offs exact:

Proposition 21 ***The equilibrium choice of incentive strength and governance structure:***

(i) Incentive strength is decreasing in $(\overline{\theta}, -\mu)$ under both governance structures, decreasing in r under centralization and decreasing in r under decentralization as long as $\overline{\theta}$ is sufficiently high (μ is sufficiently low)

(ii) Centralization dominates decentralization whenever $r > r(\theta)$ as long as $\theta < \widehat{\theta}(\mu)$, where $\frac{\partial \widehat{\theta}}{\partial \mu} > 0$. If $\theta \geq \widehat{\theta}(\mu)$, then decentralization is always preferred. Equivalently, centralization dominates decentralization whenever $r > r(\mu)$, as long as $\mu > \widehat{\mu}(\theta)$, where $\frac{\partial \widehat{\mu}}{\partial \theta} > 0$. If $\mu \leq \widehat{\mu}(\theta)$, then decentralization is always preferred.

(iii) $s^{cent}(r) > s^{dec}(r)$ whenever $EL^{cent}(r) < EL^{dec}(r)$

(iv) $p^{cent}(r) > p^{dec}(r)$ whenever $EL^{cent}(r) < EL^{dec}(r)$

These results are summarized in figure 2-5. Let us begin with the equilibrium strength of incentives. To understand this result, we need to recall that while the level and the alignment of incentives are complements in terms of increasing each other's value, they are also substitutes in terms of generating final value. Thus, at the margin, the trade-off between the level and the alignment of incentives is determined by which avenue brings about a bigger bang for a buck.

The fact that typically $\partial s/\partial r < 0$ follows from the observation in sections 5.1-2 that the value of information is decreasing in the importance of coordination while the value of improving communication is increasing in the importance of coordination. The only exception is decentralization when s is high, in which case the gains to alignment are largest when r is intermediate due to the additional improvement in decision-making, so that $\partial s/\partial r > 0$ for r high enough.

While the results with respect to r are related to value of information and alignment, the results with respect to $(\overline{\theta}, -\mu)$ are primarily related to the cost of information acquisition. To see this result, note that

$$\frac{\partial^2 (p_i^g)^2}{\partial s \partial \overline{\theta}} < 0 \qquad \text{and} \qquad \frac{\partial^2 (p_i^g)^2}{\partial s \partial \mu} > 0.$$

Thus, the agent becomes less responsive to incentives when $\overline{\theta}$ increases or μ decreases (while deciding to acquire more information). In consequence, it becomes more efficient to transmit information more accurately instead of motivating information acquisition. In the present setting, this result is further complemented by the fact that the value of incentive alignment is increased by the increased accuracy of primary information. As a result, the level of incentives is decreasing in the variance of the environment and increasing in the cost of information acquisition.

The mapping from the environment to equilibrium incentives then leads to the choice of governance structure, which is illustrated in panel (iii) and gives the behavior of boundaries for the three regions discussed above. When there is significant equilibrium conflict between the divisions, decentralization dominates centralization when coordination is sufficiently unimportant and vice versa. As $\overline{\theta}$ increases or μ decreases sufficiently, the equilibrium degree of incentive alignment becomes sufficiently high that decentralization dominates centralization for all r. Finally, the costs of inaccurate communication (and so the value of increased incentive alignment) becomes sufficiently high that motivating any additional information acquisition becomes too costly and $s = 1/2$.

To illustrate the differences in equilibrium strength of incentives and equilibrium quality of primary information, panel (iii) also plots the boundaries for $s^{cent}(r) > s^{dec}(r)$ and $p^{cent}(r) > p^{dec}(r)$. We can see that centralization is preferred only when $s^{cent}(r) > s^{dec}(r)$ and $p^{cent}(r) > p^{dec}(r)$ – both equilibrium incentives and the quality of information are higher under centralization. This result reflects the higher value of information (and correspondingly lower value of incentive alignment) under centralization. While motivating information acquisition under decentralization is easier, its value is lower and thus is substituted for incentive alignment. On the other hand, better quality of information under centralization doesn't imply that centralization is preferred. This is the joint result of (i) the higher value of incentive alignment under decentralization and (ii) the presence of stronger free incentives under decentralization. Together these allow decentralization to acquire less information but make better use of that information, thus dominating centralization. The presence of free incentives is also

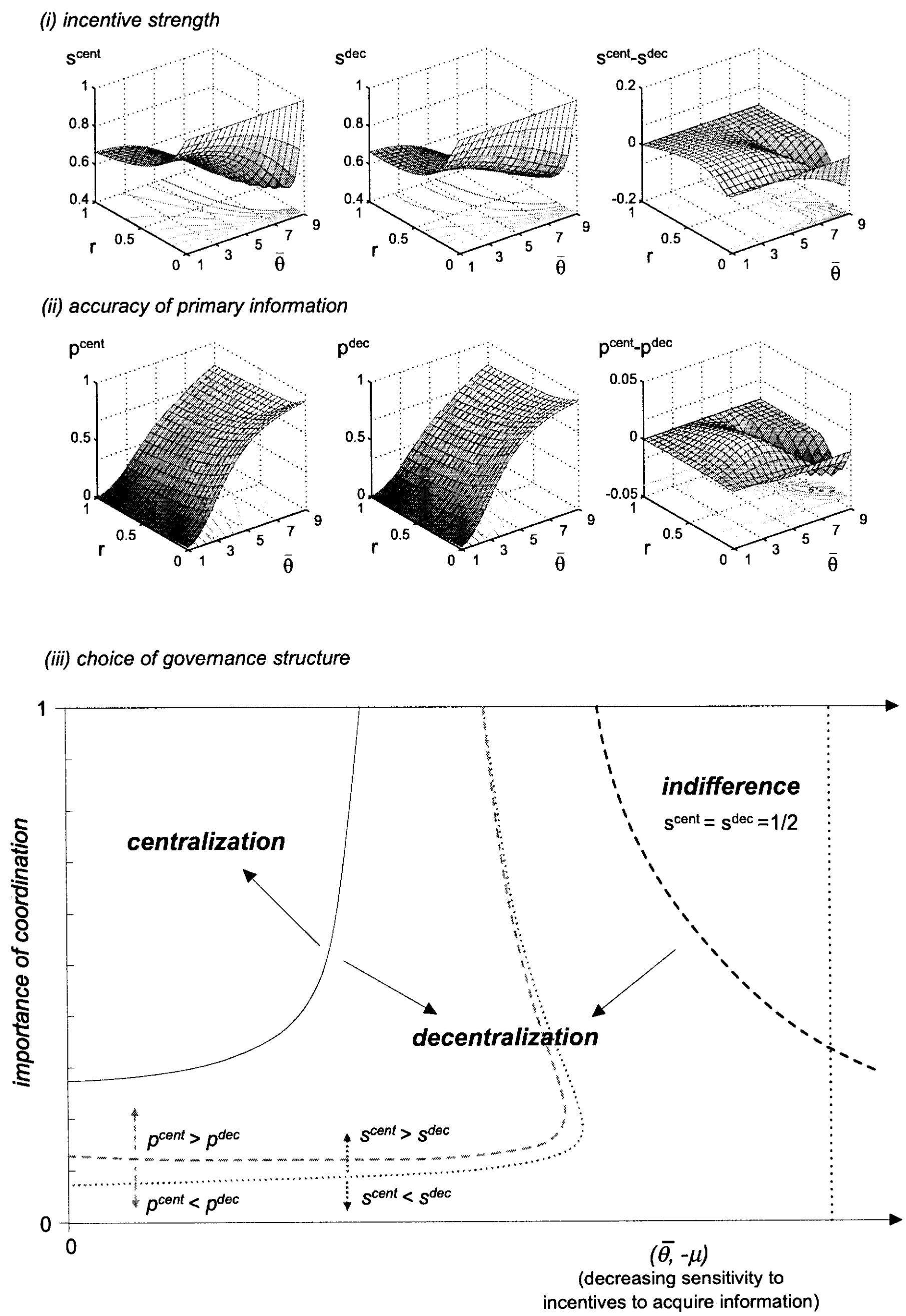


Figure 2-5: Equilibrium outcome under zero managerial effort

reflected by the fact that $p^{cent}(r) > p^{dec}(r) \rightarrow s^{cent}(r) > s^{dec}(r)$ but not vice versa – more information can be acquired under decentralization even if the strength of formal incentives is lower.

Finally, panel (ii) reflects the corresponding quality of information. Because of the structure of information acquisition, the strength of incentives and the quality of communication are inversely related, since the sensitivity to incentives is inversely related to the current level of information and because of the complementarity between the level and the alignment of incentives. The results would be highly analogous if we allowed for a baseline quality of free information $\underline{p}_i^2$, upon which the local agents could improve at cost of

$$C(p_i) = -\mu\left(\frac{e_i^2}{(1-\underline{p}_i^2)} + \ln\left(1 - \frac{e_i^2}{(1-\underline{p}_i^2)}\right)\right).$$

To summarize, under each governance structure, the level and alignment of incentives is determined by their relative value and the sensitivity of the agent to incentives to acquire information. The key advantage of centralization is relaxing the multitasking problem of acquiring information and making good decisions present under decentralization. Thus, the advantage of centralization is largest when (i) the inherent multitasking problem under decentralization is largest (intermediate r) and (ii) solving it through incentive alignment is too costly in terms of sacrificed quality of primary information (high sensitivity of p_i to incentives). In consequence, whenever centralization arises in equilibrium, the equilibrium strength of incentives is stronger than under decentralization and more accurate information is generated.

The final observation of centralization having stronger incentives than decentralization might appear counterintuitive in the face of the common association of centralization with weak incentives. However, looking at the strength of incentives under the different governance structures *conditional on the structure being the preferred choice* tells a different story. Indeed, three regions can be identified. First, we have the region of strong local incentives coupled with low importance of coordination. In this region we do indeed observe decentralization. Second, we have a region of weak local incentives coupled with intermediate to high importance of coordination, under which we do observe centralization. Thus, moderate incentives and centralization do indeed go hand in hand. However, this result is not because one would cause the other, but because both are caused by *an environment that needs coordination without sacrificing incentives to acquire information.* Finally, we have a region of weak incentives where decentralization is preferred for all levels of coordination. In this region the incentives are generally very weak and the relationship carries a flavor of a partnership. This outcome arises when doing more with what is available is more valuable than acquiring more information.

2.5.3 Managerial effort

So far we have only analyzed the trade-off between incentive strength and incentive alignment between the local divisions. We will now add the need to induce also managerial effort. The impact of this addition is summarized in the following proposition:

Proposition 22 *Importance of managerial effort and the choice of incentives and governance structure:*

(i) $\frac{\partial s}{\partial \gamma} < 0$, $\frac{\partial \widetilde{s}}{\partial \gamma} < 0$.

(ii) $\frac{\partial (s/(s+\widetilde{s}))}{\partial \gamma} > 0$

(iii) The likelihood of centralization is non-monotone in the importance of managerial effort and depends on (θ, μ). *In particular, the boundary* $\overline{r}(\theta, \mu, \gamma)$ *above which centralization is preferred is characterized by*

$\frac{\partial \overline{r}(\overline{\theta},\mu,\gamma)}{\partial \gamma} < 0$ *for* $\gamma < \overline{\gamma}(\overline{\theta}, \mu)$ *and* $\frac{\partial \overline{r}(\overline{\theta},\mu,\gamma)}{\partial \gamma} > 0$ *for* $\gamma > \overline{\gamma}(\overline{\theta}, \mu)$. *Further,* $\frac{\partial \overline{\gamma}(\overline{\theta},\mu)}{\partial \overline{\theta}} > 0$ *and* $\frac{\partial \overline{\gamma}(\overline{\theta},\mu)}{\partial \mu} < 0$.

Part (i) of the proposition is self-evident. To motivate the manager, decreases in s and $\widetilde{s}$ are perfect substitutes. In consequence, both margins are naturally used to motivate the manager when the importance of managerial effort increases. Part (ii) states that as managerial effort becomes more important, the equilibrium incentive conflict between the two divisional agents increases and follows from the following thought experiment. Consider decreasing s and $\widetilde{s}$ proportionately, so that the relative incentive conflict and thus the quality of communication and decision-making remain unchanged. However, a proportional decrease leads to (i) a decrease in the accuracy of primary information, supporting a direct increase in s, (ii) move to a more sensitive part of the cost function, supporting a further increase in s and (iii) a decrease in the value of incentive alignment, supporting a decrease in $\widetilde{s}$. In addition, there is an increasing response to incentive alignment (since the absolute distance $|s - \widetilde{s}|$ is decreased because of the proportional reduction). However, the first three effects dominate and thus the degree of incentive conflict between the divisions is increasing in the need to induce managerial effort. In other words, *as incentivizing the agents becomes increasingly costly, the benefits of aligning incentives decrease faster than the benefits of local incentives.*

With this result at hand, we can then understand how the choice between centralization and decentralization is impacted by the need to induce managerial effort, which is illustrated in figure 2-6. Let us begin with the case of $\gamma \to 0$. This setting gives simply the initial condition of no managerial effort analyzed in the previous section. The figure gives the contours (and the resulting choice between centralization and decentralization) for varying initial conditions as given by $(\overline{\theta}, \mu)$. Now, as we increase the importance of managerial effort, the likelihood of centralization is initially increasing because the incentive conflict between the divisions is increasing and, as argued above, the advantage of centralization is in managing these incentive conflicts. Indeed, $s_{j-i} = 0$ is achieved well before $s_{M-i} \to 1$, restoring a full degree of incentive conflict (recall that from the perspective of alignment, incentive conflict is maximal if no weight is placed on the other division, independent of the weight placed on own division). Eventually, however, the advantage of centralization is being eroded. Note that this result has little to do with incentive alignment. Instead, it is the result of the free incentives to acquire information under decentralization, which come to dominate the picture as $s_{M-i} \to 1$. Finally, the position of the point of inflection on the boundary depends also on the initial conditions but reflects

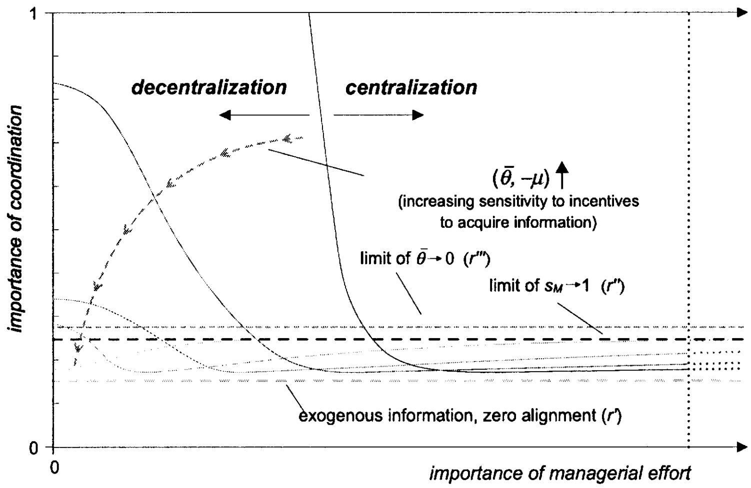


Figure 2-6: Choice of governance structure when managerial effort is valuable

more the value of managerial effort relative to information and thus how quickly the extreme incentive conflict is achieved.[9]

Letting r' denote the boundary between centralization and decentralization when maximal incentive conflict is present and no information acquisition is needed (Chapter 1), $r'' = \lim_{\gamma \to \infty} \overline{r}\left(\overline{\theta}, \mu, \gamma\right)$, the boundary when managerial effort is the overriding concern (which is independent of the initial conditions), and $r''' = \min \lim_{\gamma \to \infty} \overline{r}\left(\overline{\theta}, \mu, \gamma\right)$, which is equivalent to $\overline{\theta} \to 0$ or $\mu \to \infty$, we have that

$$r''' > r'' > r'.$$

When no managerial effort is needed, the equilibrium will always exhibit some incentive alignment at the boundary because of the presence of free incentives and the value of incentive alignment. In contrast, when managerial effort becomes the overriding concern, the divisions exhibit maximal conflict and in consequence, centralization becomes more attractive – $r''' > r''$. Finally, one could naively assume that the maximal incentive conflict setting would be analogous to the case of exogenous quality of information. This, however, is not the case because of the differing perceived value of information under the two different governance structures. In particular, because the free incentives to acquire information are higher under decentralization when the inter-divisional conflict is large, more information is acquired (which is preferred because the overall incentives are too weak from profit-maximizing perspective) and thus the boundary between centralization and decentralization is strictly higher than the boundary in the case of maximal incentive conflict and free information – $r'' > r'$.

[9] As $\overline{\theta} \uparrow$ or $\mu \downarrow$, either information becomes less valuable or its acquisition becomes more costly. In consequence, managerial effort is relatively more valuable for a given γ and thus the rate at which managerial incentives are increasing is higher, leading to a shift in the point of inflection leftward.

2.5.4 Opportunity cost of decision-making

Finally, let us add opportunity cost of decision-making. The consequences of this addition are summarized in the following proposition:

Proposition 23 ***Opportunity cost of decision-making:***

When decision-making carries an opportunity cost, the dimension of importance of coordination is divided into maximum of four intervals, where

(i) centralization is preferred on $r \in \left[0, r^1(\nu, v_M)\right]$ *and on* $r \in \left[r^2(\nu, v_M), r^3(\nu, v_M)\right]$ *and*

(ii) decentralization is preferred on $r \in \left[r^1(\nu, v_M), r^2(\nu, v_M)\right]$ *and on* $r \in \left[r^3(\nu, v_M), 1\right]$.

This result is summarized in figure 2-7. Two observations are worth making. First, when managerial time becomes valuable, decentralization becomes the preferred solution both when coordination is sufficiently unimportant *and* when it is sufficiently important. To understand this result, recall that as $r \longrightarrow 1$, the solutions under the two governance structures converged. In consequence, if managerial time is costly, it is more efficient to use decentralized decision-making, which is equally efficient in terms of the final outcome while carrying a lower opportunity cost. While centralization is eventually fully eliminated as the managerial time becomes extremely expensive, it retains its advantage longest in the region of intermediate importance of coordination where the managerial contribution to the decision-making process adds the most value.

Second, centralization becomes preferred for low importance of coordination when the local agents' time becomes valuable. Recall that when coordination is unimportant, information acquisition by the agents is most valuable. At the same time, communication is near-perfect under centralization and thus allows for specialization by the agents on information acquisition. Thus, this result is simply the converse of our first observation.

Opportunity cost of decision-making simply provides an additional dimension that needs to be considered when choosing the optimal governance structure: how much does the governance structure improve decision-making relative to its cost in terms of compromised activities. Logically, the manager should not be bothered with trivial questions that distract him from taking care of other aspects of the business and conversely, sometimes separating the decision-making function from the local level allows for more efficient specialization in information acquisition.

2.6 Conclusion

We have analyzed how monetary incentives and the allocation of decision rights can be simultaneously used to manage information acquisition, communication and decision-making when coordinated adaptation is needed and access to information is localized. Under both centralization and decentralization, the inherent conflict in incentive provision is providing strong local

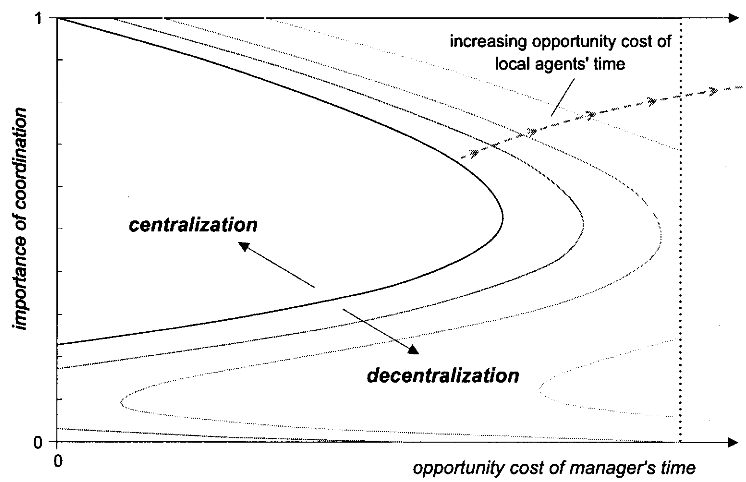


Figure 2-7: Choice of governance structure when decision-making is costly.

incentives to motivate information acquisition and balanced incentives to motivate accurate communication and appropriate decision-making.

In terms of the overall organizational performance, motivating information acquisition and aligning incentives are substitutes. After all, it matters very little whether the organizational performance is poor because of poor decisions or inaccurate information, and whether information is inaccurate because it was communicated poorly or because primary information was inaccurate. In consequence, under each governance structure, the choice of incentive strength is determined by how responsive the agent is to incentives to acquire information relative to the gains in communication and decision-making achieved through incentive alignment. Because the value of information is decreasing in the importance of coordination, value of incentive alignment is increasing in the importance of coordination and the amount of free incentives available is increasing in the importance of coordination, the incentive strength is typically decreasing in the importance of coordination under both governance structures.

However, while the quality of primary information and incentive alignment are substitutes in terms of overall performance, they also complement each other. After all, accurate communication is only valuable if there is information to transmit and conversely, information is more valuable the more accurately it gets transmitted. Because these values are dependent on the allocation of decision rights, so does the equilibrium incentive strength. In consequence, each governance structure arises as the equilibrium outcome under specific environmental conditions.

First, whenever the inter-divisional conflict is low, decentralization dominates centralization for all levels of coordination. This result follows because while the returns to incentive alignment are decreasing in terms of improvements in decision-making, they are increasing in terms of improvements in communication. In consequence, when the equilibrium incentive alignment is high, the value of information is driven by the accuracy of communication under both governance structures and accurate communication is more valuable under centralization. As a result, decentralization outperforms centralization.

Second, whenever the equilibrium inter-divisional conflict is high, then the optimal allocation of decision rights depends on the importance of coordination. When coordination is sufficiently important, then centralization outperforms decentralization because it is able to improve upon decision-making without sacrificing the quality of information transmission too much. In essence, centralization is helping with the multi-tasking problem of both acquiring and using information appropriately. In contrast, when coordination is sufficiently unimportant, then decentralization continues to outperform centralization because the mildly biased decisions under decentralization lead to a smaller loss in profitability than the garbling of information following strategic communication under centralization. However, the two solutions converge both when coordination becomes unimportant or extremely important. When there is no need to coordinate, communication becomes perfect under centralization even under maximal inter-divisional conflict while the equilibrium decisions converge to profit-maximizing decisions under decentralization when coordination becomes the overriding concern.

The equilibrium incentive conflict is in turn determined by the relative responsiveness of the agent to incentives to acquire information, with increasing sensitivity supporting stronger inter-divisional conflict, and the importance of managerial effort, with the inter-divisional conflict increasing in the importance of managerial effort. This last result follows because the value of motivating information acquisition decreases slower than the value of incentive alignment when the provision of incentives becomes more costly. Finally, if decision-making involves an opportunity cost, then if the cost of managerial time increases, decentralization becomes the preferred governance structure also when coordination is extremely important, while if the cost of local agents' time increases, then centralization becomes the preferred governance structure also when coordination is sufficiently unimportant.

2.7 Appendix A: Structure of the general solution

In this Appendix, we give the key equations behind the general solution and used in the analysis. The proofs are contained in Chapter and thus omitted.

2.7.1 Structure of the solution

Equilibrium decisions: In the model, coordination is achieved through mutual accommodation of adaptation to local conditions: d_i accommodates d_j's response to θ_j and vice versa. In particular, letting m denote the agent controlling d_i and n denote the agent controlling d_j, the equilibrium decisions can be written as

$$d_i^m = a_{i1}^g E_m\theta_i + a_{i2}^g E_m E_n \theta_j + a_{i3}^g E_n E_m \theta_i.$$

We will refer to a_{i1}^g as the *rate of direct adaptation*, as it measures the degree to which agent m, given his beliefs about θ_i, adapts to local conditions absent any response by the other decision. Similarly, we will refer to a_{i2}^g as the *rate of accommodation*, as it measures how much agent m, given his knowledge about θ_j, will accommodate d_j in an attempt to improve the coordination between the decisions, and to a_{i3}^g as the *rate of induced adaptation*, as it measures how much agent m is able to increase the amount of adaptation, given the accommodation by d_j. The sum $a_{i1}^g + a_{i3}^g = a_{i1+i3}^g$ will be called simply the *rate of adaptation.* How closely these coefficients are aligned with the first-best coefficients then depends on how much the objective functions of the decision-maker(s) deviate from the firm's objective. We will refer to this aspect of the alignment as the *quality of decision-making.* The coefficients in turn arise from the weight placed by the decision-maker(s) on adaptation and accommodation and the resulting decision-making game. In particular, the equilibrium decisions are given by:

$$d_i^m = \frac{a_1(1-b_2a_2)E_m\theta_i + a_2b_1E_mE_n\theta_j + a_2b_2a_1E_nE_m\theta_i}{1-b_2a_2},$$

where the coefficients (a_1, a_2, b_1, b_2) follow from the first-order conditions of the two agents, with

$$FOC_m : d_i = a_1 E_m\theta_i + a_2 E_m d_j$$
$$FOC_n : d_j = b_1 E_n\theta_j + b_2 E_n d_i$$

Equilibrium communication: Communication is modeled as one round of simultaneous cheap-talk between the informed local agents and the decision-maker(s). If the equilibrium decisions differ from agent i's ideal decisions, perfectly informative communication cannot be achieved because in such a setting agent i has incentives to misrepresent information. However, partially informative communication can still be achieved, where the accuracy of communication will be driven by the degree of misalignment between the sender's preferred response to information and the receiver's equilibrium response. Defining the communication to take place in the space of observed signals, the cutoffs of the most informative partition equilibrium are characterized by

$$|t_{i,n}| = \alpha\left(\varphi_i^g\right)^{|n|}\overline{\theta_i} \quad \text{with} \quad n \in \{-\infty, ..., -1, 1, ...\infty\},$$

where $\alpha\left(\varphi_i^g\right) = \frac{\varphi_i^g}{\left(1+\sqrt{1+\varphi_i^g}\right)^2} \in (0,1)$.

We will refer to φ_i^g as the *quality of communication* and it is uniquely determined by the requirement of incentive-compatibility of the partition, which in turn depends on the degree of incentive conflict between the sender and the receiver, as driven by the monetary incentives and the underlying environment.

Equilibrium expected losses: Having the equilibrium decisions and the equilibrium quality of communication, deriving the decision-dependent component of the expected loss is a simple matter of substituting in the decisions and taking expectations. This decision-component part of the expected loss can be written as

$$\begin{aligned} EL_i^g = {} & \Lambda_i^g\left(\left(p_i\overline{\theta}_i\right)^2 + \left(p_j\overline{\theta}_j\right)^2\right) + \Gamma_{i-i}^g B\left(\varphi_i^g\right)\left(p_i\overline{\theta}_i\right)^2 + \Gamma_{i-j}^g B\left(\varphi_j^g\right)\left(p_j\overline{\theta}_j\right)^2 \\ & + \pi_i\left(1-p_i^2\right)\overline{\theta}_i^2, \end{aligned}$$

where (p_i, p_j) is the quality of primary information and $\left(\Lambda_i^g, \Gamma_{i-i}^g, \Gamma_{i-j}^g\right)$ are governance-structure specific coefficients. These coefficients are determined solely by the equilibrium decisions and thus the weight placed on adaptation and coordination by the decision-maker(s). The cost of inaccurate information shows up in two places. First, $p_i < 1$ implies that primary information is inaccurate. Second, the cost of inaccurate communication about t_i is captured by $\Gamma_{i-i}^g B\left(\varphi_i^g\right)$. The particular solutions under centralization and decentralization, together with the asymmetric governance structures discussed in Appendix B are given in the following for subsections.

2.7.2 Centralization

Define

$$a_1 = \frac{s_{M-i}\kappa_i(1-r_i)}{s_{M-i}\kappa_i + s_{M-j}\kappa_j r_j}, \qquad a_2 = \frac{s_{M-i}\kappa_i r_i + s_{M-j}\kappa_j r_j}{s_{M-i}\kappa_i + s_{M-j}\kappa_j r_j},$$

$$b_1 = \frac{s_{M-j}\kappa_j(1-r_j)}{s_{M-j}\kappa_j + s_{M-i}\kappa_i r_i}, \qquad b_2 = \frac{s_{M-j}\kappa_j r_j + s_{M-i}\kappa_i r_i}{s_{M-j}\kappa_j + s_{M-i}\kappa_i r_i},$$

Then, the equilibrium decisions follow from above, while the quality of communication is given by

$$\varphi_i^{cent} = \frac{a_1\left[s_{i-i}\kappa_i(1-r_i) + (s_{i-i}\kappa_i r_i + s_{i-j}\kappa_j r_j)b_1^2 + s_{i-j}\kappa_j(1-r_j)b_2^2\right]}{\left[s_{i-i}\kappa_i(1-r_i)a_2 b_1 - (s_{i-i}\kappa_i r_i + s_{i-j}\kappa_j r_j)a_1 b_1^2 - s_{i-j}\kappa_j(1-r_j)b_2^2 a_1\right]},$$

leading to coefficients in the expected decision-dependent part of the loss of

$$\Lambda_i^{cent} = \frac{\kappa_i b_1^2\left((1-r_i)a_2^2 + r_i a_1^2\right)}{3(1-b_2 a_2)^2}, \; \Gamma_{i-i}^{cent} = \frac{\kappa_i(1-r_i)}{3} - \Lambda_i^{cent} \text{ and } \Gamma_{i-j}^{cent} = -\Lambda_i^{cent}.$$

2.7.3 Decentralization

Define

$$a_1 = \frac{s_{i-i}\kappa_i(1-r_i)}{s_{i-i}\kappa_i+s_{i-j}\kappa_j r_j}, \qquad a_2 = \frac{s_{i-i}\kappa_i r_i+s_{i-j}\kappa_j r_j}{s_{i-i}\kappa_i+s_{i-j}\kappa_j r_j},$$

$$b_1 = \frac{s_{j-j}\kappa_j(1-r_j)}{s_{j-j}\kappa_j+s_{j-i}\kappa_i r_i}, \qquad b_2 = \frac{s_{j-j}\kappa_j r_j+s_{j-i}\kappa_i r_i}{s_{j-j}\kappa_j+s_{j-i}\kappa_i r_i},$$

Then, the equilibrium decisions follow from above, while the quality of communication is given by

$$\varphi_i^{dec} = \frac{b_2 a_1\left[s_{i-i}\kappa_i(1-r_i)a_2^2+(s_{i-i}\kappa_i r_i+s_{i-j}\kappa_j r_j)a_1^2+s_{i-j}\kappa_j(1-r_j)\right]}{\left[s_{i-i}\kappa_i(1-r_i)a_2^2 b_1+(s_{i-i}\kappa_i r_i+s_{i-j}\kappa_j r_j)a_1^2 b_1-s_{i-j}\kappa_j(1-r_j)b_2 a_1\right]},$$

leading to coefficients in the expected decision-dependent part of the loss of

$$\Lambda_i^{dec} = \frac{\kappa_i b_1^2\left((1-r_i)a_2^2+r_i a_1^2\right)}{3(1-b_2a_2)^2},\ \Gamma_{i-i}^{dec} = \frac{\kappa_i\left((1-r_i)a_2^2+r_i a_1^2\right)}{3} - \Lambda_i^{dec} \text{ and } \Gamma_{i-j}^{dec} = \frac{\kappa_i r_i b_1^2}{3} - \Lambda_i^{dec}.$$

2.7.4 Partial centralization (of j)

Define

$$a_1 = \frac{s_{i-i}\kappa_i(1-r_i)}{s_{i-i}\kappa_i+s_{i-j}\kappa_j r_j}, \qquad a_2 = \frac{s_{i-i}\kappa_i r_i+s_{i-j}\kappa_j r_j}{s_{i-i}\kappa_i+s_{i-j}\kappa_j r_j},$$

$$b_1 = \frac{s_{M-j}\kappa_j(1-r_j)}{s_{M-j}\kappa_j+s_{M-i}\kappa_i r_i}, \qquad b_2 = \frac{s_{M-j}\kappa_j r_j+s_{M-i}\kappa_i r_i}{s_{M-j}\kappa_j+s_{M-i}\kappa_i r_i},$$

Then, the equilibrium decisions follow from above, while the quality of communication by agent i (retaining control) is given by

$$\varphi_i^{part(j)} = \frac{b_2 a_1\left[s_{i-i}\kappa_i(1-r_i)a_2^2+(s_{i-i}\kappa_i r_i+s_{i-j}\kappa_j r_j)a_1^2+s_{i-j}\kappa_j(1-r_j)\right]}{\left[s_{i-i}\kappa_i(1-r_i)a_2^2 b_1+(s_{i-i}\kappa_i r_i+s_{i-j}\kappa_j r_j)a_1^2 b_1-s_{i-j}\kappa_j(1-r_j)b_2 a_1\right]},$$

which is equivalent to the case of decentralization with the exception of differing constants b_1, b_2, and the quality of communication by agent j (losing control) is given by

$$\varphi_j^{part(j)} = \frac{b_1\left[s_{j-j}\kappa_j(1-r_j)+(s_{j-j}\kappa_j r_j+s_{j-i}\kappa_i r_i)a_1^2+s_{j-i}\kappa_i(1-r_i)a_2^2\right]}{\left[s_{j-j}\kappa_j(1-r_j)b_2 a_1-(s_{j-j}\kappa_j r_j+s_{j-i}\kappa_i r_i)b_1 a_1^2-s_{j-i}\kappa_i(1-r_i)a_2^2 b_1\right]},$$

which is equivalent to the case of centralization with the exception of differing constants b_1, b_2. These lead to coefficients in the expected decision-dependent part of the loss of

$$\Lambda_i^{part(j)} = \frac{\kappa_i b_1^2\left((1-r_i)a_2^2+r_i a_1^2\right)}{3(1-b_2a_2)^2},\ \Gamma_{i-i}^{part(j)} = \frac{\kappa_i\left((1-r_i)a_2^2+r_i a_1^2\right)}{3} - \Lambda_i^{part(j)} \text{ and } \Gamma_{i-j}^{part(j)} = -\Lambda_i^{part(j)}.$$

$$\Lambda_j^{part(j)} = \frac{\kappa_j a_1^2\left((1-r_j)b_2^2+r_j b_1^2\right)}{3(1-b_2a_2)^2},\ \Gamma_{j-j}^{part(j)} = \frac{\kappa_j(1-r_j)}{3} - \Lambda_j^{part(j)} \text{ and } \Gamma_{j-i}^{part(j)} = \frac{\kappa_j r_j a_1^2}{3} - \Lambda_j^{part(j)}.$$

2.7.5 Directional authority (by i)

Define

$$a_1 = \frac{s_{i-i}\kappa_i(1-r_i)}{s_{i-i}\kappa_i+s_{i-j}\kappa_j r_j}, \qquad a_2 = \frac{s_{i-i}\kappa_i r_i+s_{i-j}\kappa_j r_j}{s_{i-i}\kappa_i+s_{i-j}\kappa_j r_j},$$

$$b_1 = \frac{s_{i-j}\kappa_j(1-r_j)}{s_{i-j}\kappa_j+s_{i-i}\kappa_i r_i}, \qquad b_2 = \frac{s_{i-j}\kappa_j r_j+s_{i-i}\kappa_i r_i}{s_{i-j}\kappa_j+s_{i-i}\kappa_i r_i},$$

Then, the equilibrium decisions follow from above, while the quality of communication by agent j is given by

$$\varphi_j^{dir(i)} = \frac{b_1\left[s_{j-j}\kappa_j(1-r_j)+(s_{j-j}\kappa_j r_j+s_{j-i}\kappa_i r_i)a_1^2+s_{j-i}\kappa_i(1-r_i)a_2^2\right]}{\left[s_{j-j}\kappa_j(1-r_j)b_2a_1-(s_{j-j}\kappa_j r_j+s_{j-i}\kappa_i r_i)b_1a_1^2-s_{j-i}\kappa_i(1-r_i)a_2^2b_1\right]},$$

which is equivalent to the case of centralization with the exception of differing constants b_1, b_2, and communication by agent i is irrelevant since he controls both decisions. These lead to coefficients in the expected decision-dependent part of the loss of

$$\Lambda_i^{dir(i)} = \frac{\kappa_i b_1^2\left((1-r_i)a_2^2+r_i a_1^2\right)}{3(1-b_2a_2)^2},\ \Gamma_{i-i}^{dir(i)} = -\Lambda_i^{dir(i)} \text{ and } \Gamma_{i-j}^{dir(i)} = -\Lambda_i^{dir(i)}.$$
$$\Lambda_j^{dir(i)} = \frac{\kappa_j a_1^2\left((1-r_j)b_2^2+r_j b_1^2\right)}{3(1-b_2a_2)^2},\ \Gamma_{j-j}^{dir(i)} = \frac{\kappa_j(1-r_j)}{3} - \Lambda_j^{dir(i)} \text{ and } \Gamma_{j-i}^{dir(i)} = -\Lambda_j^{dir(i)}.$$

2.8 Appendix B: Asymmetric divisions and alternative governance structures

Having analyzed the setting with symmetric divisions, we will now extend the analysis to account for asymmetries in the importance of coordination, adaptation and the volatility of the environment faced by the two divisions. We will perform the analysis in three steps. In section B.1 we outline the basic impact that asymmetries in the importance of coordination have on decision-making under centralization and decentralization. Since asymmetric environments sometimes warrant asymmetric governance structures, section B.2 introduces two alternative governance structures and presents the equilibrium outcome when the importance of adaptation and environmental volatility remain constant across the divisions but the importance of coordination is asymmetric. Section B.3 discusses the impact of asymmetries in the importance of adaptation and the volatility of the environment. Finally, section B.4. considers an alternative payoff structure where the importance of adaptation for each division is decreasing in the importance of coordination.

To further simplify the analysis, we will limit the role of the manager to one of a decision-maker that simply makes profit-maximizing decisions conditional on the information available to her. That is, her objective function is given by $\min L_i + L_j$. In consequence, the whole pie will again be divided between the two local agents to minimize the expected loss, conditional on the governance structure. In a more detailed analysis, the weights placed on the two divisions can, in asymmetric settings, be used to manipulate the decisions made by the manager and thus the relative quality of communication by the two agents to improve the equilibrium outcome. However, a detailed analysis of this setting would take us too far afield here.

2.8.1 Equilibrium decisions when importance of coordination is asymmetric.

To understand the impact of the importance of coordination on the equilibrium decisions, it is sufficient to analyze the case of $s_{i-i} = 1$. As discussed in sections 4 and 5, incentive alignment will simply provide a monotone improvement in the quality of decisions, with the decisions converging to first-best as $s_{i-i} \to s_{i-j}$. To keep the intuition clear, we will temporarily revert to notation in terms of absolute importance of coordination and adaptation, (β_i, α_i).

Under centralization, the equilibrium decisions are profit-maximizing by assumption and given by

$$d_i^{cent} = \frac{(\alpha_j + (\beta_i + \beta_j))\alpha_i}{\alpha_j\alpha_i + (\alpha_j + \alpha_i)(\beta_i + \beta_j)} E_M\theta_i + \frac{(\beta_i + \beta_j)\alpha_j}{\alpha_j\alpha_i + (\alpha_j + \alpha_i)(\beta_i + \beta_j)} E_M\theta_j,$$

which in the case of symmetric overall importance of adaptation simplifies to

$$d_i^{cent} = \underbrace{\frac{(\alpha + \beta_i + \beta_j)}{(\alpha + 2(\beta_i + \beta_j))}}_{(1)} E_M\theta_i + \underbrace{\frac{(\beta_i + \beta_j)}{(\alpha + 2(\beta_i + \beta_j))}}_{(2)} E_M\theta_j.$$

Thus, the amount of accommodation (2) that should take place in equilibrium depends simply on the overall importance of coordination $(\beta_i + \beta_j)$, while the focal point of coordination will depend on the relative importance of adaptation for the two activities. On the other hand, under decentralization the equilibrium decisions are given by

$$d_i^{dec} = \frac{\alpha_i}{(\alpha_i + \beta_i)} E_i\theta_i + \frac{\beta_i\alpha_j}{(\alpha_i\alpha_j + \alpha_j\beta_i + \alpha_i\beta_j)} E_iE_j\theta_j + \frac{\beta_i\beta_j\alpha_i}{(\alpha_i + \beta_i)(\alpha_i\alpha_j + \alpha_j\beta_i + \alpha_i\beta_j)} E_jE_i\theta_i,$$

which, in the case of symmetric importance of adaptation, simplifies to

$$d_i^{dec} = \underbrace{\frac{\alpha}{(\alpha + \beta_i)}}_{(1a)} E_i\theta_i + \underbrace{\frac{\beta_i}{(\alpha + \beta_i + \beta_j)}}_{(2)} E_iE_j\theta_j + \underbrace{\frac{\beta_i\beta_j}{(\alpha + \beta_i)(\alpha + \beta_i + \beta_j)}}_{(1b)} E_jE_i\theta_i.$$

Thus, the amount of accommodation (2) granted by agent i depends primarily on his importance of coordination, β_i. Indeed, the amount of accommodation is *decreasing* in β_j. As division j becomes increasingly dependent on coordination, the less accommodation agent i grants to the division and so pulls the equilibrium decisions in his favor, worsening the equilibrium outcome. Thus, as we move away from the diagonal, the worse the decision-making becomes under decentralization. While the less-dependent division is going to be better off because of more favorable decisions, this gain is more than outweighed by the loss experienced by the more dependent division. Indeed, in the limit as $\beta_j \to \infty$, the decisions under decentralization converge to $d_i^{dec} = d_j^{dec} = \theta_i$, while the profit-maximizing decisions are given by $d_i^{cent} = d_j^{cent} = \frac{1}{2}E_M\theta_i + \frac{1}{2}E_M\theta_j$. This convergence was achieved on the diagonal because of the symmetric weight placed on coordination by the two divisions but not off the diagonal because of the advantageous position of the less dependent division in the decision-making stage unless $s_{i-i} \to s_{i-j}$.

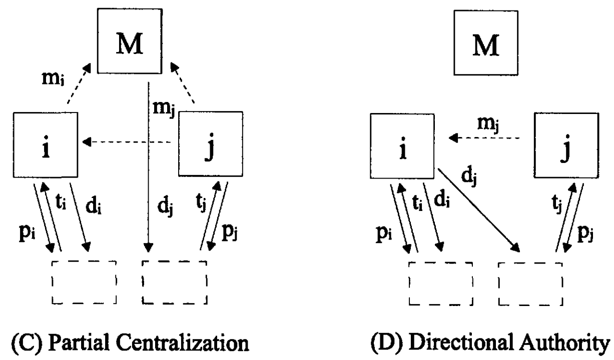


Figure 2-8: Alternative governance structures (2)

2.8.2 Equilibrium under asymmetric importance of coordination

Because of the increasing bias in decision-making when $r_i \neq r_j$, the conclusion that centralization dominates decentralization whenever (i) the equilibrium warrants sufficient conflict between the divisions, (ii) coordination is sufficiently important to at least one of the divisions and (iii) managerial time is not too costly continues to hold. However, because asymmetries in the importance of coordination translate to asymmetries in the equilibrium decisions, partial interference can do even better than centralization. In consequence, we introduce two additional governance structures, summarized in figure 2-8.

Under partial centralization, only one of the decisions is controlled by the manager, while under directional authority, both decision rights are allocated to one of the divisions. Otherwise, the governance structures are identical to centralization and decentralization analyzed so far: agents acquire information, communicate strategically and then make decisions.

The equilibrium outcome, with the equilibrium strength of incentives and the choice of governance structure is summarized in figure 2-9.

The diagonal of the figures replicates the instances of the analysis in sections 4 and 5. As the agent becomes increasingly insensitive to incentives to acquire information, the higher the degree of incentive alignment and the further along the diagonal the boundary between centralization and decentralization shifts. Similarly, the more important coordination is to either activity, the weaker the equilibrium incentives because of the lower value of information. Also, the equilibrium incentives under decentralization continue to be weaker than the incentives provided by alternative governance structures for the same environment.

What is new is that when we move sufficiently far off the diagonal, both centralization and decentralization are now dominated by partial centralization, where the manager takes control only of the less dependent division. To understand the logic behind this result, recall from the previous subsection that when the importance of coordination is asymmetric, the primary source of bias is the lack of accommodation by the less dependent division. By centralizing only this division, the manager is able to achieve an improvement in decision-making. While the equilibrium decisions won't become first-best (unless the centralized division is fully independent), at the same time *not* centralizing the other division limits the value of accurate

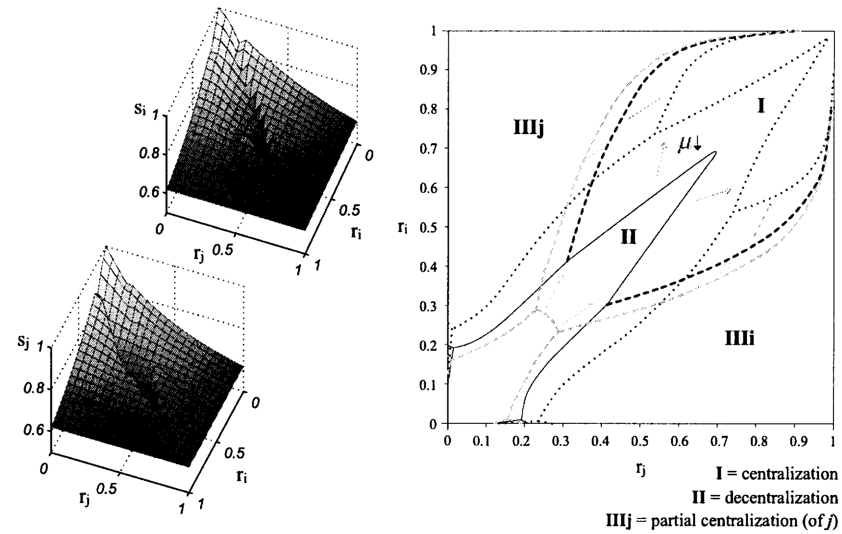


Figure 2-9: Equilibrium strength of incentives and the choice of governance structure

communication. In consequence, such partial interference can also dominate full centralization. Again, the manager is used to solve a multi-tasking problem which is too costly to solve through incentive alignment alone.

2.8.3 Equilibrium under asymmetric importance of adaptation

The final step in the analysis is to consider the situation where the importance of adaptation α_i and environmental volatility $\overline{\theta}_i$ can differ across the divisions. The exact avenues through which they translate into payoffs are slightly different. For example, differences in environmental volatility $\overline{\theta}_i$ don't directly impact equilibrium decisions or communication. However, it does change the equilibrium quality of information and the value of incentive alignment and thus the equilibrium incentives. On the other hand, differences in the importance of adaptation α_i do impact the equilibrium decisions and thus the quality of communication directly, which in turn changes the equilibrium incentives and the overall expected performance of the different governance structures.

However, while the exact avenue of these changes is different, the qualitative role of the parameters is identical. In essence, both α_i and $\overline{\theta}_i$ measure the overall importance of division i relative to division j: how important it is to get d_i "right," consisting of both correct use of information and the accuracy of that information. In consequence, as α_i or $\overline{\theta}_i$ increases, it becomes increasingly attractive to adapt a governance structure that is favorable to division i : either partial centralization of division j, which can be used to make division j more responsive to division i's needs and thus facilitating decision-making and communication by division i, or simply directional authority by agent i, in which case both decisions are controlled by him. Both structures both limit the need to transmit information about θ_i, garbling of which becomes increasingly costly when the importance of that information increases, and generate decisions that are biased in favor of that division. Further, as the importance of division i increases, both s_{i-i} and s_{i-j} are increasing: *relatively* more valuable information implies need for stronger incentives together with increased discretion, which in turn implies increased value of incentive alignment.

Since the qualitative impact of both variables is the same, we will only detail the impact of an increase in $\overline{\theta}_i$, a progression which is summarized in figure 2-10. Panel (A) begins with a mild increase in volatility. The initial impact is simply to skew figure 2-9 clockwise from the top-left corner (where coordination is most constraining to the behavior of division i), increasing the region over which j is centralized (increasing $i's$ flexibility) and decreasing the region over which i is centralized (since the inaccuracies in communication become increasingly damaging). Panel (B) continues the progression. The clockwise rotation continues, with the marginalization of centralization and partial centralization of i. Further, there is a significant expansion in the region over which decentralization becomes the preferred outcome. This result reflects the fact that the increasing asymmetry between the divisions is alleviating the inherent multi-tasking problem: the whole pie is increasingly held by the manager of division i.[10] Finally, panel (C) reaches the final stage of the progression. Now the divisional asymmetry is so large that directional authority by agent i starts to dominate the landscape, with the initial marginalization of decentralization and later the marginalization of partial centralization of j. This result follows because (i) getting d_i right becomes the dominant concern *and* because the asymmetry is now so large that agent i can be provided with incentives guiding him to make good decisions even when allowed to control both of them. Indeed, the final contour has $4\overline{\theta}_j^2 = \overline{\theta}_i^2$, which is still far from extreme and thus highlighting the complementary role of the increasing degree of incentive alignment that occurs in equilibrium.

To highlight this role of incentive alignment under asymmetry, figure 2-11 plots the share of each activity retained by their respective local agents. While perfect alignment is not yet achieved, we can see clearly how when agent i is granted control, he holds a large share of both activities in equilibrium. Conversely, we see that partial centralization of j remains the equilibrium outcome when r_j is small, and allows for stronger incentive conflict. The reason for this outcome is that when r_j is small, adaptation to θ_j remains relatively more valuable, which can better be achieved by using the manager instead of agent i as the decision-maker for d_j, as this allows for motivating information acquisition through stronger local incentives for agent j. Again, the manager remains a player breaking the multi-tasking problem when solving it through incentive alignment is too expensive.

2.8.4 An alternative loss formulation

In the analysis, we focused on the loss formulation of

$$L_i = \alpha_i (\theta_i - d_i)^2 + \beta_i (d_j - d_i)^2 .$$

[10] Indeed, if the degree of incentive alignment were exogenously controlled (and sufficiently large that governance structures matter), then this would not occur.

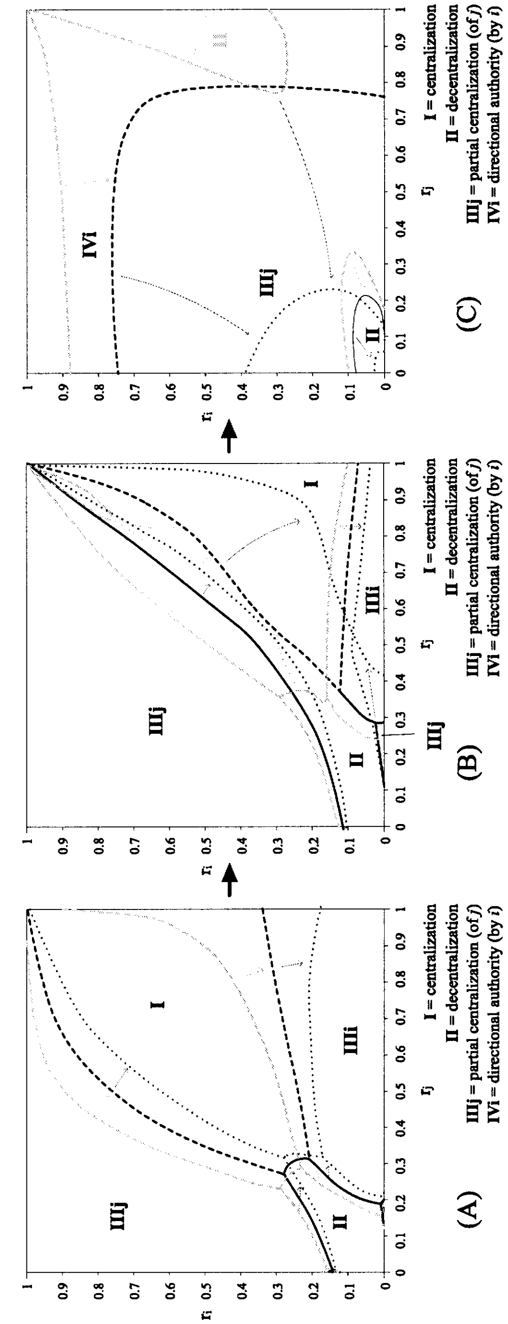


Figure 2-10: Impact of increasing $\overline{\theta}_i$ on the choice of governance structure.

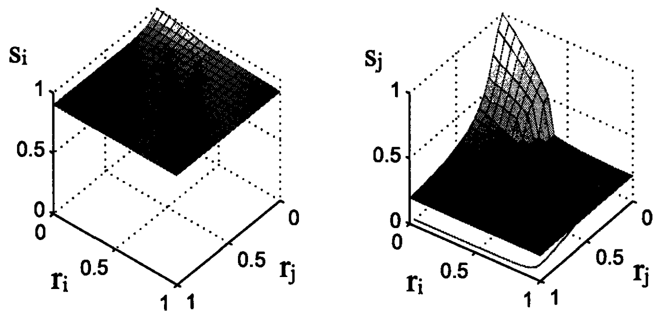


Figure 2-11: Equilibrium incentives under $4\overline{\theta}_j = \overline{\theta}_i$.

The key feature of this version was that even as $\beta_i \to \infty$, the absolute importance of adaptation remained constant. While the comparative statics of section B.3 can be interpreted in terms of changing α_i, there is also an alternative formulation that naturally embeds such considerations. Let the loss be now given by

$$L_i = \kappa_i \left[(1 - r_i)(\theta_i - d_i)^2 + r_i (d_j - d_i)^2\right],$$

but, instead of $\kappa_i = (\alpha_i + \beta_i)$, let κ_i be constant. Now, increasing the importance of coordination translates into a corresponding decrease in the importance of adaptation and allows us to directly consider asymmetries in the need for adaptation. The key difference is that now as $r_i \to 1$, first-best can be achieved, unlike the case of $\alpha_i > 0$. The difference of this formulation comes in terms of decision-making in asymmetric environments. The decisions under centralization are given by

$$d_i^{cent} = \frac{(1-r_i^2)E_M\theta_i + (r_i+r_j)(1-r_j)E_M\theta_j}{(1+r_i)(1+r_j)-(r_i+r_j)^2},$$

while under decentralization (and full incentive conflict) the decisions are given by

$$d_i^{dec} = (1 - r_i)\theta_i + \frac{(1-r_j)r_i}{(1-r_ir_j)}E_i\theta_j + \frac{(1-r_i)r_ir_j}{(1-r_ir_j)}E_j\theta_i.$$

Now, while decision-making initially worsens under decentralization when the importance of coordination increases for either division, the decisions eventually converge to first-best when r_i and/or $r_j \to 1$. The reason for this is that while $d_i^{dec}, d_j^{dec} \to \theta_i$ as $r_j \to 1$ (as above), now this outcome is indeed optimal since adaptation becomes fully irrelevant to division j.

Figure 2-12 presents the equilibrium outcome under this formulation. As we can see, the behavior along the diagonal is very similar to the case analyzed in the main body because the absolute levels drop out in the symmetric case. The only difference is in the behavior of the incentive strength. Now, in addition to having $s \to 1$ as $r \to 0$, we also have that $s \to 1$ as $r \to 1$. The reason for this is as follows. As coordination becomes increasingly important, two things

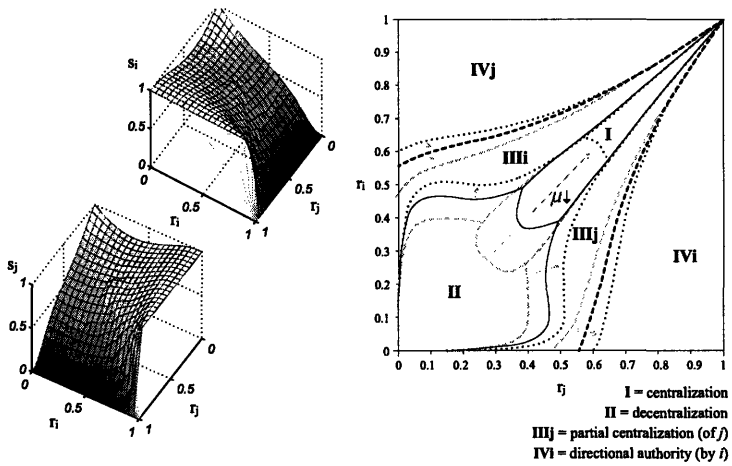


Figure 2-12: Equillibrium incentives and choice of governance structure under varying importance of adaptation.

happen. First, the value of information is decreasing even faster than under the earlier analysis. Indeed, the value of information converges to zero as $r \rightarrow 1$. Second, also communication becomes less important. This result follows because since adaptation becomes unimportant, the information content of the messages becomes irrelevant. The existence of messages is sufficient to achieve perfect coordination since the focal point of coordination doesn't matter. In this setting, since the decreasing value of information moves the agent to the flatter part of the cost curve, it turns out that the value of accurate communication decreases faster than the value of accurate information (since motivating information acquisition becomes increasingly cheap), thus leading to a situation where incentive strength is increasing in the importance of coordination.

The big difference in comparative statics occurs when we move off the diagonal. Recall that in the case of fixed importance of adaptation, moving off the diagonal increasingly worsened equilibrium decisions and this was managed by centralizing the more dependent activity. In the present setting, the decisions eventually converge to first-best and instead the primary problem becomes one of communication. Further, the value of information becomes asymmetric. In consequence, instead of centralizing the less dependent activity to balance decision-making, now we observe first partial centralization of the more dependent activity to facilitate communication and finally directional authority by the less dependent activity to fully eliminate any residual coordination failures. The logic is thus exactly the opposite of the case where the value of adaptation remains constant. The fact that partial centralization of the less dependent activity is not observed at all is caused by the fact that now achieving incentive alignment off the diagonal is easier because of the stronger change in the relative value of information. Indeed, now first-best is achieved in the limit when coordination becomes extremely important to either activity by simply allocating all payoffs to the agent who still cares about adaptation.

For the same reason, the impacts of κ_i and $\overline{\theta}_i$ on the choice of governance structure are slightly different from that of the main analysis. The outcome is illustrated in figure 2-13. We

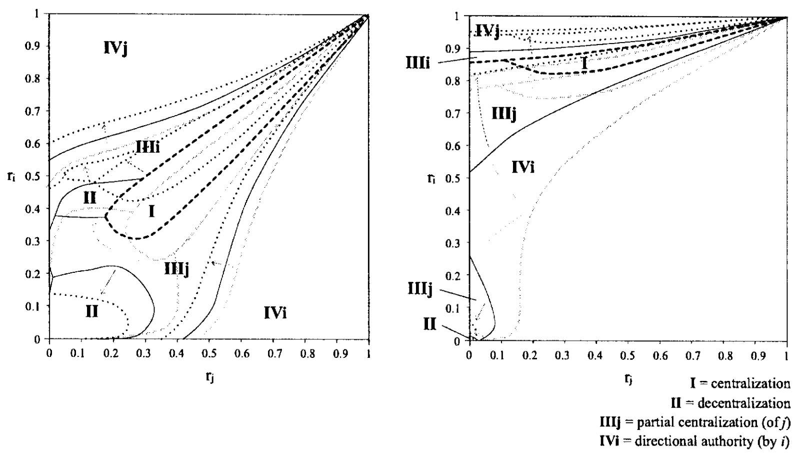


Figure 2-13: Impact of asymmetric environmental volatility on the choice of governance structure.

see that instead of skewing the governance structures clockwise from the top-left corner, now an increase in $\overline{\theta}_i$ generates an expansion from the bottom-right corner. The reason for this is that adaptation by division i is most important when r_j is large so that directional authority is preferred. However, what continues to hold is that as coordination becomes increasingly important, centralization and decentralization are compressed away and the parameter space comes to be dominated by partial centralization of j and eventually only by directional authority by i (as in the main analysis), while the rate at which the impact occurs and the exact comparative statics are clearly different because of the differences in the incentive provision problem and the scaling of the parameters. In particular, the increased smoothness of the transition in the figure is provided by the fact that when r_i is large, an increase in $\overline{\theta}_i$ has an increasingly small impact.

Chapter 3

Uncertainty, Delegation and Incentives

Abstract

How does imperfect contractibility influence the governance of a contractual relationship? We analyze a two-party decision-making problem where the optimal decision is unknown at the time of contracting. In consequence, instead of contracting on the decision directly, the parties need to design a contract that will induce good decision-making in the future. We examine how environmental uncertainty, quality of available performance measures and interim access to information influence the joint determination of the allocation of authority, use of performance pay and direct controls. We use the results from the model to cast light on (i) the conflicting empirical evidence on the risk-incentives tradeoff found in work on executive compensation and franchising, (ii) complementarities in organizational design and (iii) the determinants of the choice to delegate.

3.1 Introduction

Many contractual relationship have two features in common. First, at the time of contracting, the parties face uncertainty over the future decisions that will maximize the value of the relationship. Second, additional information about the consequences of potential actions is learned during the execution of the contract. As a result, instead of attempting to specify the complete plan ex ante or relying on constant renegotiation, many contracts simply allocate authority over different decisions among the participants and then use contractual controls to guide the exercising of that authority. The canonical example of such contracts is the employment relationship, but most contracts exhibit some degree of open-endedness with respect to the exact actions that will be taken during the execution of the contract.

This paper examines what factors determine the allocation of authority in such settings and how the contract can be used to induce appropriate use of that authority. We construct a model where a single decision that influences the payoffs of two parties needs to be made, but the optimal decision is unknown at the time of contracting. While additional information is learned by both parties before the decision needs to be made, the opportunities for renegotiation are limited. As a result, the parties need to design a contract, consisting of (i) an allocation of the decision right and (ii) a compensation package (incentive contract), that maximizes the expected value of the relationship.

We assume that the preferences of the two parties are not directly contractible. However, there exist performance measures that (imperfectly) track the preferences of the parties. Thus, while pay-for-performance is possible, the contract needs to account for "The Folly of Rewarding for A While Hoping for B" (Steven Kerr, 1975). For example, linking compensation to short-run monetary profits can yield decisions that are very different from those that maximize the net present value of a project, and linking compensation to the cost of materials can yield decisions that are very different from those that minimize the true opportunity cost of a project. In addition to using the available performance measures, we assume that the contract can specify a default decision and any penalties that the decision-maker needs to pay to (or receive from) the other party when deviating from this default decision. This component of the contract can be interpreted either narrowly (as a formal adjustment clause) or broadly (as the degree of job flexibility granted to the decision-maker).

We first derive the optimal contract, consisting of (i) the identity of the decision-maker, (ii) the weights placed on available performance measures, (iii) the default decision and (iv) the penalty scheme, under the assumption of perfect interim information and risk-neutrality. Second, we examine how the results change when we introduce asymmetric information (specific knowledge), information acquisition and risk-aversion into the model.

The analysis contributes to the literature on two different levels. First, on the level of application, the results help to explain the conflicting empirical evidence regarding the risk-incentives trade-off found in the literatures on executive compensation and franchising. The results are also found to be consistent with a number of additional regularities found in the empirical literature on organizational design and franchising. Second, on the level of theory, the model combines the logic of traditional moral hazard models with the newer literature on authority and delegation. This approach provides a simple, unified framework for analyzing the co-determination of authority, job flexibility and pay-for-performance. We hope that this explicit focus on co-determination will help in providing a more consistent framework for future empirical and theoretical work analyzing incentive contracts and organizational design.

The remainder of the paper is organized as follows. Section 1.1 reviews the results and discusses how they fit with the related empirical literature. Section 1.2 discusses how the model relates to the existing theoretical literature. Section 2 describes the model. Section 3 presents the solution under full information and risk-neutrality and outlines the impact of asymmetric information, active information acquisition and risk-aversion (with detailed analysis presented in Appendix A). Section 4 reviews the related empirical evidence in more detail and section 5 concludes.

3.1.1 Outline of the results and their relationship to empirical literature

The logic of our model highlights the observation that as the environment changes, various control instruments are adjusted simultaneously. The predictions of the model regarding the co-movements of incentive strength, job flexibility and delegation with the volatility of the environment, quality of information and quality of performance measures are found to be consistent with a number of empirical regularities found in different literatures.

Let us discuss first the empirical relationship between risk and incentives. The empirical literature has been hard-pressed to find a negative relationship between risk and incentives as predicted by classical moral hazard models (e.g. Holmström and Milgrom, 1991). The work on executive compensation has found ambiguous results, with some studies finding positive, some negative and still others an insignificant relationship between risk and incentives (summarized in Prendergast, 2002). Further, the literature on franchising has found a consistently *positive* relationship between risk and the choice to franchise (summarized in Lafontaine and Slade, 1997). While neither the literature on executive compensation nor the literature on franchising has found consistent evidence of a negative trade-off between risk and incentives, they are also in some conflict with each other. By making the distinction between determination of incentives conditional on delegation and the choice to delegate, our model not only provides an explanation for the lack of evidence for the negative trade-off between risk and incentives but also for the apparent conflict in the results found in the two literatures, as follows.

The empirical evidence on CEO compensation is best understood in terms of our results conditional on delegation, since the task structure of CEOs exhibits relatively little heterogeneity in the amount of decision rights controlled.[1] Conditional on the identity of the (risk-neutral) decision-maker, the characteristics of the optimal contract are as follows. First, the incentive strength is increasing in the volatility of the environment and decreasing in the noisiness of the performance measures. Second, incentive strength and job flexibility are complements. Third, the default decision is biased in favor of the non-deciding party. Further, if the decision-maker is risk-averse, then the relationship between volatility and incentive strength can also be non-monotone.

The intuition behind these results is straightforward. The decision-maker can be controlled either through performance pay (incentives) or direct controls. The value of incentives derives from their ability to induce the agent to respond to new information that he otherwise would not respond to. This value depends directly on how uncertain the environment is, leading to a positive relationship between incentive strength and volatility. Further, this value depends on how much flexibility the agent has in responding to such information in the first place. As a result, incentive strength and job flexibility are complements. Conversely, when the risk of misaligned performance measures increases, the incentive strength needs to be decreased to limit the gaming of the incentive contract by the decision-maker. In consequence, the incentive strength is decreasing in the noisiness of the performance measure and direct controls will be used instead. Further, because the risk of misaligned performance measures limits the degree of incentive alignment, the equilibrium decisions, absent other controls, will always favor the decision-maker. To counter this bias favoring the decision-maker, the default decision is always biased against him. Finally, risk-aversion simply provides an additional cost of uncertainty,

[1] Moving beyond CEOs, the confounding effect of endogenous delegation becomes a more prominent issue.

which counters the increasing productive value of incentives as the volatility of the environment goes up.

Our results thus suggest two potential explanations for the conflicting evidence found on the relationship between risk and incentives in the literature on executive compensation. First, much of the empirical work has not made the distinction between the volatility of the environment and the noisiness of the performance measures, instead relying on the variance of stock returns as the catch-all for risk. Our model predicts that the signs of these two types of uncertainty should be in opposite directions. Second, even if this distinction is accounted for (as in the empirical work of Shi, 2006), risk-aversion can lead to a non-monotone relationship between volatility and incentives and the sign will depend on the amount of noise in the performance measures. To our knowledge, neither the potential non-monotonicity nor the potential interaction between volatility and noise in the determination of incentive strength has been analyzed in the empirical literature.

In contrast to the case of executive compensation, where the ambiguity concerning the risk-incentives tradeoff is present conditional on delegation, our results explain the observed positive relationship between the choice to franchise via the increased authority granted to the agent (franchisee) relative to a basic employment contract. When the agent is granted more authority, more incentive pay is needed to align the interests of the agent with those of the principal. The remaining question is when should we observe more delegation.

Having derived the optimal contract conditional on the identity of the decision-maker, the remaining problem is simply one of choosing the party that can be induced to make the better decision. Our results show that the decision-maker should be the party (i) whose payoff is more sensitive to the decision, (ii) who faces a more volatile environment, (iii) whose preferences are hardest to contract on and (iv) who has the best information about the realized states of the world. These results thus qualify the common intuition that increased uncertainty about the environment yields greater delegation. In particular, increased volatility faced by the principal will lead to *less* delegation unless, first, the increased volatility is accompanied by an increasing informational advantage held by the agent and, second, sufficiently accurate performance measures exist that can be used to guide the behavior of the agent.

While in many situations, such as franchising, we would expect environmental volatility and the amount of specific knowledge to be highly correlated, moving the focus from volatility to specific knowledge (as emphasized by Jensen and Meckling, 1992) also helps to explain why in some cases increased uncertainty leads the principal to retain *more* control, such as the case of offshore drilling analyzed in Corts and Singh (2004). Further, the analysis of active information acquisition suggests why high-powered incentives to the agent are rarely observed when the principal retains authority, and thus provides a specific role for the delegation choice observed with franchising as opposed to simply providing high-powered monetary incentives.

Finally, while we are unaware of any empirical studies that have analyzed simultaneously all the links predicted by our model, a few recent studies have examined subsets of these relationships. Consistent with our results, Nagar (2002) finds that in retail banking, branch managers in more volatile banks are delegated more decision rights and receive more incentive pay. Aggarwal and Samwick (2003) classify executives according to their job classification and show that the strength of incentives is related to their job classification, evidence which is generally complemented by Barron and Waddell (2003) and Wulf (2006). With the exception of Nagar (2002), the impact of the environment on the choice to delegate is not examined.

Finally, Moyer (2006) finds evidence that the likelihood of delegation is increasing in the quality of performance measures, another aspect that has received only limited attention. To our knowledge, the distinction between job flexibility and delegation has received no empirical attention.[2]

3.1.2 Relationship of the model to theoretical literature

The present model combines and extends many of the results present in two different literatures: moral hazard and authority and delegation. We will discuss each in turn.

Moral hazard: While the discussion of the model is framed in terms of decision-making, if we fix the identity of the decision-maker, then the setting parallels closely models of hidden action, with the exception of introducing uncertainty over the marginal cost and productivity of effort. In consequence, the results of the model are related to a number of papers analyzing the typical effort-provision problem.[3]

First, random productivity of effort has been forwarded as an explanation for the ambiguous relationship between risk and incentives by a number of authors. The key distinction between volatility and noise has been made in the case of risk-aversion by Zabojnik (1996) and Baker and Jorgensen (2003), and in the case of risk-neutrality but limited liability by Raith (2004). While in our model the noise is related to misaligned performance measures, and in doing so, bears a resemblance to Baker (1992), the results are analogous.[4] We also extend these results by recognizing the possibility of external controls imposed on the decision-maker through job design.[5] Further, in contrast to much of the work on random productivity, the solution derived in section 3 is indeed the optimal contract and doesn't exogenously assume linear incentives.

Second, active information acquisition, which we discuss in Appendix A, has also been analyzed by Shi (2006). Third, the positive relationship between job flexibility and incentive strength, and their negative relationship with noise, is present in Holmström and Milgrom (1991). However, the role of volatility is not analyzed in their model. Finally, since action is by assumption hidden in all these models, the question of allocation of authority does not arise.

Authority and delegation: Our main contribution to the literature on authority and delegation is in endogenizing the degree of interim incentive conflict through the use of incentive contracts and thereby identifying contractual complications as additional determinant of the allocation of authority.

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[2] A related question is the impact of IT on the degree of decentralization. On the one hand, it can facilitate the flow of payoff-relevant information to the principal (supporting centralization). On the other hand, it can improve the quality of monitoring and performance measures (supporting decentralization). Further, note that while improvements in either monitoring or performance measures can lead to decentralization, their implications for job flexibility are very different.

[3] The link is clear once one recognizes that even providing literal "effort" is a decision to provide that level of effort.

[4] Rantakari (2007) discusses in more detail the impact of different types of uncertainty on the choice of incentive strength.

[5] While some attention has been given to action-contingent transfers, to our knowledge nobody has considered the role that the "default decision" can play in the solution.

In our analysis of the choice to delegate, the model resembles most closely Prendergast (2002). The direct overlap of the underlying forces, however, is limited to the role of specific knowledge. In our model, the relative sensitivity of the payoffs to the decision, the volatility of the environment and the level of noise in the performance measures provide independent reasons for delegation, even absent any informational advantage by one of the parties. Also, we do not need to make the assumption of exogenous cost of measuring inputs and outputs (where measuring inputs is cheaper than measuring outputs) that is made in Prendergast (2002). Further, as discussed above, the optimal contract can exhibit significant heterogeneity even conditional on the identity of the decision-maker, a feature not present in Prendergast (2002).

Three other models are related. First, Aghion and Tirole (1997) show how delegation improves the incentives of the agent to acquire information. The model, however, is silent on monetary compensation and assumes an asymmetric and exogenous degree of congruence between the preferences of the agent and the principal. Our model shows how the accuracy of available performance measures can provide microfoundations for such asymmetric degree of congruence. Further, the incentive effect is somewhat more nuanced in our setting and is discussed in the end of section 3 and in Appendix A. In particular, the model suggests why monetary incentives cannot be used as a substitute for the motivating role of delegation, even if their provision would be feasible.

Second, Dessein (2002) contrasts delegation and communication solutions in the setting of Crawford and Sobel (1982). He shows that, given a fixed bias, increased uncertainty leads to worse average quality of communication while leaving delegation unaffected, making delegation more likely in more uncertain environments. His model can thus be seen as providing microfoundations for the relationship between volatility and informational asymmetry, even if the model remains silent on incentives. Third, Alonso, Dessein and Matouschek (2006) and Chapter 1 of this thesis analyze an alternative model where the relative quality of the communication and delegation solutions is unaffected by the overall level of volatility and the choice to delegate is driven by the importance of coordination between decisions.[6] Taken together, these results suggest that the link between volatility and informational asymmetries is likely to be context-specific and something that needs to be accounted for. In contrast to the last three papers, we take the amount of informational asymmetry remaining in the decision-making stage as an exogenous parameter.[7][8]

3.2 The model

We consider a contracting problem where two parties come together and need to sign a contract to make a decision, *d*, optimal choice of which is uncertain at the time of contracting. Both

[6] On the role of coordination in organizational design, see also Dessein, Garicano and Gertner (2005), Friebel and Raith (2006) and Hart and Holmström (2002).

[7] On problems of communication, see also Crawford and Sobel (1982), Dewatripont and Tirole (2005) and Alonso (2006).

[8] There also exists a large descriptive literature on organizational and contractual design. See, for example, Simon (1947) on authority, Williamson (1975) on adaptation, Jensen and Meckling (1992) on specific knowledge and Klein (1995) on franchising.

parties are risk-neutral. Our goal is to study the joint determination of the allocation of the decision right, the degree of incentive provision and any potential constraints put on the decision itself, given the underlying environment. While the model is fully symmetric, in our discussion we will frame it as a principal-agent relationship. The relationship of the model to models of hidden action is discussed in Appendix A.5.

3.2.1 Preferences

The utilities of the principal and the agent are given by

$$U_P = K_P - \gamma(\theta_P - d)^2 \qquad \text{and} \qquad U_A = K_A - (\theta_A - d)^2,$$

$$\text{where } \begin{pmatrix} \theta_P \\ \theta_A \end{pmatrix} \sim N\left(\begin{pmatrix} \mu_P \\ \mu_A \end{pmatrix}, \begin{pmatrix} \sigma_P^2 & \sigma_{PA} \\ \sigma_{PA} & \sigma_A^2 \end{pmatrix} \right).$$

The relative importance of the decision to the principal is measured by γ, with $\gamma \in (0, \infty)$. K_P and K_A measure the maximum private returns to the principal and the agent, and θ_P and θ_A index the decision that would realize these maximum private returns to the principal and the agent, respectively. We will refer to θ_P and θ_A as the states of the principal and the agent. At the time of contracting, the distributions of the states are common knowledge, but their exact realizations are not.[9] While it is only the realized incentive conflict $|\theta_P - \theta_A|$ that matters for the payoffs, as we will see, the information contained in $|\mu_P - \mu_A|$ and σ_{PA} will be used by the optimal contract to manage the realized incentive conflict.

As an example, consider the problem of managing an R&D project. While there is naturally a need to induce literal effort, there are also likely to be a number of decisions that need to be made during the project: what avenues of research to explore, what components to develop, what equipment to purchase and so forth. Let the principal be the firm and the agent the R&D lab. Then, θ_P will index the decision that will maximize the firm value while θ_A will index the decision that will maximize the utility of the R&D lab absent any outcome-dependent transfers and includes aspects such as knowledge generation and professional satisfaction.

3.2.2 Performance measures

We assume that there are two performance measures available, given by

$$X_P(s_P, d) = -(s_P - d)^2 + \varepsilon_{X_P} \qquad \text{and} \qquad X_A(s_A, d) = -(s_A - d)^2 + \varepsilon_{X_A},$$

where $s_i = \theta_i + \varepsilon_i$, with $\varepsilon_i \sim N(0, \sigma_{\varepsilon_i}^2)$. Under our assumption of risk-neutrality throughout the main analysis, ε_{X_i} play no role in the optimal incentive contract.[10] The key behind the

[9] The model is silent on the existence of assets and asset ownership. In a more microfoundational model, (θ_A, θ_P) can potentially be directly manipulated through reallocation of asset ownership, as in Holmstrom (1999).

[10] Risk-aversion is discussed in Appendix A.3.

analysis is the presence of ε_i, which implies that the available performance measures are never perfectly aligned ex post with what the principal or the agent would have wanted to measure, and it is this ex post misalignment that causes the decision-maker always to choose suboptimally. This logic parallels the basic idea of Baker (1992) regarding misaligned performance measures.

In our R&D example, depending on the basic structure of compensation, s_P might index the project that will generate the largest revenue stream while s_A might be the project with the smallest monetary cost. Thus, s_P will be missing the non-monetary value-added of the project realized by the principal, while s_A will be missing the private development costs and professional prestige realized by the agent. Note also the distinction between s_i and X_i. If s_i is the project that maximizes the revenue stream, X_i is the revenue stream that is actually realized. Thus, X_i is always verifiable, while s_i might not be.

In addition to the output-based measures, we assume that decision-contingent transfers can be made based on

$$X_d(\overline{d}, d) = -\left(\overline{d} - d\right)^2,$$

where $\overline{d}$ is a default decision to be determined by the contract. While the direct interpretation of this component is formal decision-contingent transfers, we prefer the broader interpretation of general job flexibility granted to the agent. The basic idea is that job design can be used to make some actions more costly than others.

Given the contractible variables, the decision-maker is then offered a linear contract of the form

$$T(d) = \sum_i \alpha_i X_i + B.$$

As we will show in section 3, given the structure of s_i and the possibility of making transfers based on $\left|\overline{d} - d\right|$, this linear contract is optimal, which makes the question of whether s_i are verifiable irrelevant for this analysis. When decision-contingent transfers are not available, unconditional linear incentives will no longer in general be optimal, an aspect which is discussed in Appendix A.4. Similarly, if such transfers involve any waste (as one could expect if the cost of different choices is managed through various bureaucratic measures), the optimality of the linear contract is lost.[11]

3.2.3 Timing and information

The timing of events is summarized in figure 3-1. At $t = 0$, the principal offers a contract that consists of a default decision $\overline{d}$, weights placed on the performance measures and decision-

[11]However, the forces controlling the shape of the performance contract are very different from the variables determining the overall strength of incentives and the identity of the decision-maker. Thus, the logic of the model generalizes and the comparative statics remain almost identical. The only notable difference is in the impact of the correlation ρ between the preferences of the agent and the principal. When decision-contingent transfers are available, ρ is used with the help of decision-contingent transfers to translate information contained in θ_i about θ_j directly into the final decision, while when such transfers are not available, ρ is used only to predict the expected size of the incentive conflict.

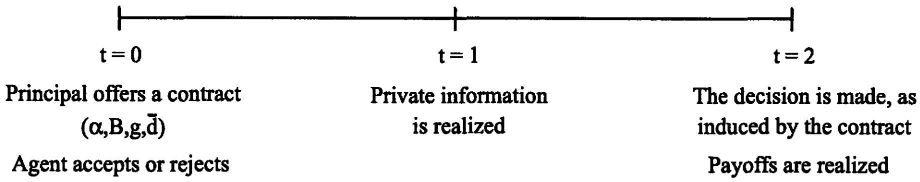

Figure 3-1: Timing of Events

contingent transfers $\boldsymbol{\alpha}$, a fixed transfer B and the identity of the decision-maker $g \in \{P, A\}$. We assume that both parties have deep pockets and so the optimization problem becomes one of maximizing the ex ante total surplus, which in turn is equivalent to minimizing the total expected loss. Substituting out B, we can write this optimization problem as

$$\min_{g,\boldsymbol{\alpha},\overline{d}} E\left(\gamma(\theta_P - d^*)^2 + (\theta_A - d^*)^2\right)$$

$$\text{s.t.} \qquad d^* \in \arg\max_{d} E\left(U_g\left(.\right) + T_g\left(.\right)|\boldsymbol{\omega}_g\right),$$

where $\boldsymbol{\omega}$ indexes the information held by the decision-maker in the decision-making stage. At $t = 1$, information about $(\theta_A, s_A, \theta_P, s_P)$ is realized. In our main analysis we will focus on the case where both parties learn all information. As we will see, there is some redundancy, as the solution is equivalent to the case where the agent learns θ_A and s_P, while the principal learns θ_P and s_A. We assume that renegotiation at this stage is not possible.[12] Finally, at $t = 2$, the decision is made by the agent controlling the decision right, as induced by incentive contract and the realization of $(\theta_A, s_A, \theta_P, s_P)$. The purpose of the incentive contract $\left(\boldsymbol{\alpha}, \overline{d}\right)$ is to induce as good decision-making as possible, given the available performance measures. Given the optimal contract for both agents, we will then choose as the decision-maker the party g who, in expectation, will make better decisions.

[12] While our assumption of prohibitively costly renegotiation is extreme, the assumption of costless renegotiation is also for many purposes a theoretical abstraction. First, even if each party had full information, costless Nash bargaining is unlikely to take place. In practice, renegotiation costs both time and money as the parties are trying to capture a larger share of the available surplus (e.g. Williamson, 1985 and Klein, Crawford and Alchian, 1978). Second, the presence of asymmetric information (introduced in section 3.4.1) would complicate the renegotiation process further. As long as there are some costs of renegotiation, there is a region over which decisions are not renegotiated ex post, even if total surplus could be increased absent such costs. The higher the costs are, the larger this region is and within this region, we still need a contract that will control the behavior of the decision-maker. Further, the better the contract is, the less often it needs to be renegotiated and the greater the resource savings.

3.3 Analysis

We begin our analysis by discussing the optimal contract and show how it can be implemented in the present environment with the simple linear contract discussed above. We then present the solution to the optimal contract under the assumption of zero correlation of preferences, as this is sufficient to understanding the key determinants in the relationship between volatility of the environment and the strength of incentives. Finally, we discuss what additional insights can be gained from the general solution and from extensions to imperfect information, information acquisition and risk-aversion by the agent. A more detailed exposition of these extensions and other observations is presented in Appendix A.

3.3.1 Optimal contracts

The key to understanding the structure of the optimal incentive contract is to recognize that the purpose of the contract is to control the responsiveness of the decision-maker to information about $(\theta_A, s_A, \theta_P, s_P)$. If the preferences of the two parties were directly contractible, then the first-best decision would be given by

$$\min_d \gamma \left(\theta_P - d\right)^2 + \left(\theta_A - d\right)^2 \rightarrow d^{FB} = \tfrac{\gamma\theta_P + \theta_A}{1+\gamma}.$$

The agency problem in the model is generated by the fact that θ_A and θ_P are not contractible. Instead, while the decision-maker i will fully internalize his own state θ_i, he can be induced to care only about the realization of s_j, which, because of the presence of ε_j, will never exactly match the preferences of the non-deciding party θ_j. Consider the case where the agent controls the decision right. Now, s_A is clearly redundant as a performance measure since the agent already knows and fully internalizes θ_A. Similarly, since θ_P is non-contractible and the agent has perfect information about s_P, θ_P is redundant as well. Thus, the only information that can be brought to bear on the agent's decision is (θ_A, s_P).

Consider now the following problem: given information about (θ_A, s_P), what decision will maximize the expected total surplus? That is, given the information that can be used to bear on the decision, what is the optimal way to use that information. This second-best decision is given by

$$d^{SB} = \tfrac{\gamma E(\theta_P | s_P, \theta_A) + \theta_A}{1+\gamma}.$$

By Bayesian updating, $E\left(\theta_P | s_P, \theta_A\right) = \beta_0\mu_P + \beta_1 s_P + \beta_2\theta_A$, where the coefficients are determined by the overall and relative informativeness of (s_P, θ_A). Thus, the second-best decision will be linear in the information of the agent:

$$d^{SB} = \delta_0\mu_P + \delta_1 s_P + \delta_2\theta_A.$$

We next show that an appropriate contract can induce this second-best decision. Given the linear contract

$$T(.) = B - \alpha_P (s_P - d)^2 - \alpha_A (s_A - d)^2 - \alpha_D \left(\overline{d} - d\right)^2$$

and individual utility

$$U(.) = K_A - (\theta_A - d)^2,$$

the agent's first-order condition can be written as

$$d^A = \eta_0 \overline{d} + \eta_1 s_P + \eta_2 s_A + \eta_3 \theta_A.$$

Thus, it is immediate that $\eta_2 = 0$ since, as mentioned above, s_A contains no additional information (over θ_A) about θ_P. The solution of $\left(\alpha_P, \alpha_D, \overline{d}\right)$ then follows from a direct matching of the coefficients to *induce the agent to respond to incoming information as a decision-maker who makes optimal decisions conditional on information only about* (s_P, θ_A). Such a solution exists and thus the linear form of the contract is optimal. A corollary of this result is that the linear delegation contract based on (s_P, θ_A) always dominates an ex ante contract based on (s_P, s_A), even if such a contingent ex ante contract was feasible.

3.3.2 Solution under zero correlation

Delegation

Consider first the case where the correlation ρ between θ_A and θ_P is zero to highlight how the optimal incentive strength varies with σ_P^2 and $\sigma_{\varepsilon_P}^2$. Since θ_A contains no information about θ_P,

$$E(\theta_P | s_P, \theta_A) = \frac{\sigma_{\varepsilon_P}^2}{\sigma_P^2 + \sigma_{\varepsilon_P}^2} \mu_P + \frac{\sigma_P^2}{\sigma_P^2 + \sigma_{\varepsilon_P}^2} s_P,$$

which implies that the second-best decision will solve

$$d^{SB} = \frac{1}{1+\gamma} \left(\gamma E(\theta_P | s_P, \theta_A) + \theta_A\right) = \frac{1}{1+\gamma} \left(\gamma \left(\frac{\sigma_{\varepsilon_P}^2}{\sigma_P^2 + \sigma_{\varepsilon_P}^2} \mu_P + \frac{\sigma_P^2}{\sigma_P^2 + \sigma_{\varepsilon_P}^2} s_P\right) + \theta_A\right).$$

At the same time, the agent's decision for any $\left(\alpha_P, \alpha_D, \overline{d}\right)$ is given by

$$d^A = \frac{\alpha_P s_P + \alpha_D \overline{d} + \theta_A}{1 + \alpha_P + \alpha_D}.$$

A straightforward matching of coefficients yields the following proposition:

Proposition 24 *The optimal incentive contract under delegation and* $\rho = 0$ *is given by*

$$\alpha_P = \frac{\sigma_P^2 \gamma}{\sigma_P^2 + \sigma_{\varepsilon_P}^2}, \qquad \alpha_d = \frac{\sigma_{\varepsilon_P}^2 \gamma}{\sigma_P^2 + \sigma_{\varepsilon_P}^2} \qquad \textit{and} \qquad \overline{d} = \mu_P.$$

Proof. Special case of proposition 4 ■

The strength of incentives is given by α_P. We can see that the higher the volatility of the principal's state, the more important it is that the agent's decisions track closely the principal's preferences. Similarly, the noisier the performance measure, the less closely the principal's state can be tracked and to avoid the 'get-what-you-pay-for' (GWYPF) problem, the less weight is placed on the performance measure. In consequence, the overall incentive strength is driven simply by the volatility-to-noise ratio $\sigma_P^2/\sigma_{\varepsilon_P}^2$, with an adjustment for the difference in the relative importance of the decision, γ.

In addition to considering linear incentives, we have also included job flexibility in the solution. The cost of deviating from the default decision $\overline{d}$ (and so the inverse of job flexibility) is given by α_d. It is also driven by the volatility-to-noise ratio but exactly in the opposite direction, with constraints increasing in $\sigma_{\varepsilon_P}^2$ and decreasing in σ_P^2. The intuition is straightforward. The agent can be controlled either through incentives or direct controls. Other things constant, when the volatility of the environment increases, incentive alignment becomes more valuable as it induces the agent to make more use of his information, which is then complemented through reduced direct controls. In consequence, incentive strength and job flexibility are complements, as in Holmström and Milgrom (1991). Similarly, they both decrease in the noisiness of the performance measure. However, unlike Holmström and Milgrom (1991) which is silent on the matter, they also co-move *positively* with the volatility of the environment.

We can also see that the default decision $\overline{d}$ is biased in favor of the principal. The intuition for this result is that since $\alpha_P < 1$, the decision made by the agent will in expectation always favor the agent, unless other constraints are introduced. To compensate for this decisional bias favoring the agent, the default decision is biased in favor of the principal. Finally, note that the optimal incentive strength and degree of job flexibility are independent of σ_A^2, the variance of the agent's individually optimal decision. This result follows simply because the agent already fully internalizes any variance in his own needs. It is only the preferences of the principal that the agent needs to be induced to internalize.

Employment

The employment solution follows symmetrically and is given by the following proposition:

Proposition 25 *The optimal incentive contract under employment and $\rho = 0$ is given by*

$$\alpha_A = \frac{\sigma_A^2}{\sigma_A^2+\sigma_{\varepsilon_A}^2}, \qquad \alpha_d = \frac{\sigma_{\varepsilon_A}^2}{\sigma_A^2+\sigma_{\varepsilon_A}^2} \qquad \textit{and} \qquad \overline{d} = \frac{\mu_A\sigma_P-\mu_P\rho\sigma_A}{\sigma_P-\rho\sigma_A}.$$

Proof. Special case of proposition 4 ■

In a symmetric two-agent model, the symmetry of the solution is immediate. On the other hand, the considerations of how the principal himself is controlled rarely arise in the basic principal-agent framework since the principal is usually just a passive party hiring the agent to perform a task. The present framework, however, highlights the fact that (absent repeated-game considerations), when granted authority, the employer is need not be any more benevolent than the employee. Just like the employee, given his wage, would like to work as little as possible and choose projects requiring minimal input by him, the employer, if given the decision right over some aspect of the employee's behavior, needs to be controlled against abusing the employee.

Choice of contract

Substituting the equilibrium decision in the total expected loss and comparing the solutions under employment and delegation yields the following proposition:

Proposition 26 *The equilibrium expected losses under (D)elegation and (E)mployment are given by*

$$EL^D = EL^{FB} + \frac{\gamma^2}{(1+\gamma)} \frac{\sigma_P^2 \sigma_{\varepsilon_P}^2}{\left(\sigma_P^2 + \sigma_{\varepsilon_P}^2\right)} \qquad \textit{and}$$
$$EL^E = EL^{FB} + \frac{1}{(1+\gamma)} \frac{\sigma_A^2 \sigma_{\varepsilon_A}^2}{\left(\sigma_A^2 + \sigma_{\varepsilon_A}^2\right)}.$$

Thus, delegation is preferred iff

$$\gamma^2 \leq \frac{\sigma_A^2 \sigma_{\varepsilon_A}^2 \left[\sigma_P^2 + \sigma_{\varepsilon_P}^2\right]}{\sigma_P^2 \sigma_{\varepsilon_P}^2 \left[\sigma_A^2 + \sigma_{\varepsilon_A}^2\right]}.$$

That is, the likelihood of delegation is increasing in $\sigma_{\varepsilon_A}^2, \sigma_A^2$ *and decreasing in* $\sigma_P^2, \sigma_{\varepsilon_P}^2$ *and* γ.

Proof. Special case of proposition 4 ■

As discussed in section 3.1, the purpose of the incentive contract is to induce decisions that are as close to first-best as possible, conditional on the information that the decision-maker can be induced to use. The quality of these decisions, in turn, depends simply on the volatility-to-noise ratio $\sigma_i^2/\sigma_{\varepsilon_i}^2$ of the state that the decision-maker is not directly internalizing, with an adjustment for the relative sensitivity of the payoff of each party to the decision. In consequence, delegation becomes more likely whenever the agent's preferences become harder to contract on $\left(\sigma_{\varepsilon_A}^2 \uparrow\right)$ or the volatility his state increases $\left(\sigma_A^2 \uparrow\right)$, while the converse happens when either the principal's preferences become harder to contract on or the principal's state becomes more volatile. Further, delegation becomes less likely when the principal's payoff becomes more sensitive to the decision (γ).

To summarize, increased uncertainty faced by the principal increases the incentive strength and job flexibility granted to the agent conditional on delegation, but it also makes delegation *less* likely. In consequence, the results so far would appear to go partially against the accumulating empirical evidence that delegation is associated with greater uncertainty. However, what the results really highlight is that uncertainty alone is not sufficient in supporting delegation. What is needed is the development of an informational asymmetry between the agent and the principal during the execution of the contract.

An example The basic logic of the analysis so far is well illustrated with offshore drilling contracts, discussed in Corts and Singh (2004). Having acquired a lease on an offshore tract, oil and gas exploration and production (E&P) companies contract with independent drilling companies to drill wells on the tract. The wells come in two forms: exploratory and development wells. Exploratory wells are used to gauge the type and value of fuels present within a tract. Development wells are used to extract efficiently these reserves. The contracts governing the relationship also come primarily in two forms: day-rate and turnkey contracts, corresponding roughly with cost-plus and fixed-price contracts, respectively. The regularities of interest for the present analysis are that (i) day-rate contracts are more prominent in governing the drilling of development wells, (ii) day-rate contract is associated with an E&P representative being present on the rig during the drilling and retaining a number of decision rights, while (iii) no representative is present under turnkey contracts and control of the project is retained by the drilling company.

The key to understanding this pattern of contracts is to recognize that while exploratory wells exhibit greater financial uncertainty as to the profitability of the tract, the drilling itself is fairly standard. In contrast, development wells exhibit significant uncertainty *over the best way of extracting the resources* at the time of contracting. In terms of the coefficients of the model, $\sigma_P^2(development) > \sigma_P^2(exploratory)$ even if $\sigma_{\varepsilon_{XP}}^2(development) > \sigma_{\varepsilon_{XP}}^2(exploratory)$. As discussed above, it is exactly high σ_P^2 that leads to the retainment of control by the principal. Also, to control the demands for adjustments made by the E&P representative, cost-plus terms are used in the financial management of the project. Further, the presence of the E&P representative on the rig is used to improve the access to information by the principal, thus limiting the rise of informational asymmetries. Conversely, when σ_P^2 is low, a fixed-price contract is used to incentivize the drilling company to manage costs better, together with discretion over such decisions.[13]

Imperfect monitoring So far we have framed the problem in a way that assumes that decisions are verifiable. The imperfections in contracting have risen from the inability to renegotiate the contract coupled with the imperfect measurability of the inputs and outputs that are demanded by different decisions. If the actions become hidden, then costly monitoring can simply force delegation: if the agent cannot be directly induced to perform actions demanded by the principal, then the only available avenue is de facto delegation which in turn necessitates the use of performance measures to indirectly guide the behavior of the agent. In between, we have different degrees of costly monitoring.

[13] The advantage of cost-plus contracts is typically considered to arise from their ability to facilitate renegotation/recontracting (e.g. Bajari and Tadelis (2001)), but another way of viewing the situation is to note that asking for adjustments under cost-plus terms does not typically require any renegotiation. Thus, instead of facilitating, we are really avoiding renegotiation.

3.3.3 General solution

The solution for $\rho \neq 0$ follows the same steps outlined above and is given by the following proposition:

Proposition 27 *The parameters of the optimal incentive contract under delegation are given by*

$$\alpha_P = \frac{\gamma(1-\rho^2)\sigma_A^2\sigma_P^2}{(1-\rho^2)\sigma_A^2\sigma_P^2+\sigma_{\varepsilon P}^2\left(\sigma_A^2+\gamma\rho\sigma_A\sigma_P\right)}, \quad \alpha_d = \frac{\sigma_{\varepsilon P}^2\gamma\left(\sigma_A^2-\rho\sigma_A\sigma_P\right)}{(1-\rho^2)\sigma_A^2\sigma_P^2+\sigma_{\varepsilon P}^2\left(\sigma_A^2+\gamma\rho\sigma_A\sigma_P\right)}, \quad \overline{d} = \frac{\mu_P\sigma_A-\mu_A\rho\sigma_P}{\sigma_A-\rho\sigma_P},$$

while the parameters of the optimal incentive contract under employment are given by

$$\alpha_A = \frac{\gamma(1-\rho^2)\sigma_A^2\sigma_P^2}{\gamma(1-\rho^2)\sigma_A^2\sigma_P^2+\sigma_{\varepsilon A}^2\left(\gamma\sigma_P^2+\rho\sigma_A\sigma_P\right)}, \quad \alpha_d = \frac{\gamma\sigma_{\varepsilon A}^2\left(\sigma_P^2-\rho\sigma_A\sigma_P\right)}{\gamma(1-\rho^2)\sigma_A^2\sigma_P^2+\sigma_{\varepsilon A}^2\left(\gamma\sigma_P^2+\rho\sigma_A\sigma_P\right)}, \quad \overline{d} = \frac{\mu_A\sigma_P-\mu_P\rho\sigma_A}{\sigma_P-\rho\sigma_A}.$$

The resulting expected losses are then given by

$$EL^E = EL^{FB} + \frac{1}{(1+\gamma)}\frac{\sigma_A^2(1-\rho^2)\sigma_{\varepsilon A}^2}{\left(\sigma_A^2(1-\rho^2)+\sigma_{\varepsilon A}^2\right)},$$
$$EL^D = EL^{FB} + \frac{\gamma^2}{(1+\gamma)}\frac{\sigma_P^2\sigma_{\varepsilon P}^2\left(1-\rho^2\right)}{\left(\sigma_P^2(1-\rho^2)+\sigma_{\varepsilon P}^2\right)}.$$

Thus, delegation is preferred iff

$$\gamma^2 \leq \frac{\sigma_A^2\sigma_{\varepsilon A}^2\left[\sigma_P^2\left(1-\rho^2\right)+\sigma_{\varepsilon P}^2\right]}{\sigma_P^2\sigma_{\varepsilon P}^2\left[\sigma_A^2(1-\rho^2)+\sigma_{\varepsilon A}^2\right]}.$$

That is, the likelihood of delegation is increasing in $\sigma_{\varepsilon A}^2, \sigma_A^2$ and decreasing in $\sigma_P^2, \sigma_{\varepsilon P}^2$ and γ. The role of ρ depends on the variance/noise ratio. In particular, if $\sigma_A^2/\sigma_{\varepsilon A}^2 > \sigma_P^2/\sigma_{\varepsilon P}^2$, then the likelihood of delegation is increasing in $|\rho|$.

Proof. See Appendix B ∎

Let us first consider the strength of incentives, α_P and α_A. We can see that the qualitative impact of the volatility of the environment and the noise in the performance measure remain the same. The only difference is that incentives will be non-monotone in ρ. To understand this result, note that as $\rho \neq 0$, θ_i becomes informative of θ_j. In consequence, it is possible to use the decision-contingent transfers to induce the decision-maker to use the information contained in his own state, instead of relying on the noisy performance measure. When $|\rho|$ is large, it is possible to rely heavily on direct controls in guiding the agent's behavior. Indeed, as $|\rho| \to 1$, θ_i becomes perfectly informative about θ_j. As a result, incentive strength will converge to zero and first-best decisions are achieved purely through job design. Conversely, the need for pay-for-performance tends to be highest when $|\rho|$ is small, since in this case direct controls are highly inefficient in guiding the behavior of the agent. Thus, *the incentive strength can be decreasing in the expected size of the incentive conflict in the decision-making stage.*[14]

[14] Of course, if decision-contingent transfers were not available, this is no longer the case. Further, the fact that this non-monotonicity is related to decision-contingent transfers resonates well with the idea of learning

Similarly, since the correlation between preferences improves contracting in both directions, its impact on the choice between delegation and employment is relatively limited. From the results we see that the role of correlation is only to reduce the decisional advantage held by either party. This result follows because an increase in the correlation between the states allows us to substitute away from the noisy performance measure towards decision-contingent transfers, which improves the overall 'quality' of both delegation and employment contracts. However, it improves more the contract that induces statistically worse decisions. Intuitively, the marginal value of increased $|\rho|$ is higher when $\sigma_i^2/\sigma_{\varepsilon_i}^2$ is low, since the ability to use direct controls is more valuable when the initial decisions are poor, and the ability to use direct controls is increasing in $|\rho|$.

3.3.4 Extensions

The analysis so far has assumed that both the principal and the agent become fully informed before the decision needs to be made. However, in many situations an informational asymmetry develops between the agent and the principal during the execution of the relationship. Store managers have often better direct access to local information than the headquarters. The R&D lab becomes better informed about the viability of various research alternatives when the project is on its way. The opimal way to extract oil is learned during the drilling. Similarly, while some information can become readily available over time, it is often also actively acquired. In this subsection, we will review some of the results that arise when we relax the assumptions of perfect and free information and risk-neutrality. A more detailed exposition of these extensions can be found in Appendix A.

Incomplete and asymmetric information

In Appendix A.1, we show how the development of an informational asymmetry between the principal and the agent can lead to more delegation. This result should come as no surprise when we recall that the ultimate purpose of the contract is to induce good decision-making. Whether decision-making is compromised because of imperfect information or imperfect performance measures makes very little difference in terms of the expected total loss. However, while the worsening of the quality of information held by the principal increases the likelihood of delegation, keeping the informational asymmetry constant, an increase in the volatility faced by the principal still decreases the likelihood of delegation. Thus, for an increase in uncertainty faced by the principal to lead to delegation, the informational asymmetry needs to be increasing in the volatility of the environment. To summarize, what matters is not uncertainty per se but the amount of informational asymmetry between the principal and the agent. In consequence,

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to contract (e.g. Mayer and Argyres, 2004). As the parties learn their environment better, direct controls can be used to substitute for pay-for-performance, independent of whether learning leads to $E(\rho)\downarrow$ or $E(\rho)\uparrow$. Even if the expected conflict increases, knowledge of the regularities involved in the conflict help to design the initial contract better. On the other hand, the parties might also learn to construct more accurate performance measures, which would imply that $\sigma_{\varepsilon_i}^2\downarrow$, in turn implying heavier use of better-constructed performance measures.

increased uncertainty can sometimes lead to more delegation (e.g. choice to franchise) and sometimes to less delegation (e.g. choice of offshore drilling contracts).

While imperfect information impacts the allocation of authority, it has only limited impact on the contractual terms conditional on delegation. This result follows because the parties naturally discount information that is imperfect. It is only the relative sensitivity that needs to be controlled. Thus, while imperfect information gets reflected in the level of incentives (where the impact depends on the exact information structure – in particular, worse information does not imply weaker incentives), the comparative statics with respect to the exogenous variables remain unchanged.

Information acquisition

While some information can become readily available over time, information is often also actively acquired. Appendix A.2 examines a setting where information about the agent's preferences remains free but the parties need to undertake privately costly effort to learn about the principal's preferences. This setting provides an alternative explanation for the correlation between uncertainty and delegation: if the agent is in a better position to acquire information, then increased uncertainty can increase the probability of delegation even if all information learned by the agent can be perfectly transmitted to the principal before decision-making. As uncertainty increases, the importance of utilizing the superior ability of the agent to acquire information becomes more valuable. Delegation of the decision right motivates the agent to acquire information as he can then use the information in a way that is beneficial to him.

Further, the results suggest why the motivational role of delegation can be hard to replicate with purely monetary incentives. Note that absent any contractual difficulties, the motivational impact of delegation could be simply replicated with monetary incentives. For example, in the model of Aghion and Tirole (1997), pay-for-performance based on the principal's preferences could be used as a substitute for delegation. There are two interrelated reasons why such a solution is unlikely to hold in our setting. First, absent any pay-for-performance, the agent places a negative value on any information about the principal's preferences. This result follows because any additional information will in expectation restrict the agent's ability to have his way. In consequence, to induce information acquisition by the agent, not only does pay-for-performance need to be positive, it needs to be sufficiently strong as to overcome this inherent negative value. Second, even if the agent can be motivated to acquire information through sufficiently strong monetary incentives, such compensation in turn generates poor decision-making. The reason for this is that the principal now has strong incentives to make decisions that will limit the amount he has to pay to the agent. In short, providing the agent with incentives to acquire information simultaneously generates incentives for the principal to make poor use of that information. In consequence, delegation arises as a motivational tool that is qualitatively different from (and in the present setting superior to) monetary compensation.

Risk aversion

Appendix A.3 analyzes the determination of incentive strength when the agent is risk-averse. The results show that while an increase in the noise in the performance measure leads to the familiar negative trade-off between noise and incentives (as in the case of risk-neutral agent analyzed above), the relationship between volatility and incentives is now non-monotone and dependent on the amount of noise. In particular, the noisier the performance measure, the lower the incentive strength and the higher the likelihood that an increase in the volatility of the environment will lead to an increase in incentives. The intuition behind this result is straightforward. When the volatility of the environment increases, there are now two opposing forces. First, the value of responsiveness increases, as above, supporting stronger incentives. Second, risk-aversion makes incentives more costly to provide, supporting weaker incentives. In consequence, the relationship is ambiguous. Further, if the performance measure is very noisy (and in consequence the level of incentives low), then the 'value' aspect of incentives can dominate the 'risk' aspect of incentives at the margin and the predicted relationship between volatility and incentives is positive.

We have not examined the impact of risk aversion on the actual choice to delegate, but the results appear ex ante ambiguous because of two opposing forces. First, given an incentive structure, then delegation can be used to allow the agent to have more control over his environment, thus supporting a positive relationship between risk-aversion and delegation. Second, not delegating can limit the need for performance pay in the first place, thus limiting the amount of risk faced by the agent and so supporting a negative relationship between risk-aversion and delegation. Casual empiricism would suggest that the latter effect often dominates.

3.4 Empirical applications

The logic and the results of the model shed light on a number of empirical findings. We will first discuss empirical work on managerial incentives, visiting the "tenuous trade-off between risk and incentives" and discussing some of the recent advances that have made the distinction between volatility and noise or examined the co-determination of different variables. Second, we will discuss how a number of empirical regularities found in the literature on franchising fit with our model. In the case of franchising, while the discussed regularities (with the exception of the positive relationship between risk and incentives) can be explained also within a traditional moral hazard framework, the advantage of our model is in providing an explicit role for delegation.

The lessons from this review are two-fold. First, a number of empirical regularities can be fruitfully viewed under the common lense of managing (mal)adaptation problems. Second, the behavior of agents is managed through multiple control instruments. Failure to recognize and control for the simultaneous determination of these instruments runs the risk of false associations and conclusions. While data limitations are always a challenge, we hope that our explicit categorization of various control instruments (delegation, job flexibility and incentives) and environmental features (volatility of the environment, informational asymmetries, the quality of performance measures and the level of non-controllable risk) will help to guide and further our understanding of the determination of different incentive systems.

3.4.1 Inside firms - managerial incentives and delegation

As reviewed in Prendergast (2002), the empirical evidence on the trade-off between risk and incentives in managerial compensation is mixed, with some studies finding a significantly positive, some studies finding a significantly negative, and still some studies finding an insignificant relationship between risk and incentives, where risk is typically measured by some version of variance of stock returns. Given that the allocation of decision rights is relatively homogeneous among CEOs (whose incentive compensation has traditionally been used as the basis for examining the relationship between risk and incentives), this setting is most appropriately analyzed as the determination of incentives conditional on delegation having already taken place.

If we consider risk-neutrality to be the appropriate representation of the problem, then the model suggests that the conflicting results are a result of the empirical studies failing to distinguish between the two types of uncertainty (volatility and noise), leading to a potential misspecification problem in the existing empirical work. Recall that the optimal strength of incentives conditional on delegation was given by

$$\alpha_P = \frac{\sigma_P^2\gamma}{\sigma_P^2+\sigma_{\varepsilon_P}^2}.$$

We see that the optimal strength of incentives is increasing in the volatility of the state itself and decreasing in the noise contained in the performance measure. Further, if the agent is risk-averse, α_P can be non-monotone in σ_P^2 and $\sigma_{\varepsilon_P}^2$ and σ_P^2 will interact in the determination of the equilibrium strength of incentives, with high $\sigma_{\varepsilon_P}^2$ increasing the likelihood that α_P is increasing in σ_P^2. Thus, not only should empirical work account for the distinction between volatility and noise, but also account for the possibility that the relationship between volatility and incentive strength can be inherently non-monotone.

Recent advances

(i) Volatility and noise Shi (2006), motivated by an information-acquisition perspective, is to our knowledge the only empirical paper that makes the distinction between volatility and noise. He decomposes the variance of a firm's stock return to its market-, industry- and firm-specific components and finds that the strength of incentives is decreasing in market-level risk while increasing in industry- and firm-specific risk. Further, he finds that when the definition of the industry is broadened, the positive relationship is weakened and becomes eventually negative. While this decomposition is clearly an imperfect proxy for the theoretical constructs themselves, the evidence is highly suggestive that forces beyond risk-aversion and noisy performance measures are at play in the determination of managerial incentives.[15]

[15] These results stand in some contrast to Jin (2002) and Garvey and Milbourn (2003) who also decompose the return risk to idiosyncratic and market components, but from a relative performance evaluation perspective, and

To our knowledge, no paper has attempted to examine the potential non-linearity in the relationship between volatility and incentives or the interaction between the impacts of volatility and noise. Further, a common feature in much of the literature on executive compensation is the use of various firm-level characteristics such as book-to-market ratio, R&D and advertising intensities and industry classifications simply as additive control instruments. In contrast, our analysis suggests that such variables can contain valuable information regarding the environment and the importance of managerial control. In consequence they can influence not only the overall sensitivity of compensation but also potentially how the return uncertainty translates to incentive compensation.

Finding variables that are better associated with the theoretical constructs of both volatility and managerial control than firm- and industry-level stock return volatility should prove valuable in furthering our understanding of the link between the environment faced by a firm and its chosen managerial compensation policy. For example, Finkelstein and Boyd (1998) provide evidence that the *level* of managerial compensation is tied to the degree to which the manager is able to influence the performance of the firm, as measured by various variables along the lines mentioned above, and Shi (2006) explicitly discusses how pay-for-performance sensitivity is lower in capital-intensive industries. To our knowledge, the question of whether these variables further translate into differences in the link between incentive strength and volatility or noise has not been examined.

(ii) Delegation and beyond managers While the set of tasks that a CEO performs is relatively homogenous, with the above qualifier that the environment and, relatedly, the extent to which the CEO is able to control it, can vary across industries, the task set of other managers and workers can exhibit significant variation. A number of recent papers have examined how the incentive compensation varies by executive rank and how the degree of delegation within a group is influenced by uncertainty. While these studies do in general identify the importance of delegation, they in turn tend to pool all risk under one heading.

Aggarwal and Samwick (2003) provide empirical evidence on how the top management incentives vary by responsibility. Grouping executives in four categories according to their responsibilities, they show that the pay-for-performance sensitivity is significantly higher for CEOs than for divisional managers, with the strength of incentives decreasing in all categories with return volatility. These results are complemented by Barron and Waddell (2003), who rank executives within a firm according to their pay level, and provide evidence that the highest-paid executives also face the strongest incentives. While these results clearly illustrate that the incentives provided depend on the responsibilities of the agent, they do not shed light on how the division of responsibilities is in turn influenced by the environment.

Better evidence of the determinants of delegation is provided by analyzing a single category of managers. Nagar (2002) analyzes the degree of authority and incentive compensation of retail branch managers. He finds that, consistent with our results, the degree of delegation of

find that compensation is not related to the systematic (market) part while decreasing in the firm (idiosyncratic) risk. The decompositions used, however, are different, and Shi (2006) places more weight on industry-level risk and recognizes the potential endogeneity of the level of volatility.

responsibilities to branch level is higher in high-growth, volatile and innovative banks, and that branch managers with more authority receive more incentive-based pay. Wulf (2006), using data from a proprietary compensation survey of Hewitt Associates on the compensation of division managers, also finds that the compensation of division managers with broader authority is more sensitive to global performance measures, while conditional on the degree of authority, the trade-off between risk and incentives is negative. Finally, Moers (2006) provides evidence that the likelihood of delegation is increasing in the quality of contractible performance measures, as also predicted by our model.

Some recent studies have also examined how firm-level compensation policies and other parameters vary with various environmental variables. Foss and Laursen (2005) use survey data from Danish firms on the firm-level use of performance pay, delegation and relate it to measures of uncertainty such as the innovativeness of the firm and profit variance. They find that the use of performance pay is increasing in uncertainty and that this relationship is increasingly strong as the knowledge intensity of the industry increases (suggesting that environmental variables can indeed impact the strength of different links, as discussed above). They also find some evidence of increased use of delegation in more uncertain environments. Using similar data but from the British Workplace Employee Relations Survey of 1998, DeVaro and Kurtulus (2006) find that there is a negative relationship between risk and incentives (a relationship which is amplified when controlling for delegation), a positive relationship between risk and delegation and a positive relationship between performance pay and delegation, thus providing the most consistent piece of evidence in accordance with our model. Finally, Demers, Shackell and Widener (2002) examine the joint determination of performance pay, performance measurement and the allocation of decision rights in B2C Internet companies. Combining survey and archival data, they find that all three are complementary. However, potentially because of the low cross-sectional variation and the relatively small sample size, they find only little evidence on their relationship with various environmental variables, such as knowledge intensity and customer orientation.

3.4.2 Franchising and other contracts

The joint analysis of allocation of authority and choice of compensation policies inside firms (and beyond top executives) is significantly constrained because of lack of detailed data. In contrast, a wealth of data exists on contracts between firms. In this subsection, we will first review how some of the determinants of the choice to franchise fit with our model and then make some observations on work on other contracts.

The decision to franchise

Lafontaine and Slade (1997,1998) review the existing empirical work on the decision to franchise. They document a number of empirical regularities, of which the ones of most interest to us are (i) risk is positively related to the choice to franchise, (ii) the importance of the agent's effort is positively related to the choice to franchise, (iii) high cost of monitoring output or sales is positively related to company operation, and (iv) high cost of monitoring effort directly is negatively related to company operation. With the exception of (i), variants of the traditional hidden action model are able to explain all the regularities when viewing franchising as a choice to provide high-powered incentives. The additional contribution of our model is that it provides an explicit role for the delegation of responsibilities to the agent, thus identifying franchising as an arrangement that is qualitatively different from simply providing high-powered monetary incentives.

(i) Risk is positively related to the use of high-powered incentives/decision to franchise: As discussed above, much of apparent risk is uncertainty that a well-informed party is able to react to, captured in our model by the variance of states. We showed that while increased uncertainty faced by the principal doesn't necessarily lead to delegation, if an informational asymmetry develops between the principal and the agent and/or information needs to be actively collected, then delegation of decision-making will be used to motivate information acquisition and/or encourage responsiveness to that information. Thus, to the extent that the various measures, such as variation in detrended sales per outlet and fraction of outlets discontinued within a given period of time, used to capture risk (noise) actually capture volatility that the agent is in a better position to respond to, then increased uncertainty should indeed lead to franchising instead of company-ownership.[16]

(ii) The importance of the agent's effort is positively related to the decision to franchise: While it is an old prediction of models of moral hazard that the incentives of the agent are increasing in the importance of his effort, this explanation still leaves unanswered the question of why franchising instead of higher bonuses under company ownership. Our model suggests that when effort needs to be directed at information acquisition, then delegation can be necessary to induce information acquisition by the agent. Further, some of the measures that have been used to measure the importance of the agent's effort, such as capital/labor ratio, amount of discretionary inputs and "personalized service" dummy, appear to potentially correlate with the value of the *responsiveness* of the agent.

(iii) & (iv) A high cost of monitoring output or sales is positively related to company operation, while a high cost of monitoring effort directly is negatively related to company operation: Again, these regularities conform with the prediction of the moral hazard models with respect to the strength of incentives, while our model extends this logic to the choice to delegate. In particular, these two results together highlight the practical fact that

[16] An interesting alternative is provided by Mazzeo (2004). He highlights the point that the work on the choice to franchise ignores the franchisee's choice to be a fully independent agent. He finds evidence that in the motel industry, the likelihood of chain affiliation (as opposed to independent operation) is increasing in the uncertainty of the environment, suggesting a potential insurance feature of chain affiliation.

who gets to decide depends not only on the information available to the participants but also on the degree of controls available. Recall that the decision to delegate was given by

$$\gamma^2 \leq \frac{\sigma_A^2 \sigma_{\varepsilon_A}^2 \left[\sigma_P^2(1-\rho^2)+\sigma_{\varepsilon_P}^2\right]}{\sigma_P^2 \sigma_{\varepsilon_P}^2 \left[\sigma_A^2(1-\rho^2)+\sigma_{\varepsilon_A}^2\right]}.$$

Now, the difficulty of monitoring output or sales can be associated with the difficulty of contracting on the principal's (franchisor's) preferences (high $\sigma_{\varepsilon_P}^2$), indeed supporting company operation. The cost of monitoring the agent's effort is logically equivalent but slightly more nuanced. First, if the action d is truly hidden, then the principal is *de facto* forced to delegate that decision to the agent, with the only means of controlling him being high-powered incentives. Second, which was the focus of our model, even if d is transferable between the agent and the principal, if measuring the impact of that decision on the agent is sufficiently hard, then formal delegation will take place.

Contractual allocation of decision rights

While the empirical work on franchising has tended to approach the choice to franchise from the traditional moral hazard perspective (at the expense of considerations of the allocation of authority), the empirical work on other contracts has tended to take a property rights approach (at the neglect of most maladaptation problems during the execution of the contract). The notable exceptions are the papers by Arrunada et al (2001) and Zanarone (2005), who study the relationship between car manufacturers and dealerships. They show for the cases of Spain and Italy, respectively, how more control rights are allocated to manufacturers in networks where the risk of the dealers' moral hazard is higher and the cost of misbehavior on the manufacturer is higher, as measured by the size of the network (free-riding) and the unit price of cars (brand value) respectively. We can consider brand value to be reflected by γ, which measured how important appropriate decisions are to the principal, while the size of the network (and potential spillovers) is weakly analogous to $\sigma_{\varepsilon_P}^2$, since an increase in potential spillovers makes the provision of sharp incentives harder. Increase in either makes the retainment of decision rights by the principal more likely.

A significant body of empirical work examines the allocation of control in biotech alliances. Because of their focus on property rights, most of the results are only remotely related to our framework. Suffice to say that while our model is quiet on asset ownership, this body of work largely neglects any adaptation problems during the execution of the contracts. Further theoretical and empirical work is clearly needed to examine both the distinction and interdependencies among monetary payments, actual decision rights and property/control rights, which in turn can be used both as hostages to generate endogenous "performance measures" and to reallocate returns/motivate investment. An interesting study is provided by Lerner and Malmendier (2003), who illustrate how the absence of a specifiable lead product candidate (high ex ante uncertainty) leads to the allocation of termination and broad licensing rights to the financing firm. The logic of their model resonates well with the maladaptation framework: the inability to contract ex ante leads to the use of contractual terms that function to induce appropriate conduct by the R&D firm during the execution of the agreement. In this case, control rights are used as a hostage to induce appropriate behavior.

3.5 Conclusion

We have analyzed the joint determination of allocation of a decision right, incentive strength and job flexibility, as influenced by the underlying environment. First, conditional on the allocation of the decision right, we showed that the greater the ex ante uncertainty over the appropriate decision, the stronger the incentive strength and the greater the job flexibility grated to the decision-maker. Conversely, the noisier the performance measures used to align incentives, the lower the incentive strength and the lower the job flexibility granted to the decision-maker. These results resonate well with the basic logic that as the environment becomes more uncertain, responsiveness of the decision-maker becomes more valuable and, as a result, indirect incentive alignment through the use of performance measures is used as a substitute for direct controls. We suggested the distinction between volatility and noise as an explanation for the conflicting empirical evidence on the trade-off between risk and incentives found in the literature on executive compensation and complemented this distinction by noting the additional considerations that arise if the agent is risk-averse.

Second, we examined the choice to delegate. In the full-information setting, we showed how the allocation of the decision right depended on the relative importance of the decision, relative volatility of the environment and the relative contractibility of preferences. In particular, when the uncertainty faced by the principal increased, the likelihood of delegation *decreased.* We illustrated the logic of this result with the example of offshore drilling. In the extensions, we saw that, in contrast with the full-information case, increased uncertainty faced by the principal at the time of contracting could lead to increased delegation if (i) an informational asymmetry developed during the execution of the contract between the agent and the principal (specific knowledge) and/or (ii) it became more efficient to rely on information acquisition by the agent. We suggested the positive relationship between uncertainty and delegation as an explanation for the positive relationship between uncertainty and the choice to franchise found in the empirical literature, as opposed to any inherent need to provide stronger monetary incentives.

Moving beyond the risk-incentives trade-off, the predictions of the model were found to be broadly consistent with the emerging empirical literature examining the co-determination of authority and incentive strength inside firms and with other empirical determinants of the choice to franchise. Reflecting the predictions of the model with the empirical literature, the framework analyzed suggests that future empirical work needs to pay more detailed attention to the distinctions between different types of uncertainty, co-determination of organizational variables and the distinction between decision and ownership rights to provide an internally consistent estimation framework. At the same time, the existing empirical work suggests that future theoretical work is needed to examine the interactions between decision and ownership rights and among specific investment, moral hazard and maladaptation perspectives of contracting and organizational structures.

3.6 Appendix A: Extensions

3.6.1 Imperfect information

In many practical situations we would expect a natural informational asymmetry to develop between the agent and the principal, with the principal having worse direct access to information about local conditions. In this section we provide an illustration how such an informational asymmetry alters the choice to delegate and the underlying contract.

First, note that imperfect information has only a small impact on the degree of job flexibility and incentive strength. This result follows because the decision-maker, when making decisions, already internalizes any imperfections in the information itself. The only purpose of the incentive contract is to control the *relative* responsiveness of the agent to that information.[17]

The more significant effect of imperfect information comes from the worsening of the quality of the decisions. As a simple example, consider a situation where the agent learns perfectly (s_P, θ_A) and the principal learns perfectly s_A but receives only imperfect information about θ_P. That is, the principal receives only a signal $v_P = \theta_P + \eta_P$ about the realization of his state, where $\eta_P \sim N(0, \sigma^2_{\eta_P})$. The imperfection can be seen as arising from a variety of sources. First, the principal can have limited direct access to information. Second, if information is communicated from downstream, such communication takes time and the information will be outdated by the time it is used to make decisions. Third, incentive conflicts between the agent and the principal are likely to lead to garbling of information.[18] Finally, assume that $\rho = 0$ and $\gamma = 1$.

Under these informational assumptions, the solution under delegation remains unchanged. Under employment, the decision of the principal is now given by

$$d^P = \frac{\alpha_A s_A + \alpha_D \bar{d} + E_P(\theta_P|v_P)}{1 + \alpha_A + \alpha_D},$$

while the second-best decision is given by

$$d^{SB} = \frac{E_P(\theta_A|s_A) + E_P(\theta_P|v_P)}{2}.$$

Matching coefficients and solving for the expected loss yields the following proposition:

[17]Some effects are present on levels but not comparative statics, For example, to see how the level of incentives is affected, consider a situation where the agent has imperfect information about both s_P and θ_P (signals v_{P1} and v_{P2}, respectively). Then, when making decisions, the agent will form beliefs through $E(s_P|v_{P1}, v_{P2})$. Now, if v_{P2} receives no weight, then the solution parallels that in section 3. If v_{P2} receives a positive weight, then the correlation with θ_P is increased and it is optimal to provide *stronger* incentives. Indeed, if the agent receives no direct information about s_P but observes θ_P, then $E(s_P|\theta_P) = \theta_P$ and we actually achieve first-best decision-making.

[18]In a more detailed model, this degree of garbling is going to depend on the degree of expected and realized incentive conflict and our assumption of fixed noise is not exactly representative of the problem. For more detailed models of communication, see e.g. Dessein (2002), Alonso (2006), Alonso, Dessein and Matouschek (2006) and Chapter 1 of this thesis.

Proposition 28 *The parameters of the optimal incentive contract under employment are given by*

$$\alpha_A = \frac{\sigma_A^2}{\sigma_{\varepsilon A}^2+\sigma_A^2} \qquad \alpha_D = \frac{\sigma_{\varepsilon A}^2}{\sigma_{\varepsilon A}^2+\sigma_A^2} \qquad \overline{d} = \mu_A.$$

The resulting expected loss is then given by

$$EL^E = EL^{FB} + \frac{1}{2}\left[\left(\frac{\sigma_A^2\sigma_{\varepsilon A}^2}{\sigma_A^2+\sigma_{\varepsilon A}^2}\right) + \left(\frac{\sigma_P^2\sigma_{\eta P}^2}{\sigma_P^2+\sigma_{\eta P}^2}\right)\right].$$

Thus, delegation is preferred over employment iff

$$\frac{\sigma_P^2(x_{\varepsilon p}-x_{\eta p})}{(1+x_{\varepsilon p})(1+x_{\eta p})} < \left(\frac{\sigma_A^2\sigma_{\varepsilon A}^2}{\sigma_A^2+\sigma_{\varepsilon A}^2}\right),$$

where $x_{\varepsilon p} = \frac{\sigma_{\varepsilon P}^2}{\sigma_P^2}$ *and* $x_{\eta p} = \frac{\sigma_{\eta P}^2}{\sigma_P^2}$.

Proof. See Appendix B ∎

From the proposition we see that imperfect information held by the principal simply provides an additional source of loss, which in this example is in its consequences equivalent to an imperfect performance measure. This should not be a surprise, since from the perspective of expected loss, it matters very little whether a party makes poor decisions because he can be provided only with poor incentives or whether the decisions are poor because the party in question simply has inaccurate information.

As regards to the delegation choice, it is then immediate that if the agent's information is more informative than the principal's with respect to θ_P ($x_{\varepsilon p} < x_{\eta p}$), then delegation is always preferred. Thus, an informational advantage held by the agent increases the likelihood of delegation. However, note that if the relative quality of information is held constant, when the amount of volatility faced by the principal changes, then it is still the case that an increase in volatility will decrease the likelihood of delegation. This is because an increase in σ_P^2 still increases the relative importance of tracking θ_P closely, and if $x_{\eta p} < x_{\varepsilon p}$, the principal is still in a better position to do so. As a result, if the informational environment is constant between delegation and employment, even if an informational asymmetry increases the likelihood of delegation, the informational asymmetry itself needs to increase if *increasing* uncertainty faced by the principal is to lead to delegation. This, however, is a natural conclusion if the value of speedy response and/or the accuracy of information transmission are affected by increased volatility.

3.6.2 Information acquisition

While some information can become readily available to the parties, it often also needs to be actively acquired. While full analysis of the information acquisition problem is beyond the scope of this paper, the basic logic is relatively straightforward. If the agent is in a better position to acquire information, then delegation can be a superior means to induce such information acquisition. We will illustrate this result with a simple example. We will assume that decision-contingent transfers are not available, $\rho = 0$, $\mu_A = \mu_P = 0$ and that information about s_A and θ_A is readily available. However, effort needs to be exerted to learn s_P and/or θ_P. We will further assume that the joint cost function is such that given any incentives, the agent will acquire information only about s_P and the principal will acquire information only about θ_P. In particular, we will assume that the agent learns s_P with probability p_A (and knows whether the signal received is accurate or not) after investing

$$C_A(p_A) = -F(\sigma_P^2)\,\beta_A\,(p_A + \ln(1 - p_A)),$$

where $F'(\sigma_P^2) > 0$ to capture the idea that becoming informed gets harder as the uncertainty increases. Similarly, the principal learns θ_P with probability p_P after investing

$$C_P(p_P) = -F(\sigma_P^2)\,\beta_P\,(p_P + \ln(1 - p_P)).$$

Finally, we assume that if information acquisition by either party is successful, it is automatically transmitted to the party holding the decision right, implying that evidence can neither be falsified nor hidden. We will analyze the relative performance of two types of contracts. Under delegation, the agent's incentives are provided only through X_P. Under employment, the decision-making of the principal is moderated through X_A but no incentives are provided to the agent through X_P. While this distinction appears arbitrary, there is an inherent asymmetry in the problem that supports such a solution. We will discuss the reasons for this simplification below when discussing each of the contracts.

Delegation

Under delegation, the loss to the principal in the decision-making stage is given by

$$L_P = E\left[\left(\theta_P - d^A\right)^2 - \alpha_P\left(s_P - d^A\right)^2 | p_A, p_P\right] + C_P(p_P),$$

while the loss to the agent is given by

$$L_P = E\left[\left(\theta_A - d^A\right)^2 + \alpha_P\left(s_P - d^A\right)^2 | p_A, p_P\right] + C_A(p_A).$$

In any eventuality, the decision of the agent is given by $d^A = \frac{\alpha_P E(s_P|\omega) + \theta_A}{1+\alpha_P}$. Thus, if the agent learns s_P, then he will ignore information about θ_P. However, if he fails while the principal succeeds in information acquisition, then $E(s_P|\omega) = \theta_P$. Finally, if both parties fail, $E(s_P|\omega) = 0$. With a little rearranging, we get the first-order conditions for the two parties, which are given by

$$\text{agent:} \qquad \frac{\alpha_P^2}{(\alpha_P+1)}\left[\left(\sigma_P^2 + \sigma_{\varepsilon P}^2\right) - p_P\sigma_P^2\right] = \frac{F(\sigma_P^2)\beta_A p_A}{1-p_A},$$

$$\text{principal:} \qquad (1 - p_A)\,\frac{(1-\alpha_P)(\alpha_P^2+2\alpha_P)}{(\alpha_P+1)^2}\sigma_P^2 = \frac{F(\sigma_P^2)\beta_P p_P}{1-p_P}.$$

Examining first the agent's first-order condition, we see that the incentives to acquire information are crucially tied to the strength of incentives. After all, the agent doesn't care about the payoff to the principal unless the performance measure is used. If the agent is successful, the reduction in variance is proportional to $\left(\sigma_P^2 + \sigma_\varepsilon^2\right)$. If the agent fails but the principal succeeds, the agent is still able to utilize θ_P. Thus, any information acquisition by the principal weakens the agent's incentives to acquire information: efforts are substitutes.

In a similar fashion, the information of the principal will be used only if the agent fails, captured by $(1 - p_A)$. Further, the principal's incentives to acquire information are non-monotone in α_P. First, as α_P becomes positive, information becomes valuable as the agent will respond to it. However, as α_P grows, the level of payoffs to the principal that is dependent on information goes down. In consequence, incentives to acquire information will eventually start decreasing.[19] However, for all interior α_P the principal has positive incentives to acquire information because his direct utility depends on the decision responding to θ_P.

To summarize, α_P plays a triple role: motivate information acquisition by both the agent and the principal and control the decision-making by the agent. Solving for the total expected payoff gives then

$$
\begin{aligned}
E\left(L_A + L_P\right) = {} & \tfrac{2\left(\sigma_P^2\left(1-p_A^*\right)\left(1-p_P^*\right)\alpha_P + p_A^*\alpha_P^2\sigma_\varepsilon^2\right)}{\left(1+\alpha_P\right)^2} + \tfrac{\left(1+\alpha_P^2\right)}{\left(1+\alpha_P\right)^2}\left(\sigma_A^2 + \sigma_P^2\right) \\
& - F\left(\sigma_P^2\right)\beta_A\left(p_A^* + \ln\left(1 - p_A^*\right)\right) - F\left(\sigma_P^2\right)\beta_P\left(p_P^* + \ln\left(1 - p_P^*\right)\right),
\end{aligned}
$$

where (p_A^*, p_P^*) solve the first-order conditions above. We can see that the first-best solution (gross of information cost) is not achieved for two reasons. First, with probability $(1 - p_A^*)(1 - p_P^*)$ both parties fail in their information acquisition and the decision made is uninformed. Second, with probability p_A^* the agent becomes informed and thus responds to s_P, not θ_P, which introduces the misalignment problem discussed in the previous sections.

Use of X_A : Theoretically, $\alpha_A X_A$ could potentially be used to improve the delegation outcome by managing the relative incentives of the principal and the agent to acquire information. This, however, appears at most of limited importance. The reason for this is that if payments based on X_A are used, then the agent will have incentives to use his decision right in a suboptimal fashion to limit such transfers. In consequence, $|\alpha_A|$ can never be large, and the value of any use is uncertain.

Employment

Under employment, $\alpha_P = 0$ and so the agent has no incentives to acquire information. In consequence, the problem collapses into a single-agent problem where α_A is simply used to control the incentives and decisions of the principal. In this case, the principal's first order condition is

[19] This result follows because the payoff is $L_P - \alpha_P X_P$.

$$p_P^* = \frac{\sigma_P^2}{\left((1+\alpha_A)F\left(\sigma_P^2\right)\beta_P+\sigma_P^2\right)},$$

and the expected total loss is given by

$$\frac{2\left(\left(1-p_P^*\right)\sigma_P^2\alpha_A+\alpha_A^2\sigma_{\varepsilon A}^2\right)}{(1+\alpha_A)^2} + \frac{(1+\alpha_A^2)}{(1+\alpha_A)^2}\left(\sigma_A^2+\sigma_P^2\right) - F\left(\sigma_P^2\right)\beta_P\left[p_P^* + \ln\left(1-p_P^*\right)\right].$$

Thus, the loss is bounded away from the minimal (gross) loss for two reasons. First, sometimes the principal fails to acquire information, which makes decisions uninformed. Second, the noisy performance measure s_A is generating constantly biased decisions. Also note that the incentives to acquire information are decreasing in α_A since increased weight placed on the performance measure tracking the agent's preferences decreases the responsiveness of the principal to information about his own needs.

Use of X_P : While our assumption that X_A is not used under delegation appears relatively innocuous, our assumption that X_P is not used under employment appears contrary to the immediate logic. After all, it is through X_P that the agent can be motivated to acquire information. However, the reason for this assumption parallels that of not using X_A under delegation. First, setting $\alpha_P > 0$ to incentivize the agent to acquire information will cause gaming by the principal. If the agent is provided with positive incentives to acquire information, then the corresponding decision by the principal is given by

$$d^P = \frac{E(\theta_P|\omega)-\alpha_P E(s_P|\omega)+\alpha_A s_A}{1-\alpha_P+\alpha_A}.$$

In consequence, $\alpha_P > 0$ will lead to increased suboptimality of decisions. In addition to this effect, there are three further reasons why the use of X_P is of limited value. First, if the principal is often informed (p_A is large), then learning s_P by the agent will only *damage* the pay-for-performance by the agent, since the decision by the principal in this case is negatively correlated with s_P.[20] Second, even if the principal is uninformed, he will still discount s_P and the net response is given by $(\beta - \alpha_P)\, s_p$, where β is the signal-to-noise ratio $\sigma_P^2/\left(\sigma_P^2+\sigma_{\varepsilon P}^2\right)$. Third, even if the principal is rarely informed and $\beta > \alpha_P$, so that the decision is positively correlated with the signal, the agent needs to be provided with *strictly positive* incentives to acquire information.

To see this final result, note that if the agent is compensated through X_P, then his payoff is

$$\alpha_P X_P + L_A - \alpha_A X_A.$$

Now, if the agent succeeds in information acquisition, the loss due to X_P is reduced but the loss due to $L_A - \alpha_A X_A$ is *increased* because of the additional adjustment. Thus, unless α_A is very large, so that most of the adjustment cost is passed to the principal, α_P needs to be

[20] Indeed, if it is likely that the principal is going to succeed in his information acquisition, then the agent would prefer to acquire information about θ_P to limit the gaming caused by principal's knowledge of s_P. Further, if p_A is large, then the value of that information is going to be low and unlikely to be worth inducing in the first place.

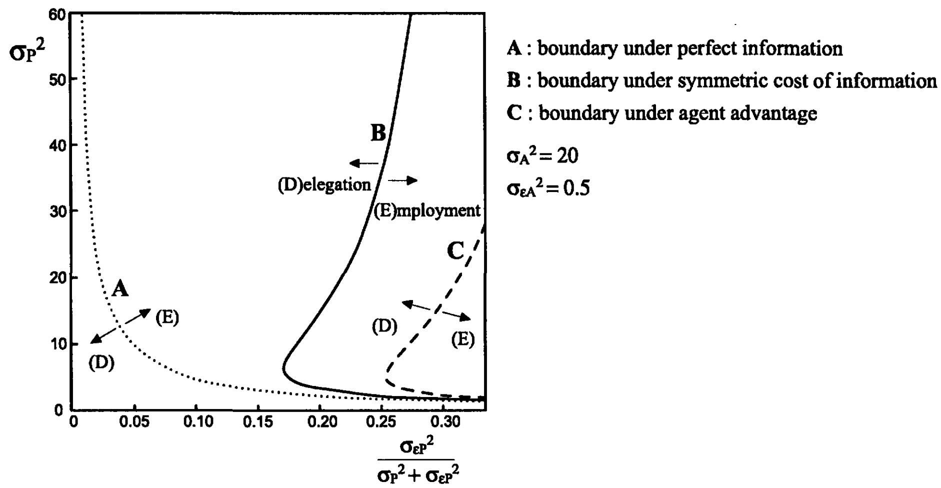

Figure 3-2: Active information acquisition and the boundary between delegation and employment

large to overcome this. And large α_P in turn will lead to very bad decisions. This discussion highlights the big difference in motives to learn information about (s_P, θ_P) by the agent and the principal. The principal is directly motivated to acquire information because his payoff is positively correlated with that information. Thus, he has positive incentives to acquire information under delegation for all interior α_P. The agent, on the other hand, strictly prefers no information under the employment contract, and any information acquisition by him needs to be motivated by compensation that is strictly able to overcome this negative incentive. And providing such incentives can be impossible (e.g. if $\beta < \alpha_P$, in which case no incentives can be provided) or too costly.[21]

Choice of contract

The specific results clearly depend on the exact shape of $F\left(\sigma_P^2\right)$. To illustrate some of the results, we will assume that $F\left(\sigma_P^2\right) = \left(\sigma_P^2\right)^2$. That is, the cost of information is increasing in the volatility of the environment. An example of the boundary choice is given in figure 3-2.

In generating the results, we assume that $\sigma_A^2 = 20$ while $\sigma_{\varepsilon A}^2 = 0.5$, implying that the preferences of the agent are almost perfectly contractible. This aspect is reflected by the location of the boundary line under perfect information (given by A), showing that under perfect information employment covers much of the analyzed parameter space. When information becomes costly, the superior information collection properties of delegation shift the boundary left (given by B). Of more interest is the observation that now the likelihood of delegation

[21] If the agent were able to hide information, then the incentives of the agent could potentially be improved by altering the perceived value of information.

can be *increasing* in σ_P^2, even holding the noise-to-volatility ratio $\sigma_{\varepsilon P}^2/\left(\sigma_P^2+\sigma_{\varepsilon P}^2\right)$ constant. The intuition for this result is that as σ_P^2 grows, information becomes more valuable and thus the superior information collection ability of delegation becomes more valuable. As the agent becomes more able to collect information, this advantage is further amplified, as reflected by boundary C.

Contracting with third parties The fact that the parties need to contract with each other limits the use of X_A in the case of delegation and X_P in the case of employment. If the contracts were with respect to a third party, then the decisional disadvantage would be absent. Further, the use of X_P in the case of delegation would no longer weaken the incentives of the principal. However, in the case of employment, α_P still needs to be large to induce information acquisition by the agent. Indeed, to induce information acquisition by the agent, the agent should bear the compensation based on X_A, as this limits the cost of information, while the principal should not bear the cost of X_P to avoid the decisional complications.

3.6.3 Risk-aversion

Assume now that the agent has mean-variance preferences with risk-aversion coefficient r. Further, assume that the decision has to be taken by the agent (as an effort choice), no decision-contingent transfers are available and that $\gamma=1$. Further, assume that the performance measure is perfect up to an additive error term:

$$X_P=-\left(\theta_P-d^A\right)^2+\varepsilon_{X_P}.$$

The agent is then offered a contract

$$T(.)=B-\alpha_P\left(\left(\theta_P-d^A\right)^2+\varepsilon_{X_P}\right),$$

where the terms of the contract are chosen by the principal to

$$\begin{aligned}
&\max_{B,\alpha_P} E\left(K_P-\left(\theta_P-d^A\right)^2-T(.)\right)\\
\text{s.t.}\quad & E\left(K_A-\left(\theta_A-d^A\right)^2+T(.)\right)-rVar\left(K_A-\left(\theta_A-d^A\right)^2+T(.)\right)\geq 0\\
& d^A\in\arg\max_d K_A-\left(\theta_A-d^A\right)^2+T(.),
\end{aligned}$$

which, after substituting out B, is equivalent to

$$\begin{aligned}
&\min_\alpha E\left[\left(\theta_P-d^A\right)^2+\left(\theta_A-d^A\right)^2\right]+rVar\left[\alpha_P\left(\theta_P-d^A\right)^2+\alpha_P\varepsilon_{X_P}+\left(\theta_A-d^A\right)^2\right]\\
s.t.\quad & d^A=\tfrac{\alpha_P\theta_P+\theta_A}{\alpha_P+1}.
\end{aligned}$$

Taking the first-order condition and rearranging gives

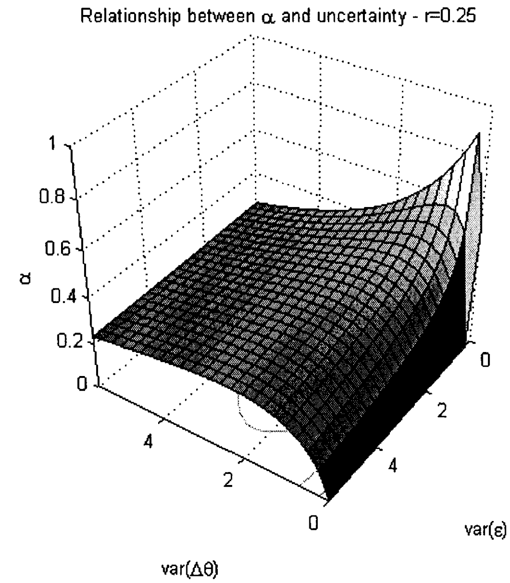

Figure 3-3: Relationship between optimal incentives and uncertainty under risk-aversion

Proposition 29 *The optimal incentive strength is implicitly defined by:*

$$\frac{1}{(\alpha_P+1)^3}\left[(\alpha_P-1)\left(\Delta\mu^2+\sigma^2_{\Delta\theta}\right)+r\alpha_P\left(2\sigma^2_{\Delta\theta}\left(\sigma^2_{\Delta\theta}+2\Delta\mu^2\right)\right)\right]+r\alpha_P\sigma^2_{\varepsilon_{X_P}}=0,$$

where $\Delta\mu^2=(\mu_A-\mu_P)^2$ *and* $\sigma^2_{\Delta\theta}=Var(\theta_A-\theta_P)$.

Thus,

$$\frac{\partial\alpha_P}{\partial\sigma^2_{\varepsilon_{X_P}}}<0 \qquad \text{and} \qquad sign\left(\frac{\partial\alpha_P}{\partial\sigma^2_{\Delta\theta}}\right)=sign\left(1-\alpha_P\left(1+4r\left(\Delta\mu^2+\sigma^2_{\Delta\theta}\right)\right)\right).$$

Proof. See Appendix B ■

Thus, as in all models hidden action with risk-aversion, the strength of incentives is decreasing in the noisiness of the performance measure, $\sigma^2_{\varepsilon_{X_P}}$. This aspect is thus unchanged, simply shifting the source of agency problem from misalignment to risk-aversion.

What risk-aversion does change is the monotonicity result regarding the relationship between the volatility of the environment and incentives provided. The intuition for this result is clear. As $\sigma^2_{\Delta\theta}$ increases, the 'productive' value of incentives goes up as in the case of a risk-neutral agent. However, at the same time, as long as $\alpha_P>0$, this also translates to a larger risk-cost of incentives. Which effect dominates depends on the equilibrium α_P. In particular, if α_P is small, then the increase in the value of incentives is likely to dominate, because low α_P implies low initial pass-through of volatility of the environment to volatility of pay (since the pass-through is proportional to α_P^2).

The observation that the sign of $\partial\alpha_P/\partial\sigma^2_{\Delta\theta}$ depends on α_P implies in turn that $\partial\alpha_P/\partial\sigma^2_{\Delta\theta}$ will depend on $\sigma^2_{\varepsilon X_P}$. Note that in essence the equilibrium strength of incentives balances the productive value of incentives, determined by the value of inducing the agent to respond to the realized $(\theta_A - \theta_P)$, which in turn is related to $\sigma^2_{\Delta\theta}$, and the cost of providing those incentives, determined by the overall uncertainty $\left(\sigma^2_{\varepsilon X_P}, \sigma^2_{\Delta\theta}\right)$. When $\sigma^2_{\varepsilon X_P} >> \sigma^2_{\Delta\theta}$, then the risk-compensation component is dominated by $\sigma^2_{\varepsilon X_P}$. In consequence, $\partial\alpha_P/\partial\sigma^2_{\Delta\theta} > 0$ because the productive value will dominate the marginal change. The converse happens when $\sigma^2_{\varepsilon X_P} << \sigma^2_{\Delta\theta}$ and then $\partial\alpha_P/\partial\sigma^2_{\Delta\theta} < 0$. An example of this interaction between $\sigma^2_{\varepsilon X_P}$ and $\sigma^2_{\Delta\theta}$ in determining the optimal linear α_P is given in figure 3-3.

The comparative statics of $\partial\alpha_P/\partial\sigma^2_{\Delta\theta} \gtreqless 0$ and $\partial\alpha_P/\partial\sigma^2_{\varepsilon X_P} < 0$ are qualitatively equal to those presented in Baker and Jorgensen (2003). This result should be no surprise since, while the structure of the models differs slightly, the structure of uncertainty is the same in both settings: $\sigma^2_{\Delta\theta} > 0$, $\sigma^2_{\varepsilon X_P} > 0$ and $\sigma^2_{\varepsilon_P} = 0$.[22]

3.6.4 Insufficient controls, job-design and second-best

The key behind the simplicity of our solution was the use of $\alpha_D\left(\bar{d} - d\right)^2$ to manage the responsiveness of the agent, which allowed us to derive a simple optimal linear contract and we did not need to consider whether (s_A, s_P) are directly verifiable or whether only (X_A, X_P) are verifiable. Let us first consider a more general setting to illustrate more the role of decision-contingent transfers. The ability to achieve the constrained optimum comes down to the ability to devise a compensation policy, subject to the decision-maker's IC constraint, that induces d_i such that (assuming a unique solution)

$$E\left(U_P'\left(\theta_P, d_i\right) + U_A'(\theta_A, d_i)|s_j, \theta_i\right) = 0 \qquad \forall s_j, \theta_i.$$

Given the appropriate monotonicity conditions and a sufficient degree of contractibility, we can find functions satisfying this condition, while the linearity of such a solution hinges on the linearity between changes in the margins. With access to performance measures X_P and X_d, we can rewrite this in the case of delegation as:

$$E\left(U_P'\left(\theta_P, d_A\right)|s_P, \theta_A\right) = \alpha_P X_P'(s_P, d_A) + \alpha_d X_d'\left(\bar{d}, d_A\right) \qquad \forall s_j, \theta_i.$$

Thus, a linear solution exists if there is a linear relationship between the change in the expectation of marginal utility of the principal with respect to s_P and θ_A and the change in the marginal return to the agent given the contract offered. We can see that $\bar{d}$ buys us an additional

[22] Risk-aversion might lead to either less or more delegation. On the one hand, the risk-aversion by the agent limits the degree of incentive alignment. On the other hand, giving control of the decision to the agent limits the risk-compensation required. We have not examined if either effect dominates always or under what conditions one effect dominates the other.

degree of freedom that allows us to manage both the relative and absolute responsiveness of the agent. If we are not able to contract on decisions directly, both linearity and the constrained optimality of the solution is usually lost.

The more flexible interpretation of $\alpha_D\left(\overline{d}-d\right)^2$ is the job flexibility granted to the agent. The basic idea is that even if decisions are non-verifiable, job design can be used to guide the behavior of the agent by making certain actions easier to take than others. In essence, $\alpha_D\left(\overline{d}-d\right)^2$ itself can be a non-verifiable component that is embedded in the working environment of the agent. This interpretation is clearly limited by our assumption of no waste. However, it is often possible to cause *destruction* of utility, with the introduction of bureaucratic complexity that the agent holding the decision right needs to overcome to implement certain decisions. While the solution will no longer be linear due to typical screening arguments (at intermediate values of θ_A, when choosing the decision we need to acknowledge the fact that the marginal waste caused by that decision also has to be paid on all more extreme decisions, leading to convexity), it can still be used to provide some control of the decision-maker. Further, note that the *value* aspect of direct controls is unaffected whether their use is costly or not. Thus, while the shape of the optimal contract is affected, as long as the cost is independent of the underlying uncertainty, the basic comparative statics hold. Also, note that such destruction of utility can be used to smooth the optimal delegation sets discussed in e.g. Holmström (1984) and Alonso and Matouschek (2006), which are in essence examples of a transfer function where $\alpha_D = 0$ for decisions inside the allowed set and $\alpha_D \to \infty$ for decisions outside the allowed set.

To understand the solution in absence of any decision-contingent transfers, let us return now back to our quadratic framework. Let ω denote the contractible information and let the contract be given by

$$T\left(.\right) = B + \alpha_P\left(\omega\right)X_P\left(.\right) + \alpha_A\left(\omega\right)X_A\left(.\right).$$

Now, consider the case of delegation. Then, the optimal weight on the performance measures is given by

$$\alpha_P\left(\omega\right) = \frac{\gamma E\left[\left(\theta_P-\theta_A\right)^2|\omega\right]}{E\left[\left(\theta_P-\theta_A\right)^2|\omega\right]+(1+\gamma)\sigma^2_{\varepsilon_P}} \qquad \textit{and} \qquad \alpha_A\left(\omega\right) = 0.$$

To understand this result, recall that there are two sources of losses that the incentive contract needs to mange: the GWYPF problem caused by $\sigma^2_{\varepsilon_i} > 0$ and biased decisions caused by $\alpha_P < 1$. When decisions could be contracted on directly, second-best decisions could be induced since the expected bias in the decisions caused by $\alpha_P < 1$ could be managed through α_d and $\overline{d}$. Now, the size of the GWYPF problem is independent of the realized states while the expected value of incentive alignment is increasing in $\left(\theta_A-\theta_P\right)^2$. The optimal incentive strength then equates these two in the margin. For example, consider the case where (s_A, s_P) are verifiable. The solution yields simply

$$\alpha_P(s_A,s_P) = \frac{E\left[\left(\theta_P-\theta_A\right)^2|s_A,s_P\right]}{E\left[\left(\theta_P-\theta_A\right)^2|s_A,s_P\right]+(1+\gamma)\sigma^2_{\varepsilon_P}} = \frac{\left(\Delta\mu_{|s_A,s_P}\right)^2+\sigma^2_{\Delta\theta|s_A,s_P}}{\left(\Delta\mu_{|s_A,s_P}\right)^2+\sigma^2_{\Delta\theta|s_A,s_P}+(1+\gamma)\sigma^2_{\varepsilon_P}}.$$

The incentive strength is thus simply conditioned on the incoming information to reflect the expected size of the incentive conflict. Note also that we still don't want to condition the compensation directly on s_A to avoid introducing $\sigma^2_{\varepsilon_A}$, but that doesn't prevent us from using its realization to condition α_P.

Similar conditioning could be used also in the case where neither s_k can be contracted on, as X_k still contain information about the size of the incentive conflict. However, using X_k to condition the incentive strength has two additional complications. First, as the actual realizations of X_k are influenced by the agent, one needs consider the incentive compatibility of the slope structure intended. Thus, while the logic above holds, the actual level of incentives has to back out the manipulation by the agent. Second, this manipulation will lead to additional GWYPF problems, much in the same way that the error in s_i keeps the optimal slope away from one. Indeed, if only X_k are verifiable and $\sigma^2_{\varepsilon X_k} \to \infty$, the contract becomes linear again since X_k become fully uninformative about the underlying size of the incentive conflict. In particular, it becomes a simple measure of the ex ante expected incentive conflict, given by

$$\alpha_P = \frac{E(\theta_P-\theta_A)^2}{E(\theta_P-\theta_A)^2+(1+\gamma)\sigma^2_{\varepsilon_P}}.$$

Thus, the comparative statics on the strength of incentives remain the same as in the analysis of section 3, with the exception that the incentive strength is now increasing in the volatility of the preferences of both parties (since this increases the expected size of the incentive conflict) and decreasing in the correlation between preferences (since this decreases the expected size of the incentive conflict) because direct controls can no longer be used to induce the agent to use information about θ_A in responding to θ_P.

3.6.5 Models of hidden action

As mentioned in the introduction, conditional on the agent holding the decision right, our model is directly analogous to a model of hidden action. This similarity results from the observation that after the states of the world have been realized, we have a globally concave problem, where the decision that is individually optimal to the decision-maker is traded via the incentive contract for a more favorable decision to the other agent, a situation which is identical to the principal 'purchasing' literal effort from the agent, where the agent's default point is zero effort. The only difference to the basic linear-quadratic formulation of the moral hazard problem is that now the production function is quadratic, not linear, and the marginal value of effort, measured by the distance between θ_A and θ_P, is random.

This construction is illustrated in figure 3-4. The realization of θ_A determines the location of the agent's zero-cost effort level, while θ_P determines the level of effort at which all benefits of effort are exhausted. The optimal effort choice would then satisfy d^{FB}, where the marginal cost of effort matches the marginal productivity of effort. However, the realization of s_p will alter the value of effort as perceived by the agent, leading to the GWYPF problem. Given an incentive strength of α, the agent then chooses an effort level $d^A \neq d^{FB}$.

Letting $\sigma^2_P > 0$ but $\sigma^2_A = 0$, so that the marginal cost of effort exhibits no randomness, we get the setting of a basic random productivity model. With $Var(\varepsilon_p) > 0$,$\sigma^2_P = 0$ and risk-neutrality, the model becomes analogous to Baker (1992). Introducing risk-aversion and letting $Var(\varepsilon_p) = 0$ but $Var(\varepsilon_{X_P}) > 0$, the model becomes analogous to Zabojnik (1996) and Baker and Jorgensen (2003). Finally, letting $\sigma^2_P \to 0$ while maintaining risk-aversion and

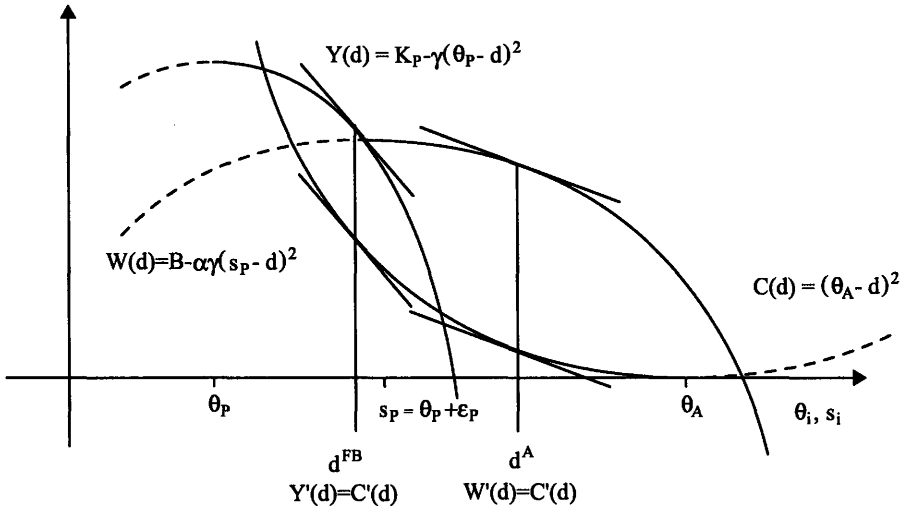

Figure 3-4: The interim problem and hidden action interpretation

$Var\left(\varepsilon_{X_P}\right) > 0$, we are back to the single-action moral hazard problem with an additive error term (e.g. Holmström (1979)).

The point of departure in our model is that the action need not be hidden. Indeed, taking the literal interpretation of the component $\alpha_D\left(\overline{d}-d\right)^2$ implies that the decision cannot be hidden. However, the basic agency problem remains when three conditions are met. First, there is uncertainty over the optimal course of action at the time of contracting. If this were not the case, the parties could write a contract directly on the optimal decision (or use a forcing contract to induce appropriate behavior, which is equivalent). Second, the preferences are not perfectly contractible. Third, opportunities for renegotiation (between the time that additional information is revealed and the decision needs to be made) are limited.

3.7 Appendix B: Proofs and derivations

Proposition 27: Optimal Contract

We derive the solution in the case of delegation, the solution in the case of employment is symmetric. The second-best decision is given by

$d_A^{FB} = \frac{\gamma E(\theta_P|s_P,\theta_A)+\theta_A}{1+\gamma}$.

Given normality of the random variables, their joint distribution is given by

$$\begin{pmatrix} \theta_P \\ s_P \\ \theta_A \end{pmatrix} \sim N\begin{pmatrix} \mu_P & \sigma_P^2 & \sigma_P^2 & \sigma_{AP} \\ \mu_P \;, & \sigma_P^2 & \sigma_P^2+\sigma_{\varepsilon_P}^2 & \sigma_{AP} \\ \mu_A & \sigma_{AP} & \sigma_{AP} & \sigma_A^2 \end{pmatrix}.$$

Therefore, we can write

$$E(\theta_P|s_P,\theta_A) = \mu_P + \left(\begin{array}{cc} \sigma_P^2 & \sigma_{AP} \end{array} \right) \left(\begin{array}{cc} \sigma_P^2 + \sigma_{\varepsilon_P}^2 & \sigma_{AP} \\ \sigma_{AP} & \sigma_A^2 \end{array} \right)^{-1} \left(\begin{array}{c} s_P - \mu_P \\ \theta_A - \mu_A \end{array} \right),$$

which after a little algebra simplifies to:

$$\mu_P + \frac{\sigma_P^2\sigma_A^2(1-\rho^2)(s_P-\mu_P)+\sigma_{AP}\sigma_{\varepsilon_P}^2(\theta_A-\mu_A)}{\sigma_{\varepsilon_P}^2\sigma_A^2+(1-\rho^2)\sigma_P^2\sigma_A^2} = \frac{\mu_P(\sigma_{\varepsilon_P}^2\sigma_A^2)-\sigma_{AP}\sigma_{\varepsilon_P}^2\mu_A+\sigma_P^2\sigma_A^2(1-\rho^2)s_P+\sigma_{AP}\sigma_{\varepsilon_P}^2(\theta_A)}{\sigma_{\varepsilon_P}^2\sigma_A^2+(1-\rho^2)\sigma_P^2\sigma_A^2}.$$

Thus, the optimal decision can be written as:

$$d_A^{FB} = \frac{\gamma E(\theta_P|s_P,\theta_A)+\theta_A}{1+\gamma} = \frac{\gamma\left(\frac{\mu_P(\sigma_{\varepsilon_P}^2\sigma_A^2)-\sigma_{AP}\sigma_{\varepsilon_P}^2\mu_A+\sigma_P^2\sigma_A^2(1-\rho^2)s_P+\sigma_{AP}\sigma_{\varepsilon_P}^2\theta_A}{\sigma_{\varepsilon_P}^2\sigma_A^2+(1-\rho^2)\sigma_P^2\sigma_A^2}\right)+\theta_A}{1+\gamma}$$

$$= \frac{\gamma\mu_P\sigma_{\varepsilon_P}^2\sigma_A^2-\gamma\sigma_{AP}\sigma_{\varepsilon_P}^2\mu_A+\gamma\sigma_P^2\sigma_A^2(1-\rho^2)s_P+\theta_A\left(\sigma_{\varepsilon_P}^2\sigma_A^2+(1-\rho^2)\sigma_P^2\sigma_A^2+\gamma\sigma_{AP}\sigma_{\varepsilon_P}^2\right)}{(1+\gamma)\left(\sigma_{\varepsilon_P}^2\sigma_A^2+(1-\rho^2)\sigma_P^2\sigma_A^2\right)}.$$

Given a contract $\alpha_P X_P + \alpha_D X_D + B$, the agent chooses a decision satisfying

$$d^A = \frac{\alpha_P s_P+\alpha_D\bar{d}+\theta_A}{\alpha_P+\alpha_D+1}.$$

The rest is simply about matching coefficients so that

$$\frac{\alpha_P s_P+\alpha_D\bar{d}+\theta_A}{\alpha_P+\alpha_D+1} = \frac{\gamma\mu_P\sigma_{\varepsilon_P}^2\sigma_A^2-\gamma\sigma_{AP}\sigma_{\varepsilon_P}^2\mu_A+\gamma\sigma_P^2\sigma_A^2(1-\rho^2)s_P+\theta_A\left(\sigma_{\varepsilon_P}^2\sigma_A^2+(1-\rho^2)\sigma_P^2\sigma_A^2+\gamma\sigma_{AP}\sigma_{\varepsilon_P}^2\right)}{(1+\gamma)\left(\sigma_{\varepsilon_P}^2\sigma_A^2+(1-\rho^2)\sigma_P^2\sigma_A^2\right)}.$$

To simplify, let $\alpha = \frac{\alpha_P}{\alpha_P+\alpha_D+1}, \beta = \frac{\alpha_D}{\alpha_P+\alpha_D+1}, \delta = \frac{1}{\alpha_P+\alpha_D+1} = 1-\alpha-\beta$, then

$$\alpha s_P + \beta\bar{d} + \delta\theta_A = \frac{\left(\gamma\mu_P\sigma_{\varepsilon_P}^2\sigma_A^2-\gamma\sigma_{AP}\sigma_{\varepsilon_P}^2\mu_A\right)+\gamma\sigma_P^2\sigma_A^2(1-\rho^2)s_P+\theta_A\left(\sigma_{\varepsilon_P}^2\sigma_A^2+(1-\rho^2)\sigma_P^2\sigma_A^2+\gamma\sigma_{AP}\sigma_{\varepsilon_P}^2\right)}{(1+\gamma)\left(\sigma_{\varepsilon_P}^2\sigma_A^2+(1-\rho^2)\sigma_P^2\sigma_A^2\right)}.$$

Matching coefficients gives

$$\alpha = \frac{\gamma\sigma_P^2\sigma_A^2(1-\rho^2)}{(1+\gamma)\left(\sigma_{\varepsilon_P}^2\sigma_A^2+(1-\rho^2)\sigma_P^2\sigma_A^2\right)}$$
$$\beta\bar{d} = \frac{\left(\gamma\mu_P\sigma_{\varepsilon_P}^2\sigma_A^2-\gamma\sigma_{AP}\sigma_{\varepsilon_P}^2\mu_A\right)}{(1+\gamma)\left(\sigma_{\varepsilon_P}^2\sigma_A^2+(1-\rho^2)\sigma_P^2\sigma_A^2\right)}$$
$$\delta = \frac{\left(\sigma_{\varepsilon_P}^2\sigma_A^2+(1-\rho^2)\sigma_P^2\sigma_A^2+\gamma\sigma_{AP}\sigma_{\varepsilon_P}^2\right)}{(1+\gamma)\left(\sigma_{\varepsilon_P}^2\sigma_A^2+(1-\rho^2)\sigma_P^2\sigma_A^2\right)}.$$

Now,

$$\frac{\alpha}{\delta} = \frac{\frac{\alpha_P}{\alpha_P+\alpha_D+1}}{\frac{1}{\alpha_P+\alpha_D+1}} = \alpha_P = \frac{\gamma\sigma_P^2\sigma_A^2(1-\rho^2)}{(1-\rho^2)\sigma_P^2\sigma_A^2+\sigma_{\varepsilon_P}^2\left(\sigma_A^2+\gamma\rho\sigma_A\sigma_P\right)}.$$

Similarly,

$$\delta = \frac{1}{\alpha_P+\alpha_D+1} \to \delta\alpha_D = (1-\delta) - \delta\alpha_P,$$

so that

$$
\begin{aligned}
&\frac{\left(\sigma_{\varepsilon_P}^2\sigma_A^2+\left(1-\rho^2\right)\sigma_P^2\sigma_A^2+\gamma\sigma_{AP}\sigma_{\varepsilon_P}^2\right)}{(1+\gamma)\left(\sigma_{\varepsilon_P}^2\sigma_A^2+(1-\rho^2)\sigma_P^2\sigma_A^2\right)}\alpha_D \\
&= \left(1-\frac{\left(\sigma_{\varepsilon_P}^2\sigma_A^2+\left(1-\rho^2\right)\sigma_P^2\sigma_A^2+\gamma\sigma_{AP}\sigma_{\varepsilon_P}^2\right)}{(1+\gamma)\left(\sigma_{\varepsilon_P}^2\sigma_A^2+(1-\rho^2)\sigma_P^2\sigma_A^2\right)}\right) \\
&\quad -\frac{\left(\sigma_{\varepsilon_P}^2\sigma_A^2+\left(1-\rho^2\right)\sigma_P^2\sigma_A^2+\gamma\sigma_{AP}\sigma_{\varepsilon_P}^2\right)}{(1+\gamma)\left(\sigma_{\varepsilon_P}^2\sigma_A^2+(1-\rho^2)\sigma_P^2\sigma_A^2\right)}\frac{\gamma\sigma_P^2\sigma_A^2\left(1-\rho^2\right)}{(1-\rho^2)\sigma_P^2\sigma_A^2+\sigma_{\varepsilon_P}^2\left(\sigma_A^2+\gamma\rho\sigma_A\sigma_P\right)},
\end{aligned}
$$

giving $\alpha_D = \frac{\gamma\sigma_{\varepsilon_P}^2\left(\sigma_A^2-\rho\sigma_A\sigma_P\right)}{(1-\rho^2)\sigma_P^2\sigma_A^2+\sigma_{\varepsilon_P}^2\left(\sigma_A^2+\gamma\rho\sigma_A\sigma_P\right)}$.

Finally, we have that

$$\frac{\beta\overline{d}}{\delta} = \alpha_D\overline{d} = \frac{\gamma\sigma_{\varepsilon_P}^2\left(\sigma_A^2-\rho\sigma_A\sigma_P\right)}{(1-\rho^2)\sigma_P^2\sigma_A^2+\sigma_{\varepsilon_P}^2\left(\sigma_A^2+\gamma\rho\sigma_A\sigma_P\right)}\overline{d} = \frac{\left(\gamma_P\sigma_{\varepsilon_P}^2\mu\sigma_A^2-\gamma_P\sigma_{\varepsilon_P}^2\sigma_{AP}\mu_A\right)}{(1-\rho^2)\sigma_P^2\sigma_A^2+\sigma_{\varepsilon_P}^2\left(\sigma_A^2+\gamma\rho\sigma_A\sigma_P\right)}$$

$$\rightarrow \overline{d} = \frac{\mu_P\sigma_A^2-\rho\sigma_A\sigma_P\mu_A}{\sigma_A^2-\gamma\rho\sigma_A\sigma_P} = \frac{\mu_P\sigma_A-\rho\sigma_P\mu_A}{\sigma_A-\gamma\rho\sigma_P}.$$

Thus, the optimal contract is given by:

$\alpha_P X_P + \alpha_D X_D + B$, where

$$\alpha_P = \frac{\gamma\sigma_P^2\sigma_A^2\left(1-\rho^2\right)}{(1-\rho^2)\sigma_P^2\sigma_A^2+\sigma_{\varepsilon_P}^2\left(\sigma_A^2+\gamma\rho\sigma_A\sigma_P\right)},\quad \alpha_D = \frac{\gamma\sigma_{\varepsilon_P}^2\left(\sigma_A^2-\rho\sigma_A\sigma_P\right)}{(1-\rho^2)\sigma_P^2\sigma_A^2+\sigma_{\varepsilon_P}^2\left(\sigma_A^2+\gamma\rho\sigma_A\sigma_P\right)},\quad \overline{d} = \frac{\mu_P\sigma_A-\rho\sigma_P\mu_A}{\sigma_A-\gamma\rho\sigma_P}$$

The case of employment is symmetric, with an adjustment for γ. The expected loss follows by noting that we can write

$$E\left(\gamma\left(\theta_P-d^i\right)^2+\left(\theta_A-d^i\right)^2\right) = E\left(\gamma\left(\theta_P-d^{FB}+d^{FB}-d^i\right)^2+\left(\theta_A-d^{FB}+d^{FB}-d^i\right)^2\right)$$

$$= \left(\left(1+\gamma\right)E\left(\theta_A-d^{FB}\right)^2+\left(1+\gamma\right)E\left(d^{FB}-d^i\right)^2\right)$$

In the case of delegation,

$$E\left(d^{FB}-d^A\right)^2 = \left(\frac{\gamma\theta_P+\theta_A}{1+\gamma}-\frac{\alpha_P s_P+\alpha_d\overline{d}+\theta_A}{1+\alpha_P+\alpha_d}\right)^2.$$

To simplify the derivation, note from above that

$$\frac{\alpha_P s_P+\alpha_d\overline{d}+\theta_A}{1+\alpha_P+\alpha_d} = \frac{\gamma E(\theta_P|s_P,\theta_A)+\theta_A}{1+\gamma},$$

so we have that

$$E\left(d^{FB}-d^A\right)^2 = \frac{\gamma^2}{(1+\gamma)^2}\left(\theta_P-E\left(\theta_P|s_P,\theta_A\right)\right)^2.$$

Recall that the conditional variance is given simply by

$$\widetilde{\sigma}_P^2 = \sigma_P^2-\Sigma_{12}\Sigma_{22}^{-1}\Sigma_{21},$$

and from above we have that

$$\Sigma_{12}\Sigma_{22}^{-1}\Sigma_{21} = \begin{pmatrix} \sigma_P^2 & \sigma_{AP} \end{pmatrix} \begin{pmatrix} \sigma_P^2 + \sigma_{\varepsilon_P}^2 & \sigma_{AP} \\ \sigma_{AP} & \sigma_A^2 \end{pmatrix}^{-1} \begin{pmatrix} \sigma_P^2 \\ \sigma_{AP} \end{pmatrix} = \frac{\sigma_P^2(\sigma_P^2(1-\rho^2)+\rho^2(\sigma_{\varepsilon_P}^2))}{\sigma_P^2(1-\rho^2)+\sigma_{\varepsilon_P}^2},$$

so

$$\sigma_P^2 - \Sigma_{12}\Sigma_{22}^{-1}\Sigma_{21} = \frac{\sigma_P^2\sigma_{\varepsilon_P}^2(1-\rho^2)}{\sigma_P^2(1-\rho^2)+\sigma_{\varepsilon_P}^2} = \frac{\sigma_P^2 x(1-\rho^2)}{\sigma_P^2((1-\rho^2)+x)}$$

$$\frac{\gamma^2\sigma_P^2(1-\rho^2)x_P}{(1+\gamma)((1-\rho^2)+x_P)}$$

Proposition 28: Imperfect information

$d^P = \frac{\alpha_A s_A + \alpha_D \bar{d} + E_P(\theta_P|v_P)}{1+\alpha_A+\alpha_D}$ and $d^{SB} = \frac{E_P(\theta_A|s_A)+E_P(\theta_P|v_P)}{2}$,

while

$$E_P(\theta_A|s_A) = \frac{\sigma_{\varepsilon_A}^2}{\sigma_{\varepsilon_A}^2+\sigma_A^2}\mu_A + \frac{\sigma_A^2}{\sigma_{\varepsilon_A}^2+\sigma_A^2}s_A.$$

So the coefficients need to satisfy

$$d^P = \frac{\alpha_A s_A + \alpha_D \bar{d} + E_P(\theta_P|v_P)}{1+\alpha_A+\alpha_D} = \frac{\frac{\sigma_{\varepsilon_A}^2}{\sigma_{\varepsilon_A}^2+\sigma_A^2}\mu_A + \frac{\sigma_A^2}{\sigma_{\varepsilon_A}^2+\sigma_A^2}s_A + E_P(\theta_P|v_P)}{2},$$

which gives directly

$$\alpha_A = \frac{\sigma_A^2}{\sigma_{\varepsilon_A}^2+\sigma_A^2} \qquad \alpha_D = \frac{\sigma_{\varepsilon_A}^2}{\sigma_{\varepsilon_A}^2+\sigma_A^2} \qquad \bar{d} = \mu_A.$$

The expected loss follows as above. We can write the expected loss as

$$E\left(\left(\theta_P - d^{FB}\right)^2 + \left(\theta_A - d^{FB}\right)^2 + 2\left(d^{FB} - d^P\right)^2\right),$$

where $d^P = \frac{E(\theta_P|v_P)+E(\theta_A|s_A)}{2}$,

so

$$\tfrac{1}{4}E\left((\theta_A - E(\theta_A|s_A)) + (\theta_P - E(\theta_P|v_P))\right)^2 = \tfrac{1}{4}E\left((\theta_A - E(\theta_A|s_A))^2 + (\theta_P - E(\theta_P|v_P))^2\right)$$

$$\tfrac{1}{4}E\left((\theta_A - E(\theta_A|s_A))^2 + (\theta_P - E(\theta_P|v_P))^2\right) = \tfrac{1}{4}\left[\left(\frac{\sigma_A^2\sigma_{\varepsilon A}^2}{\sigma_A^2+\sigma_{\varepsilon A}^2}\right) + \left(\frac{\sigma_P^2\sigma_{\eta_P}^2}{\sigma_P^2+\sigma_{\eta_P}^2}\right)\right]$$

Solution for Information Acquisition

Delegation

Let us first consider the agent's incentives. Taking the expectations and rearranging we get

$$EL_A = \frac{\alpha_P}{(\alpha_P+1)}\left[\alpha_P E\left(s_P - E\left(s_P|\omega\right)\right)^2 + E\left(\theta_A^2 + s_P^2\right)\right].$$

With probability p_A the agent learns s_P, while with probability $(1-p_A)\,p_P$ the agent fails while the manager succeeds. Thus, we can write the expected loss as

$$\begin{aligned} p_A&\left(-\frac{\alpha_P^2\left(\sigma_P^2+\sigma_\varepsilon^2\right)}{(\alpha_P+1)}\right) + (1-p_A)\,p_P\left(-\frac{\alpha_P^2\left(\sigma_P^2\right)}{(\alpha_P+1)}\right) \\ &+\frac{\alpha_P}{(\alpha_P+1)}\left[(1+\alpha_P)\left(\sigma_P^2+\sigma_\varepsilon^2\right)+\sigma_A^2\right] - F\left(\sigma_P^2\right)\beta_A\left(p_A + \ln\left(1-p_A\right)\right), \end{aligned}$$

which gives the first-order condition

$$\frac{\alpha_P^2}{(\alpha_P+1)}\left[\left(\sigma_P^2+\sigma_\varepsilon^2\right)\right] - p_P\frac{\alpha_P^2}{(\alpha_P+1)}\sigma_P^2 = \frac{F\left(\sigma_P^2\right)\beta_A p_A}{1-p_A}.$$

For the manager, rearranging the expected loss function

$$E\left[\left(\theta_P - d^A\right)^2 - \alpha_P\left(s_P - d^A\right)^2|p_A,p_P\right] + C_P\left(p_P\right)$$

yields a first-order condition

$$(1-p_A)\,\frac{(1-\alpha_P)\left(\alpha_P^2+2\alpha_P\right)}{(\alpha_P+1)^2}\sigma_P^2 = \frac{F\left(\sigma_P^2\right)\beta_P p_P}{1-p_P}.$$

The expected total performance is then given by

$$\begin{aligned} E\left(L_A+L_P\right) = p_A&\left(\left(\theta_P-d^A\right)^2+\left(\theta_A-d^A\right)^2\right) \\ &+(1-p_A)\,p_P\left(\left(\theta_P-d^A\right)^2+\left(\theta_A-d^A\right)^2\right) \\ &+(1-p_A-(1-p_A)\,p_P)\left(\left(\theta_P-d^A\right)^2+\left(\theta_A-d^A\right)^2\right) \\ &+C_A\left(p_A\right)+C_P\left(p_P\right), \end{aligned}$$

which, after a little rearranging simplifies to

$$\begin{aligned} &\frac{2\left(\sigma_P^2\left(1-p_A^*\right)\left(1-p_P^*\right)\alpha_P+p_A^*\alpha_P^2\sigma_\varepsilon^2\right)}{(1+\alpha_P)^2}+\frac{\left(1+\alpha_P^2\right)}{(1+\alpha_P)^2}\left(\sigma_A^2+\sigma_P^2\right) \\ &\quad -F\left(\sigma_P^2\right)\beta_A\left(p_A^*+\ln\left(1-p_A^*\right)\right)-F\left(\sigma_P^2\right)\beta_P\left(p_P^*+\ln\left(1-p_P^*\right)\right), \end{aligned}$$

where p_A^*, p_P^* solve the two first-order conditions above. In contrast, under perfect information

$$E\left(L_A+L_P\right) = \frac{2\alpha_P^2\sigma_\varepsilon^2}{(1+\alpha_P)^2}+\frac{\left(1+\alpha_P^2\right)}{(1+\alpha_P)^2}\left(\sigma_A^2+\sigma_P^2\right),$$

with $\alpha_P^* = \frac{\sigma_A^2+\sigma_P^2}{\sigma_A^2+\sigma_P^2+2\sigma_\varepsilon^2}$.

Employment

Under employment, the agent becomes a passive participant. Otherwise, the analysis parallels that above. That is, the principal solves:

$$\min_{p_P} \left[p_P E\left(L_P|\theta_P, s_A\right) + \left(1-p_P\right) E\left(L_P|0, s_A\right)\right] - C_P\left(p_P\right)$$

giving the principal's choice of p_P

$$\frac{\sigma_P^2}{\left((1+\alpha_A)F\left(\sigma_P^2\right)\beta_P+\sigma_P^2\right)} = p_P$$

and expected total loss of

$$\frac{2(1-p_P)\sigma_P^2\alpha_A}{(1+\alpha_A)^2} + \frac{1}{(1+\alpha_A)^2}\left(\left(1+\alpha_A^2\right)\left(\sigma_A^2+\sigma_P^2\right) + 2\alpha_A^2\sigma_{\varepsilon A}^2\right) - \beta_P\left[p_P + \ln\left(1-p_P\right)\right].$$

In contrast, under perfect information we have

$$\frac{\left(1+\alpha_A^2\right)}{(1+\alpha_A)^2}\left(\sigma_A^2+\sigma_P^2\right) + \frac{2\alpha_A^2}{(1+\alpha_A)^2}\sigma_{\varepsilon A}^2,$$

with $\alpha_A^* = \frac{\sigma_A^2+\sigma_P^2}{\sigma_A^2+\sigma_P^2+2\sigma_{\varepsilon A}^2}$

Proposition 29: Risk-Aversion and Incentive Strength

$$\min_{\alpha_P} E\left[\left(\theta_P-d^A\right)^2+\left(\theta_A-d^A\right)^2\right] + rVar\left[\alpha_P\left(\theta_P-d^A\right)^2+\alpha_P\varepsilon_P+\left(\theta_A-d^A\right)^2\right]$$

$$s.t. \qquad d^A = \frac{\alpha_P\theta_P+\theta_A}{\alpha_P+1}.$$

Substituting in the decision, we have that:

$$\left(\theta_P-d^A\right)^2+\left(\theta_A-d^A\right)^2 = \frac{1+\alpha_P^2}{(\alpha_P+1)^2}\left(\theta_P-\theta_A\right)^2$$

The problem becomes:

$$\min_{\alpha_P} \frac{1+\alpha_P^2}{(\alpha_P+1)^2} E\left(\theta_P-\theta_A\right)^2 + r\left(\frac{\alpha_P+\alpha_P^2}{(\alpha_P+1)^2}\right)^2 Var\left(\theta_P-\theta_A\right)^2 + r\alpha_P^2\sigma_{\varepsilon_P}^2$$

$$\min_{\alpha_P} \frac{1+\alpha_P^2}{(\alpha_P+1)^2} E\left(\theta_P-\theta_A\right)^2 + \frac{r\alpha_P^2}{(\alpha_P+1)^2} Var\left(\theta_P-\theta_A\right)^2 + r\alpha_P^2\sigma_{\varepsilon_P}^2.$$

Thus, the first-best incentive strength is implicitly defined by

$$\frac{1}{(\alpha_P+1)^3}\left[\left(\alpha_P-1\right)E\left(\theta_P-\theta_A\right)^2 + r\alpha_P Var\left(\theta_P-\theta_A\right)^2\right] + r\alpha_P\sigma_{\varepsilon_P}^2 = 0$$

Now, denote the distribution of $\theta_P-\theta_A$ by $\theta_P-\theta_A \sim N\left(\Delta\mu, \sigma_{\Delta\theta}^2\right)$. Then,

$$E\left(\theta_P-\theta_A\right)^2 = \Delta\mu^2 + \sigma_{\Delta\theta}^2$$

$$Var\left(\theta_P-\theta_A\right)^2 = 2\sigma_{\Delta\theta}^2\left(\sigma_{\Delta\theta}^2 + 2\Delta\mu^2\right),$$

so we can write this as

$$\frac{1}{(\alpha_P+1)^3}\left[(\alpha_P-1)\left(\Delta\mu^2+\sigma^2_{\Delta\theta}\right)+r\alpha_P\left(2\sigma^2_{\Delta\theta}\left(\sigma^2_{\Delta\theta}+2\Delta\mu^2\right)\right)\right]+r\alpha_P\sigma^2_{\varepsilon_P}=0.$$

Thus,

$$\frac{\partial\alpha_P}{\partial\sigma^2_{\varepsilon_P}}<0 \qquad and \qquad sign\left(\frac{\partial\alpha_P}{\partial\sigma^2_{\Delta\theta}}\right)=sign\left(1-\alpha_P\left(1+4r\left(\Delta\mu^2+\sigma^2_{\Delta\theta}\right)\right)\right).$$

Which follow directly by the implicit function theorem.

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