

Department of Economics

Issn 1441-5429

Discussion paper 19/08

**INFORMATION GATHERING, DELEGATED CONTRACTING AND CORPORATE
HIERARCHIES**

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March 23, 2008

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¹This project was started during the first author's visit to the University of Pittsburgh and the Research Institute of Capital Formation, Development Bank of Japan, whose warm hospitality is gratefully acknowledged. We are thankful for many helpful comments from the seminar audience at various institutions. This project was funded by a Discovery Project Grant (DP0664577) from the Australian Research Council. The usual disclaimer applies.

Information Gathering, Delegated Contracting, and Corporate Hierarchies

Abstract

In a typical corporate hierarchy, the manager is delegated the authority to make strategic decisions, and to contract with other employees. We study when such delegation can be optimal. In centralization, the owner retains the authority, which fails to motivate the manager to acquire valuable information, leading to suboptimal decisions and inefficient incentive provision to the worker. Beneficial delegation should necessarily motivate the manager to acquire information, which is possible only when the authority is delegated to the manager. We also document comparative statics results regarding the benefits of delegation and discuss when delegation is more likely to dominate centralization.

JEL Codes: C72, D21, D82, L22.

Keywords: Corporate hierarchies, information gathering, delegation, centralization.

1. Introduction

The so-called separation of ownership and control (Berle and Means, 1932; Fama and Jensen, 1983) refers to the fact that the nominal owners of corporations - shareholders - delegate authority to managers. The authority is vested in several important dimensions for the top managers of corporations. They make strategic decisions that set directions for corporations, employ subordinates, and contract with external suppliers. This multiple dimension of authority is a deciding factor for the organizational form of corporations. Rather than a set of two-tier hierarchies in which owners are at the top of each two-tier hierarchy, modern corporations are often organized as multi-tier hierarchies.¹ Chandler (1977, 1990) attributes such a transformation of family-oriented “personal capitalism” to “managerial capitalism” in the US to a sharp increase in demand for, and supply of professional, qualified managers as corporations become larger with increasingly sophisticated operations. The resulting modern business enterprise, according to Chandler, is an organization with many distinct operating units that are managed by a hierarchy of professional, salaried executives. In such organizations, shareholders hire top managers - through boards - and managers, in turn, hire subordinates or contract with external suppliers. Why are such multi-tier hierarchies, rather than multiple two-tier hierarchies, often the norm? Why are managers, instead of other stakeholders, at the center of the multi-tier hierarchy? This study attempts to provide answers to these questions from an incentive perspective.

A typical explanation for delegation in corporations is based on managers' expertise and the ensuing benefits of specialization. Jensen and Murphy (1990, p. 251) put it aptly: “Managers often have better information than shareholders and boards in identifying investment opportunities and assessing the profitability of potential projects; indeed, the expectation that managers will make superior investment decisions explains why shareholders relinquish decision rights over their assets by purchasing common stocks.” Underlying this explanation is the assumption that communicating managers' information is costly, or that shareholders or boards do not have necessary expertise to process the information for decision-making even if communicating the

¹Separation of ownership and control in this sense, although not universally the case, is most prevalent in the Anglo-American system of corporate governance. See La Porta, Lopez-De-Silanes and Shleifer (1999).

information is costless.² For, otherwise, shareholders or boards will be able to make decisions based on the information that managers have, which is the central insight from the revelation principle.

We take Jensen and Murphy's explanation as a starting point, but go a step further by assuming that managers need to incur private costs to acquire and process information. The incentive problem becomes relatively easier without such costs. Our basic model is thus embedded in an environment where managers can, at some costs, acquire information necessary for investment decisions, which cannot be used by shareholders in designing incentive contracts for managers.

Several authors have resorted to such contractual incompleteness either implicitly or explicitly to explain why a multi-tier hierarchy with delegation can be superior to a centralized mechanism. In the context of general revelation mechanisms, Melumad, Mookherjee and Reichelstein (1995) show that the outcome of an optimal revelation mechanism can be achieved using decentralized contracts and proper sequencing of the contracts. Thus their main point is that, when various contracting costs such as those of communicating information necessary for the revelation mechanism are taken into account, there may be benefits to delegation. Laffont and Martimort (1998) show that delegation can dominate centralized contracts when the possibility of collusion down the hierarchy is combined with limits on communication. The limits on communication, according to these authors, require the centralized contracts be anonymous, and different agents be treated symmetrically. This facilitates collusion. With decentralization, such a problem disappears. The main lesson from these studies is that, to have hierarchical decentralization emerge endogenously as an optimal organizational form, there must be limits to using centralized revelation mechanisms.

Our paper is similar in spirit to the above studies, but has more concrete objectives. Specifically we describe what we believe is a realistic, but tractable model of a corporate hierarchy, and show when and why putting managers at the center of the multi-tier hierarchy can benefit shareholders. The main point of this paper can be explained using a simple scenario. Consider a firm that consists of three parties, whom we call the owner, the manager and the worker. The firm has two investment projects, for which

²The benefits of hierarchies facing the costs of communicating and processing information have been put forward by Arrow (1974) and Williamson (1983) among many others.

the owner provides necessary funds. The manager can acquire private information at some costs, which can be used in choosing a right project to undertake. The worker can exert effort that can increase the likelihood that the chosen project is successful. Neither the manager's information nor the worker's effort can be used for contracting purpose.

In a centralized mechanism, the owner has the authority to choose a project based on the manager's report, and design contracts for both agents based on the return from the chosen project. Although the manager's information cannot be used directly for contracting purpose, it can be used indirectly through the project choice. In a hierarchical mechanism, authority is delegated to the agent in the middle of the three-tier contracting relationship: the owner designs a contract for the agent in the middle, who chooses a project and designs a contract for the other agent. If the manager is delegated authority, he makes a project choice based on his own information. If the worker is delegated authority, he solicits the manager's information to make a project choice.

Our main point is that, for a hierarchical mechanism to dominate centralized contracting, authority should necessarily be delegated to the manager, not the worker. The intuition is as follows. In a centralized mechanism, the owner needs to control both the manager's incentives for information gathering and truthful report, and the worker's incentives for optimal effort. The manager's information is valuable for project choice and subsequent contract design for the worker. The worker's contract in turn affects the return from the chosen project, based on which the manager is paid. Knowing this, the manager has an incentive to manipulate his information if it is expected to increase the worker's effort level via his contract, which may not be optimal for the owner. This makes the manager's incentive compatibility constraints more stringent than those in the standard principal-agent model. As a result, it is too costly for the owner to motivate the manager to gather information and the centralized mechanism fails to induce the manager to gather information. The resulting project choice is suboptimal and the worker's contract fails to provide efficient incentives to the worker. Delegating authority to the worker suffers from similar problems since the worker has to solicit the manager's information for project choice.

If authority is delegated to the manager, however, the owner can disentangle the interlocking incentives. Delegation effectively makes the manager a

residual claimant in the subcontracting stage with the worker. Therefore the delegated contracting authority motivates the manager to design an efficient contract for the worker, which is possible if the manager gathers information and uses it for an optimal project choice.³ Thus the decision-making authority and the delegated contracting authority are complementary. Of course the efficiency benefits of delegation do not automatically flow back to the owner. If the manager enjoys too much rent as a result of delegation, then the owner may be better off with centralization. We show that delegation is more likely to benefit the owner as the manager's cost of information gathering becomes smaller, the manager's information becomes more valuable, and the worker's cost of effort becomes larger.

Other studies on delegation in a hierarchy include, among others, Baron and Besanko (1992), Gilbert and Riordan (1995), McAfee and McMillan (1995), Baliga and Sjöström (1998), Macho-Stadler and Pérez-Castrillo (1998), Mookherjee and Reichelstein (2001), Faure-Grimaud, Laffont and Martimort (2003), and Mookherjee and Tsumagari (2004). Baron and Besanko (1992), and Gilbert and Riordan (1995) establish equivalence between centralized and decentralized mechanisms when risk-neutral agents provide complementary inputs to production. McAfee and McMillan (1995) consider a three-tier hierarchy subject to limited liability constraints, showing losses involved in a three-tier hierarchy relative to centralized contracting. Equivalence of a decentralized mechanism and a centralized mechanism subject to the possibility of side-contracting is established in a moral hazard environment by Baliga and Sjöström (1998), and Macho-Stadler and Pérez-Castrillo (1998), in an environment with additional coordination problems by Mookherjee and Reichelstein (2001), and in a principal-supervisor-agent setup by Faure-Grimaud, Laffont and Martimort (2003).⁴ An additional con-

³In a similar vein but in a costly verification environment, Choe (1998) shows that the contract designed by the informed party can reduce the verification cost compared to the one designed by the uninformed party. The reason is that the informed party, in an attempt to maximize the value of his residual claim, designs the contract to give himself truth-telling incentives.

⁴The equivalence result can be also shown in our model. Suppose side-contracting between the manager and the worker is possible under centralization. Then the owner can implement the equilibrium outcome from manager delegation by offering the manager the same contract that she would offer under manager delegation, and the null contract to the worker. Since the worker's effort is essential, the manager will then offer the worker a side-contract that is exactly the same as the worker's contract under manager delegation.

clusion of Baliga and Sjöström (1998) relates to the pattern of delegation: the agent with superior information is more likely to be delegated. Mookherjee and Tsumagari (2004) consider a general adverse selection model to show that hierarchical delegation is in general strictly dominated by centralization subject to collusion due to double marginalization of rents.⁵ While not directly concerned with delegation, Itoh (1992, 1993) studies a multiple-agent moral hazard environment to show when the principal can benefit by allowing coalition of agents, when agents can monitor each other. With the equivalence result described above, his findings can be regarded as supportive of delegation over centralization when agents have informational advantages over the principal.

Our work differs from, but complements these and afore-mentioned studies on hierarchy at least in two important ways. In our model, the manager is not endowed with private information. Rather, he needs to incur private costs to acquire information. Because of this information acquisition, there are benefits from delegating authority to the manager. In the above studies on hierarchy, there is no a priori reason why a particular agent should be at the center of the multi-tier hierarchy.⁶ It could be any of the agents supplying inputs. In our model, delegation can benefit the owner only when the manager, not the worker, assumes the role of the delegated agent. Thus the benefits of delegation come from circumventing the irreconcilable conflicts between the information holder and the decision maker, which may arise under centralization, preventing a certain outcome from being implementable.

Second and related, the managerial input and the worker's input are quite distinct. We believe that the manager's information acquisition and subsequent decision making are what distinguish managerial inputs from those of other employees in corporations.⁷ Roughly speaking, the manager's decision

⁵The main difference between Laffont and Martimort (1998) and Mookherjee and Tsumagari (2004) is that, in the former, the cost types are binary and the bargaining power in the side-contracting at the collusion stage is fixed exogenously. In Mookherjee and Tsumagari, the bargaining power in the collusion stage is determined endogenously by the initial contract offered by the principal. Because of this, the principal can control the outcome from collusion to some extent. Laffont and Martimort were aware of this. They argue that their modeling choice will lead to the best outcome for the agents, hence the lowest bound of what the principal can achieve when collusion is possible (footnote 9, p. 286).

⁶As mentioned above, Baliga and Sjöström (1998) is a notable exception.

⁷In his classic work, Simon (1960) argues that the most important role of managers is

making can be identified with the choice of a particular distribution of profits, while other employees' inputs affect the likelihood of profit realization given the chosen distribution. It is in this sense that the manager's main role can be described as that of direction setting. We thus expect optimal incentive schemes for the manager to be quite different from those for other employees. Indeed we show that the manager, when delegated authority, can actively affect his own payoff through the choice of project and the design of contract for the worker. Thus incentives and authority are strongly complementary for the party who is delegated authority. For the worker, the scope of such influence upon his own payoff is limited, as is the case for employees lower in the corporate hierarchy: the worker in our paper is paid an efficiency wage under manager delegation.⁸

The rest of the paper is organized as follows. Section 2 describes the basic model. Section 3 studies the centralized mechanism. Section 4 analyzes the case of manager delegation, which is then compared with centralization in Section 5. Section 6 discusses other relevant issues and extends our results. Section 7 concludes the paper. The appendix contains the proofs of the results that are not central to the exposition of our main ideas.

2. The Model

There are three parties, whom we call the owner, the manager and the worker.⁹ The owner has two projects, denoted by ψ_1 and ψ_2 , whose return has the same support: $x > 0$ (success) or 0 (failure). The return is publicly observable and can be used for contracting purpose. The manager can privately observe a signal $\theta \in \{\theta_1, \theta_2\}$ at a monetary cost of $c > 0$, which we will call information gathering. The signal is a perfect predictor of a 'state' which

gathering, processing information, and making decisions based on this. According to him, managing is synonymous with decision-making. Case studies by Mintzberg (1973) provide rich supporting evidence for this. Radner (1993) also treats information processing as the main task of managers, distinct from the roles played by other employees.

⁸One could take this as an incentives-based explanation of why stock options have been the single most important incentive for CEOs in Anglo-American corporations (Murphy, 1999). While the use of stock options for non-executive employees was also growing in the late 1990s (Core and Guay, 2001), the proportion of incentives provided through stock options is eclipsed compared to that for CEOs (*The Economist*, 2003, p. 9).

⁹We will use the female gender pronoun for the owner and the male gender pronoun for the manager and the worker.

is a random variable that assumes θ_1 and θ_2 with probabilities $\pi \in (0, 1)$ and $1 - \pi$, respectively. If the manager does not gather information, then he observes nothing and we denote this null signal by \emptyset , and the set of all possible signals by $\Theta = \{\theta_1, \theta_2, \emptyset\}$. The worker privately chooses ‘work’ or ‘shirk’. The monetary cost of work is ℓ and that of shirk is normalized to 0. Given θ_i , the success probability for ψ_1 (ψ_2 , respectively) is p_i (q_i , respectively) if the worker chooses work.¹⁰ If the worker chooses shirk, then the success probability is r for either project and state.¹¹ We assume that all the players are risk neutral, limited liability sets a lower bound of 0 for payments to the manager and the worker, and that reservation utilities for both agents are zero. It then follows that both the manager and the worker find any contract weakly better than the reservation value. Hence, we assume in the sequel that they will accept any nonnegative contract.

The owner wishes to hire the manager to use his information for project choice, and the worker to exert effort for the chosen project. We consider two organizational structures that the owner may wish to employ for this purpose. In a centralized structure, the owner contracts with the manager who makes a report regarding his information, based on which she decides on which project to undertake and what kind of contract to offer to the worker. We assume that the the communication of the manager’s information is informal hence unverifiable. As mentioned in the introduction, some form of transaction costs in communicating local information to the principal is a necessary condition for effective delegation. We take the simplest form of transaction costs that the manager’s information is not verifiable. The contracts in this case thus depend only upon the project choice and the final return. In a delegated structure, the owner contracts with only one of the agents, who is delegated the authority to choose a project to undertake and to contract directly with the other agent. Either the manager or the worker can be the delegated agent. But the owner never benefits from delegating authority to the worker, which is shown in Section 6.2. Therefore we focus on delegation to the manager except in Section 6.2.

The game trees in the two organizational structures are described more precisely below. Under centralization, the owner first offers a contract to the

¹⁰Projects are identified with p and q and, states, with the subscripts.

¹¹Our main qualitative results are robust to different success probabilities when the worker shirks, as long as they are sufficiently small relative to p_i and q_i .

manager that specifies a salary $s_{i\rho} \geq 0$ for each of the contingencies that a project $\psi_i \in \{\psi_1, \psi_2\}$ is undertaken and a final return $\rho \in \{x, 0\}$ is produced. The manager accepts the contract, privately decides whether to gather information, and sends a message $m \in \Theta$ to the owner. Upon receiving m , the owner selects a project to undertake and offers a contract to the worker. The project choice decision is denoted by a mapping $C : \Theta \rightarrow \{\psi_1, \psi_2\}$. If the owner selected $\psi_i \in \{\psi_1, \psi_2\}$, then the worker's contract specifies a wage $w_{i\rho} \geq 0$ for each possible return $\rho \in \{x, 0\}$. The worker accepts the contract and decides on his action. Finally, the return ρ is realized, the manager and the worker are paid, and the owner keeps the remainder, $\rho - s_{i\rho} - w_{i\rho}$ for $i = 1, 2$.

Under delegation, the owner offers a contract to the manager that specifies a salary $\sigma_\rho \geq 0$ contingent only on the final return ρ . That it may not depend on the project choice is for expositional convenience. Relaxing this assumption only reinforces our main insight because it would enhance the performance of the delegated structure for the owner.¹² The manager accepts it, privately decides whether to gather information and selects a project, and then offers a contract to the worker. If the manager chose $\psi_i \in \{\psi_1, \psi_2\}$, then the worker's contract specifies a wage $\omega_{i\rho} \geq 0$ for each $\rho \in \{x, 0\}$. The worker accepts and decides his action. Finally the return ρ is realized and payments are made: the owner retains $\rho - \sigma_\rho$, the manager $\sigma_\rho - \omega_{i\rho}$, and the worker gets $\omega_{i\rho}$ for $i = 1, 2$. Figure 1 shows the time-line for the two organizational structures.

— **Figure 1 goes about here.** —

The players' objectives are to maximize their respective expected payoffs. Since the worker is risk-neutral, the optimal contract to induce shirk from the worker in either organizational structure is 0 regardless of ρ , and that to induce work is a positive wage only when $\rho = x$ such that the increment in expected wage from work is ℓ , the cost of work. In the sequel we take this observation granted and denote the wage contract by w_i or ω_i as shorthand for w_{ix} and ω_{ix} , respectively. Similarly, we can simplify the manager's contract under centralization to $s_{i0} = 0$ and denote $s_{i\rho} \geq 0$ by s_i for $i = 1, 2$.

¹²We believe that it also carries some realism. When the owner delegates the operation of the firm to the manager, she would be interested in the final performance but not in the details of operation.

The described structure of the game is common knowledge. We analyze and compare the sequential equilibrium between the two structures. An ‘outcome’ refers to a specification of the manager’s action, project choice and the worker’s action for each state.

Define $\Delta p_i \equiv p_i - r$, $\Delta q_i \equiv q_i - r$, $i = 1, 2$. These are improvements in success probabilities due to the worker’s contribution. We maintain the following assumptions.

Assumption 1: $\pi p_1 + (1 - \pi)p_2 > \pi q_1 + (1 - \pi)q_2$.

Assumption 2: $p_1 > p_2 > r$, $q_2 > q_1 > r$, $\Delta p_1 > \frac{\ell}{x} > \Delta q_2$.

Assumption 1 states that the two projects are asymmetric under the prior belief. That is, if the owner has to make a project choice without the manager’s information, then she would prefer ψ_1 to ψ_2 provided that the worker is induced to work. It is intended to resolve a tie-breaking situation. Assumption 2 implies that an optimal project choice is necessarily state-dependent, and that the worker’s input is valuable only when ψ_1 is chosen in θ_1 . These are minimal assumptions that make the incentive problems for both agents non-trivial. To see this, suppose that the worker’s input is valuable in both projects if they are optimally chosen, i.e., $\Delta p_1 > \frac{\ell}{x}$ and $\Delta q_2 > \frac{\ell}{x}$. Then the manager’s information is valuable only for project choice, but not for incentive provision to the worker. In this case, the owner can provide separate incentives to the manager and the worker, thereby implementing the desired outcome through centralization. Therefore delegation and the accompanied interlocking incentives do not have much bite. In Section 6.3, we show this formally by demonstrating that delegation is never optimal if $\Delta p_1 > \frac{\ell}{x}$ and $\Delta q_2 > \frac{\ell}{x}$.

3. Centralization

Under centralization, the owner designs contracts for both agents. Suppose that the manager gathers information given the contract (s_1, s_2) . Given that the contract satisfies the manager’s incentive compatibility (IC), the manager reports the signal truthfully. There are four possible cases of project choice based on the manager’s report: (i) $C(\theta_i) = \psi_1$ for $i = 1, 2$; (ii) $C(\theta_i) = \psi_2$ for $i = 1, 2$; (iii) $C(\theta_i) = \psi_j$ for $i \neq j$; (iv) $C(\theta_i) = \psi_i$ for

$i = 1, 2$. Since the contract that induces the manager to gather information is costly for the owner, if the manager gathers information in equilibrium, the information should be used. There is no point for the owner to know the state if she were to induce the worker to shirk in both states. Thus if the manager gathers information, the worker should be induced to work in at least one of the two states. Moreover, Assumption 2 implies that the worker's effort is valuable only when ψ_1 is chosen in θ_1 . In all the other cases, the owner is better off by inducing shirk from the worker since the payment to induce work is nonnegative. Therefore if the manager gathers information in equilibrium, the only outcome that the owner would want to implement involves the worker working only when ψ_1 is chosen in θ_1 . We show below that the owner cannot implement this outcome.

Suppose that the owner offers the worker $w \geq 0$ to induce work in θ_1 , and $w = 0$ to induce shirk in θ_2 . Based on the discussions above, we need to look at only two possible cases of project choice where ψ_1 is chosen in θ_1 . Consider first the case where $C(\theta_i) = \psi_1$ for $i = 1, 2$. Then the manager's IC requires $p_1 s_1 \geq r s_1 \geq p_2 s_1$, where the first inequality concerns θ_1 and the second inequality, θ_2 . But this is impossible since $p_2 > r$. The next case has $C(\theta_i) = \psi_i$ for $i = 1, 2$. The manager's IC in this case is $p_1 s_1 \geq r s_2 \geq p_2 s_1$, which implies $s_2 \geq \frac{p_2}{r} s_1 > s_1$. Then, in θ_2 , the owner is better off choosing ψ_1 rather than ψ_2 . It is because the expected payment when ψ_1 is chosen is $r s_1$, which is smaller than $r s_2$, the expected payment when ψ_2 is chosen.¹³ In sum, there cannot be an equilibrium in which the manager gathers information and the worker works only when ψ_1 is chosen in θ_1 . Consequently the owner does not benefit from the manager's information and, therefore, would not induce the manager to gather information.

The logic behind the above result is as follows. Under centralization, the owner needs to control both the manager's incentives for information gathering and truthful report, and the worker's incentives. The manager's information is valuable for project choice and subsequent contract design for the worker. If the marginal value of the worker's input is negative for a project selected based on the manager's report, then an optimal contract should induce the worker to shirk. The optimal shirk from the worker, however, reduces the probability that the manager will be paid. Thus the manager has an incentive to make an untruthful report if it is expected to induce work

¹³Recall that, in θ_2 , the owner offers the worker $w = 0$ to induce shirk.

from the worker even if it leads to a suboptimal project choice at the cost to the owner. Eliciting truthful reports from the manager then requires the owner to reward the manager more when his report leads to optimal shirk from the worker ($s_2 > s_1$ in the second case above). This makes it too costly for the owner to motivate the manager to gather information. Summarizing the discussions so far, we have

Proposition 1: In no equilibrium under centralization, the manager gathers information.

There are two reasons for the above impossibility result. First, the timing of contracting under centralization is such that the owner designs the worker's contract after learning the manager's report. Since the worker's action affects the manager's expected payoff, the manager will then have incentives to make untruthful reports, if necessary, to increase his expected payoff. The resulting stringent incentive constraints for the manager eliminate the benefits of the manager's information for the owner. Therefore, if the owner can commit to the worker's contract that depends only on the return from the project before receiving the report from the manager and making a project choice, then she can motivate the manager to gather information. However this does not necessarily benefit the owner compared to when she can also use project choice for contracting purpose. This is discussed in Section 6.1. Second, under centralization, the owner has to design contracts for both agents to control their respective incentives. As we will show in the next section, delegation of authority to the manager allows the owner to disentangle the incentives of the two agents. It relieves the owner from the onus of project choice and contract design for the worker. The owner offers a contract only to the manager to provide the incentives for information gathering. The manager in turn uses his information for project choice, based on which to control the worker's incentives.

In any equilibrium under centralization, therefore, the owner does not make a positive payment to the manager who does not gather information. The owner cannot distinguish between the states, hence induces the same action from the worker. If it is optimal for her to induce shirk from the worker, then the owner does not use the inputs from either agent. We call this proprietorship. The owner's expected payoff under proprietorship is

$$Z_P \equiv rx. \quad [1]$$

If the owner induces the worker to work under centralization, then project choice matters. If she chooses ψ_1 , then she has to pay the worker $\frac{\ell}{\pi\Delta p_1 + (1-\pi)\Delta p_2}$ in case of success, resulting in the worker's expected payoff of $\frac{r\ell}{\pi\Delta p_1 + (1-\pi)\Delta p_2}$. The owner's expected payoff is then

$$Z_C \equiv (\pi p_1 + (1-\pi)p_2) \left(x - \frac{\ell}{\pi\Delta p_1 + (1-\pi)\Delta p_2} \right). \quad [2]$$

If she chooses ψ_2 , then she pays the worker $\frac{\ell}{\pi\Delta q_1 + (1-\pi)\Delta q_2}$ and obtains the expected payoff of $(\pi q_1 + (1-\pi)q_2) \left(x - \frac{\ell}{\pi\Delta q_1 + (1-\pi)\Delta q_2} \right)$, which is smaller than Z_C due to Assumption 1. This leads to

Proposition 2: In the equilibrium under centralization, the owner offers a null contract to the manager. If $Z_C > Z_P$, then the owner chooses ψ_1 and induces the worker to work by offering $w_1 = \frac{\ell}{\pi\Delta p_1 + (1-\pi)\Delta p_2}$ in case of success. If the inequality is reversed, then the owner chooses proprietorship.

4. Manager Delegation

The owner continues to design a contract for the manager, who is now delegated the authority to select a project and design a contract for the worker. Since our main focus is when delegation can benefit the owner, delegation should necessarily implement the outcome that is not possible to implement under centralization. More precisely, it is easy to see that delegation does not benefit the owner if it cannot motivate the manager to gather information.

Proposition 3: Suppose the delegated manager does not gather information. Then, the owner can induce the same outcome under centralization at the same or a lower cost.

Proof: Suppose the delegated manager does not gather information. Then he either chooses ψ_1 and induces work by offering $\omega_1 = \frac{\ell}{\pi\Delta p_1 + (1-\pi)\Delta p_2}$, or chooses either project and induces shirk by offering $\omega_1 = \omega_2 = 0$. In either

case, the owner can induce the same outcome centrally by offering the manager $s_1 = s_2 = 0$ and replicating the delegated manager's decisions in project choice and contracting with the worker. ■

In light of Proposition 3, we focus on the outcomes in which the delegated manager gathers information in equilibrium. Again, there is no point for him to gather information if he were to induce shirk from the worker in both states. In addition, since the salary to the manager is at most x , he has no incentive to induce work from the worker in state θ_2 due to Assumption 2. Hence, in any equilibrium we are interested in,

(MD) The manager gathers information, chooses ψ_1 and induces work from the worker in θ_1 , and induces shirk in θ_2 .

Note that (MD) is the first-best outcome which is not implementable under centralization. If manager delegation can implement (MD), the larger total surplus of the first-best outcome is the benefit of delegation. However the owner may not prefer delegation to centralization even if the first-best outcome is possible under the former. This is because she may have to leave too large a rent to the manager to induce the desirable action. Delegation therefore entails both costs and benefits to the owner. The central aim of this paper is to delineate when such benefits outweigh costs, in which case meaningful delegation will emerge endogenously. Given that the owner has a final say in the choice of mechanism, we could view such endogenous delegation as an incentive-based explanation of transition from 'personal capitalism' to 'managerial capitalism'.

We now turn to the subcontracting game between the manager and the worker. Denote the manager's contract by σ and the worker's contract by $\omega_i \geq 0$ for $i = 1, 2$, which is a payment for success when ψ_i is chosen. Consistent with our assumption, the contract cannot be directly dependent on the manager's private information. When offering a contract to the worker, however, the manager may have acquired information. Thus the manager can design the worker's contract indirectly contingent on his private information. That is, the worker's contract can be designed to signal the manager's information: given ω_i , the worker decides on his action based on an inference on the manager's information on the state. Denote this belief by $\mu(\theta|\psi_i, \omega_i)$, $i = 1, 2$.

The equilibrium leading to outcome (MD) is described in more detail as follows: the owner contracts with the manager paying $\sigma \geq 0$ in case of success; the manager accepts the contract and incurs c to gather information; if θ_1 is observed, he chooses ψ_1 and offers the worker $\omega_1 \geq 0$ in case of success, which the worker accepts and chooses to work; if θ_2 is observed, the manager chooses ψ_2 and offers the worker $\omega_2 \geq 0$ in case of success,¹⁴ which the worker accepts and does not exert effort.

Below we check the conditions for such a strategy profile to indeed constitute an equilibrium. Since the lowest wage to induce shirk is clearly 0, $\omega_2 = 0$ in equilibrium. When ω_1 is offered, the worker correctly infers θ_1 , hence he would work as long as

$$\omega_1 \geq \frac{\ell}{\Delta p_1}. \quad [3]$$

Given ω_1 satisfying [3], the worker's equilibrium strategy is 'work' if and only if $\omega_1 \geq \frac{\ell}{\Delta p_1}$ when ψ_1 is chosen, and 'work' if and only if $\omega_2 \geq \frac{\ell}{\Delta p_2}$ when ψ_2 is chosen. The worker's belief supporting the above strategy is $\mu(\theta_1|\psi_1, \omega_1) = 1$ for $\omega_1 \geq \frac{\ell}{\Delta p_1}$ and 0 otherwise, and $\mu(\theta_2|\psi_2, \omega_2) = 1$ for all $\omega_2 > 0$.¹⁵ The manager's equilibrium expected payoff is then

$$V_1 \equiv \pi p_1(\sigma - \omega_1) + (1 - \pi)r\sigma - c. \quad [4]$$

To check the manager's incentive compatibility (IC), we consider possible deviations by the manager. Once he gathers information, no deviation is profitable in θ_2 as explained earlier. In θ_1 , he would get $r\sigma$ regardless of the project if he induced shirk from the worker; choosing ψ_1 and offering ω_1 is best as long as he induces work. Hence, the manager's IC after he gathered information is

$$p_1(\sigma - \omega_1) \geq r\sigma. \quad [5]$$

If he does not gather information, he is best off either by choosing ψ_1 and offering ω_1 that satisfies [3] (i.e., inducing work) or by taking either project and offering 0. The conditions for neither to be profitable are

$$V_1 \geq (\pi p_1 + (1 - \pi)p_2)(\sigma - \omega_1) \Leftrightarrow (1 - \pi)(r\sigma - p_2(\sigma - \omega_1)) \geq c \quad [6]$$

¹⁴If the worker is induced to shirk, then project choice does not matter. We assume in this case that the manager chooses ψ_2 because it renders the equilibrium more stable.

¹⁵We focus on pure strategies of the worker only since the worker would accept any positive wage offer because nonnegative payoff is guaranteed by shirking.

and

$$V_1 \geq r\sigma \Leftrightarrow \pi(p_1(\sigma - \omega_1) - r\sigma) \geq c. \quad [7]$$

Since [7] implies [5], the manager's IC is summarized by [6] and [7]. In the (ω_1, σ) -space, [6] is satisfied in the area below a positively sloped straight line, and [7] is satisfied in the area above a flatter (yet, positively sloped) straight line. It is straightforward to verify that the value of ω_1 at the intersection of these two lines is given by

$$\omega^* \equiv \frac{c}{r(p_1 - p_2)} \left(\frac{\Delta p_1}{1 - \pi} + \frac{\Delta p_2}{\pi} \right). \quad [8]$$

Together with the worker's IC condition [3], we deduce that if $\omega^* \leq \frac{\ell}{\Delta p_1}$ which is equivalent to $\ell \geq \frac{c\Delta p_1[\pi\Delta p_1 + (1-\pi)\Delta p_2]}{\pi(1-\pi)(p_1-p_2)r}$, then the outcome (MD) can be implemented least costly for the owner when

$$\omega_1 = \frac{\ell}{\Delta p_1} \quad \text{and} \quad \sigma = \frac{1}{\Delta p_1} \left(\frac{c}{\pi} + \frac{p_1 \ell}{\Delta p_1} \right) \quad [9]$$

where σ in [9] is the smallest value of σ that satisfies [6] and [7] when $\omega_1 = \frac{\ell}{\Delta p_1}$. If $\omega^* > \frac{\ell}{\Delta p_1}$, then the outcome (MD) can be implemented least costly for the owner at the intersection of [6] and [7], i.e., when

$$\omega_1 = \omega^* \quad \text{and} \quad \sigma = \frac{1}{\Delta p_1} \left(\frac{c}{\pi} + \frac{cp_1}{r(p_1 - p_2)} \left(\frac{\Delta p_1}{1 - \pi} + \frac{\Delta p_2}{\pi} \right) \right). \quad [10]$$

In either case, the owner's expected payoff is

$$Z_D \equiv (\pi p_1 + (1 - \pi)r)(x - \sigma). \quad [11]$$

Proposition 4: (a) If $\omega^* \leq \frac{\ell}{\Delta p_1}$, then the owner can implement (MD) at minimum cost by offering the manager $\sigma = \frac{1}{\Delta p_1} \left(\frac{c}{\pi} + \frac{p_1 \ell}{\Delta p_1} \right)$ in case of success. The optimal subcontract the manager offers the worker is $\omega_1 = \frac{\ell}{\Delta p_1}$ and $\omega_2 = 0$. (b) If $\omega^* > \frac{\ell}{\Delta p_1}$, then the owner can implement (MD) at minimum cost by offering the manager σ in [10] in case of success. The optimal subcontract the manager offers the worker is $\omega_1 = \omega^*$ in [8] and $\omega_2 = 0$.

5. Centralization vs. Manager Delegation

In this section we compare manager delegation and centralization, and analyze when the owner can benefit from delegating authority to the manager. For non-vacuous comparison, we assume that x is large enough so that the salary needed to induce (MD) in Proposition 4 is less than x . The owner's expected payoff depends on whether or not the inequality $\omega^* \leq \frac{\ell}{\Delta p_1}$ holds. We focus on the case where the inequality holds,¹⁶ whence the owner's expected payoff is

$$Z_D \equiv (\pi p_1 + (1 - \pi)r) \left(x - \frac{c}{\pi \Delta p_1} - \frac{p_1 \ell}{(\Delta p_1)^2} \right). \quad [12]$$

We compare Z_D with the owner's expected payoffs from centralization and proprietorship, Z_C and Z_P .

Let us start with a numerical example where parameter values are: $p_1 = 0.9$, $p_2 = 0.3$, $q_1 = 0.4$, $q_2 = 0.45$, $\pi = 0.63$, $r = 0.25$, $\ell = 4$, $c = 0.1$, $x = 20$. These values satisfy Assumptions 1, 2 and $\omega^* \leq \frac{\ell}{\Delta p_1}$. The owner's equilibrium expected payoffs are calculated as $Z_C = 7.22$, $Z_P = 5$, $Z_D = 7.41$, verifying that the owner is better off under manager delegation by implementing (MD). To see how manager delegation performs relative to centralization, we plot how the owner's expected payoffs change as c , ℓ and π change. The changes in these parameter values are all restricted to the range consistent with our assumptions.¹⁷

Figure 2.1 shows how the owner's equilibrium expected payoffs change when c changes from 0.01 to 0.39. As c increases, Z_D decreases while Z_C and Z_P are independent of c . Thus the owner is better off under manager delegation for lower values of c . In Figure 2.2, the owner's equilibrium expected payoffs are plotted against ℓ as ℓ changes from 4 to 7.8. As ℓ increases, both Z_D and Z_C decrease but Z_D decreases at a smaller rate. At low values of ℓ , the owner prefers centralization to manager delegation. As ℓ increases, manager delegation dominates centralization until it is eventually dominated by proprietorship. Finally, Figure 2.3 shows how the owner's

¹⁶The other case is analogous but the algebra is much messier. The details are available upon request from the authors.

¹⁷In the examples of Figures 2.2 and 2.3, the value of c is set at 0.28, which makes Z_C larger than Z_D at the start in Figure 2.2, and Z_P larger than Z_D at the start in Figure 2.3.

equilibrium expected payoffs change as π changes from 0.3 to 0.8. Again manager delegation dominates centralization and proprietorship for intermediate values of π . But it is dominated by proprietorship for small values of π , and by centralization for large values of π . The patterns in which the optimal form of organizational structure changes in these figures are indeed general as discussed below.

— **Figure 2 goes about here.** —

Consider c first, the manager's cost of information gathering. From the above example, we know that there is a set of parameter values for which $Z_D = \max\{Z_C, Z_P\}$. Denote such value of c by \hat{c} .¹⁸ Let us now fix all other parameter values but change c . Since Z_C and Z_P are independent of c , and Z_D decreases in c , Z_D is the largest for all $c < \hat{c}$. As c increases beyond \hat{c} , either Z_C or Z_P is larger than Z_D . This is intuitively clear because higher c means higher cost of inducing the manager to gather information under manager delegation. Under centralization and proprietorship, the manager is not compensated because he plays no role. This leads to

Proposition 5: Fix a set of parameter values and the value of c denoted by \hat{c} for which $Z_D = \max\{Z_C, Z_P\}$. Then $Z_D \geq \max\{Z_C, Z_P\}$ for all $c \leq \hat{c}$, and $Z_D \leq \max\{Z_C, Z_P\}$ for all $c \geq \hat{c}$.

The next is ℓ , the cost of work for the worker. Recall that centralization results in suboptimal incentives for the worker since the owner does not have access to the manager's information. That is, the worker works in θ_2 even if his marginal product is less than the cost of work. An increase in ℓ then magnifies this inefficiency of centralization. While an increase in ℓ also increases the cost of the manager's compensation under delegation, the delegated manager uses his information to correct the inefficient work incentives for the worker. Indeed it is easy to see that the worker is strictly worse off under manager delegation than under centralization.¹⁹ On balance, the inefficiency of centralization is more pronounced than the increase in the compensation cost as ℓ increases, which is shown in the proof of the following proposition. Therefore we expect centralization to dominate manager

¹⁸In Figure 2.1, the approximate value of \hat{c} is 0.216.

¹⁹Denoting the worker's equilibrium expected payoffs by U_C and U_D under centralization and delegation respectively, one can show that $U_C - U_D = \frac{r\ell}{\pi\Delta p_1 + (1-\pi)\Delta p_2} - \frac{\pi r\ell}{\Delta p_1} > 0$.

delegation for small values of ℓ , which is reversed when ℓ becomes large. However, if ℓ becomes sufficiently large, then proprietorship dominates both organizational structures because both Z_C and Z_D decrease in ℓ while Z_P is independent of ℓ .²⁰ Summarizing, we have

Proposition 6: Fix a set of parameter values and the value of ℓ denoted by ℓ_1 for which $Z_D = Z_C > Z_P$. Then there is a nonempty interval (ℓ_1, ℓ_2) such that $Z_D < Z_C$ for all $\ell < \ell_1$, $Z_D \geq \max\{Z_C, Z_P\}$ for all $\ell \in [\ell_1, \ell_2]$, and $Z_D < Z_P$ for all $\ell > \ell_2$.

Proof: See the appendix.

Finally consider π , the prior probability of state θ_1 . The value of the manager's information is its use in identifying the different states, based on which to choose a project and provide proper incentives to the worker. Therefore the manager's information does not have much value when π becomes too large or too small. If π is so small that inducing shirk is almost certainly optimal, then the owner is best off with proprietorship. Similarly, if π is so large that selecting ψ_1 and inducing work is almost certainly optimal, then the owner is best off with centralization without the manager's information. It then follows that delegation can be optimal for intermediate values of π . In this case, the manager's information is valuable since uninformed decisions carry a large risk. It can be shown that the set of values of π for which Z_D is larger than Z_C and Z_P given other parameter values, is convex.²¹

Proposition 7: Fix a set of parameter values and the value of π denoted by $\hat{\pi}$ for which $Z_D = Z_C > Z_P$. Then there is a nonempty interval of π with $\hat{\pi}$ as an endpoint, on which $Z_D \geq \max\{Z_C, Z_P\}$ with strict inequality in the interior of the interval. Moreover, there is an interval $[0, \pi_1]$ with $\pi_1 < \hat{\pi}$ where $Z_P > \max\{Z_C, Z_D\}$, and an interval $[\pi_1, 1]$ with $\pi_2 > \hat{\pi}$ where $Z_D < Z_C$

Proof: See the appendix.

We summarize the main findings of this section. Under centralization, the owner is unable to motivate the manager to gather information. As

²⁰In Figure 2.2, the approximate value of ℓ is 4.579 when $Z_D = Z_C$, and 5.509 when $Z_D = Z_P$.

²¹In Figure 2.3, this interval is approximately given by $[0.363, 0.617]$.

a result, she makes a suboptimal project choice, and the ensuing contract for the worker leaves the worker too much rent. If the delegated manager gathers information, then project choice is optimal and the worker's rent can be reduced. Choosing manager delegation instead of centralization, the owner thus trades off the benefits of better information and lower incentive cost for the worker against the compensation cost for the manager. The benefits of delegation increase as the manager's information becomes more valuable and the worker needs to be compensated more for his effort. On the other hand, the cost of manager delegation increases as it becomes more costly for the manager to gather information. As a consequence, manager delegation is more likely to dominate centralization if the manager's cost of information gathering is smaller, the worker's cost of work is larger, and the manager's information becomes more valuable.

6. Further Discussions and Extensions

6.1. Alternative contracting under centralization

Under centralization, we assumed that the owner designs the worker's contract after receiving the manager's report and making a project choice. This resulted in the impossibility of an equilibrium in which the manager gathers information. The reason for this is stringent incentive compatibility constraints for the manager. Since the manager knows that his information will be used (indirectly through project choice) in contract design for the worker, which in turn affects his expected payoff, he is tempted to make a false report to induce the worker to work even though it may not be optimal for the owner. The stringent incentive compatibility constraints for the manager increase the cost of using the manager's information for the owner, which is not in her interest.

Consider now an alternative timing of contracting in which the owner simultaneously offers contracts to both agents before receiving the manager's report and making a project choice. Furthermore, suppose that the owner uses contracts that are based on the final return only. Since the owner uses only return-based contracts without the manager's information, she cannot induce different work decisions from the worker in different states: the worker

is induced to work in both states or shirk in both states.²² In this case, the manager's information does not have the indirect effect of affecting the worker's action. Thus it is easier to elicit truth-telling from the manager compared to centralization in our main model. Then it is possible to show that there is an equilibrium where the manager gathers information and reports it truthfully.

Proposition 8: Suppose the owner designs contracts based only on the final return from the project before receiving the manager's report. Then an equilibrium exists in which the manager gathers and truthfully reports information, the project choice is $C(\theta_i) = \psi_i$, $i = 1, 2$, and the worker works in both states.

Proof: See the appendix.

The main reason for the above result is that the manager's report cannot affect the worker's action via the worker's contract. This reduces the manager's incentive to manipulate information, thereby relaxing his incentive compatibility constraints. This alternative contracting can thus ameliorate the manager's incentive problem in the presence of interlocking incentives.

6.2. Worker delegation

The analyses of the previous sections indicate that manager delegation can benefit the owner only when delegation implements the outcome that the owner could not implement under centralization. Then, can the owner benefit by delegating authority to the worker instead? Specifically, the game under worker delegation proceeds as: the owner offers the worker a contract; the worker offers the manager a contract; the manager decides on information gathering and makes a report to the worker; the worker chooses a project and makes his effort decision. In this new game, the worker faces the same problem as the owner under centralization when offering a contract to the manager. Since the worker's effort decision follows the manager's report, the manager still has incentives to make a false report to induce work from the worker. As in centralization, this makes it impossible for the worker to induce

²²The timing of contracting is also crucial. If the owner offers the worker a contract after receiving the manager's report and making a project choice, then she can induce different work decisions from the worker even using return-based contracts.

the manager to gather information. Consequently, worker delegation cannot implement an outcome that cannot be implemented under centralization. The worker makes a project choice and decides on his effort without the manager's information, which the owner can replicate under centralization.

Proposition 9: The owner is never better off under worker delegation than under centralization.

Proof: See the appendix.

6.3. Extension to $\Delta p_1 > \Delta q_2 > \frac{\ell}{x}$

In this section we consider the case that Assumption 2 is relaxed as $\Delta p_1 > \Delta q_2 > \frac{\ell}{x}$. Proposition 3 still holds. Relative to the previous case, the following outcome can be optimal now:

(MD2) The manager gathers information, the project choice is ψ_i in state θ_i , $i = 1, 2$, and the worker works in both states.

This outcome may be implementable under centralization as well as under delegation. In fact, if the manager gathers information under centralization, this is the equilibrium outcome: in the proof of Proposition 1, Assumption 2 is used only to eliminate (MD2). We show below that if (MD2) is implementable under centralization, it can be done at no higher cost for the owner than under delegation. Therefore, delegation may be preferred by the owner only if it can implement an outcome, (MD) or (MD2), that cannot be implemented under centralization. That is, the benefits of delegation come from circumventing the irreconcilable conflicts between the information holder and the decision maker, which may arise under centralization, preventing a certain outcome from being implementable. The benefits do not stem from more economical implementation of the same outcome: even though the worker's incentives can be provided more efficiently under delegation, it comes at the additional cost of motivating the manager.

Proposition 10: Suppose $\Delta p_1 > \Delta q_2 > \frac{\ell}{x}$. If (MD2) is implementable under both centralization and delegation, then the owner weakly prefers to implement it under centralization.

Proof: See the appendix.

Corollary: If the owner prefers manager delegation to centralization, then she should necessarily implement an outcome that is not implementable under centralization, which is either (MD) or (MD2).

7. Conclusion

This paper has studied a model with a principal and two agents. One of the agents, called the manager, can acquire private information that can be used in choosing an investment project. The other agent, called the worker, exerts private effort that affects the success probability of the chosen project. The principal supplies funds necessary to undertake the chosen project. Identifying authority as the right to make a project choice and to design contracts for the agents, we have studied the equilibria of different organizational structures depending on the allocation of authority. Under centralization, the principal retains authority while delegation confers authority to a delegated agent. Our main results concern when the principal can benefit from delegation compared to centralization. A necessary condition for this is that delegation should motivate the manager to acquire information, which is possible only when authority is delegated to the manager.

Manager delegation results in an optimal project choice and efficient work incentives for the worker, which neither centralization nor worker delegation can implement. These efficiency gains from manager delegation are weighed against the costs of motivating the manager. Beneficial delegation obtains when the benefits exceed the costs, which is more likely if the manager's cost of information acquisition becomes smaller, the manager's information becomes more valuable, and the worker's cost of effort becomes larger.

An additional conclusion from this paper is that the delegated agent has more influence upon his own compensation than the other agent does, since the delegated agent assumes residual claim in the subcontracting stage. This, combined with the decision-making authority, can be viewed as a reasonable portrayal of a corporate hierarchy where top managers, not other stakeholders, are delegated authority, whose key role is that of direction-setting, and who are often motivated through stock and stock options. An extension of the current model that can more fruitfully elucidate the nature of incentive pay in a hierarchy seems to be an exciting avenue for future research.

Appendix

Proof of Proposition 6: We first show that Z_C decreases faster than Z_D as ℓ increases. Differentiating [2] with respect to ℓ gives us $\frac{\partial Z_C}{\partial \ell} = -\frac{\pi p_1 + (1-\pi)p_2}{\pi \Delta p_1 + (1-\pi)\Delta p_2} < 0$. Differentiating [12] with respect to ℓ leads to $\frac{\partial Z_D}{\partial \ell} = -\frac{p_1(\pi p_1 + (1-\pi)r)}{(\Delta p_1)^2} < 0$. Thus both Z_C and Z_D decrease linearly in ℓ . Since $Z_C = Z_D$ for the given set of parameter values and $\ell = \ell_1$, we have, from [2] and [12],

$$\frac{\pi p_1 + (1-\pi)p_2}{\pi \Delta p_1 + (1-\pi)\Delta p_2} = \frac{(1-\pi)\Delta p_2 x + (\pi p_1 + (1-\pi)r)\sigma}{\ell_1}. \quad [A1]$$

Using [A1], we can write

$$\left| \frac{\partial Z_C}{\partial \ell} \right| - \left| \frac{\partial Z_D}{\partial \ell} \right| = \frac{(1-\pi)\Delta p_2 x}{\ell_1} + (\pi p_1 + (1-\pi)r) \left\{ \frac{\sigma}{\ell_1} - \frac{p_1}{(\Delta p_1)^2} \right\}. \quad [A2]$$

Since $\sigma = \frac{c}{\pi \Delta p_1} + \frac{p_1 \ell_1}{(\Delta p_1)^2}$, the terms inside the curly bracket in [A2] are reduced to $\frac{\sigma}{\ell_1} - \frac{p_1}{(\Delta p_1)^2} = \frac{c}{\pi \Delta p_1 \ell_1} > 0$. Therefore $|\frac{\partial Z_C}{\partial \ell}| > |\frac{\partial Z_D}{\partial \ell}|$ around $\ell = \ell_1$. Since both Z_C and Z_D are linear in ℓ and $Z_C = Z_D$ when $\ell = \ell_1$, we must have $Z_C > Z_D$ for all $\ell < \ell_1$ and $Z_C \leq Z_D$ for all $\ell \geq \ell_1$. Since $Z_D > Z_P$ when $\ell = \ell_1$ and Z_P is independent of ℓ , there is $\ell_2 > \ell_1$ where $Z_D = Z_P$. Thus $Z_D \geq \max\{Z_C, Z_P\}$ for all $\ell \in [\ell_1, \ell_2]$ and $Z_D < Z_P$ for all $\ell > \ell_2$. ■

Proof of Proposition 7: We show first that Z_P is the largest as π becomes arbitrarily small. Taking the limit as $\pi \rightarrow 0$, we have $Z_D \rightarrow -\infty$ and $Z_C \rightarrow p_2(x - \ell/\Delta p_2) < Z_P = rx$ since $\Delta p_2 x < \ell$ by Assumption 2. We show next that both Z_D and Z_C are monotonically increasing in π . Differentiating Z_D and Z_C with respect to π , we have

$$\begin{aligned} \frac{\partial Z_D}{\partial \pi} &= \frac{c(\pi p_1 + (1-\pi)r)}{\pi^2 \Delta p_1} + \Delta p_1 \left(x - \frac{c}{\pi \Delta p_1} - \frac{p_1 \ell}{(\Delta p_1)^2} \right) > 0, \quad \text{and} \\ \frac{\partial Z_C}{\partial \pi} &= \frac{\ell(p_1 - p_2)(\pi p_1 + (1-\pi)p_2)}{(\pi \Delta p_1 + (1-\pi)\Delta p_2)^2} + (p_1 - p_2) \left(x - \frac{\ell}{\pi \Delta p_1 + (1-\pi)\Delta p_2} \right) > 0. \end{aligned}$$

Since $Z_D = Z_C > Z_P = rx$ when $\pi = \hat{\pi}$ and both Z_C and Z_D are increasing in π , there is an interval of $[0, \pi_1]$ with $\pi_1 < \hat{\pi}$, on which $Z_P > \max\{Z_C, Z_D\}$.

Next, when $\pi = 1$, we have $Z_D = p_1(x - \frac{c\Delta p_1 + p_1 \ell}{(\Delta p_1)^2}) < Z_C = p_1(x - \ell/\Delta p_1)$. Since $Z_D = Z_C$ when $\pi = \hat{\pi}$ and both Z_D and Z_C are increasing in π , there is an interval $[\pi_2, 1]$ with $\pi_2 > \hat{\pi}$, on which $Z_C > Z_D$.

Define $f(\pi) \equiv Z_D(\pi) - Z_C(\pi)$. Then, from the above, we have $\lim_{\pi \rightarrow 0} f(\pi) < 0$, $\lim_{\pi \rightarrow 1} f(\pi) < 0$, and $f(\hat{\pi}) = 0$. To show the rest of the proposition, it is sufficient to show that f is strictly quasi-concave.

By rearranging the above formulas, we have

$$f'(\pi) = \frac{cr}{\Delta p_1} \left(A + \frac{1}{\pi^2} - B \frac{1}{(\pi + a)^2} \right)$$

where

$$A = \frac{x\Delta p_1 \Delta p_2 - p_1 \ell}{cr}, \quad B = \frac{\ell \Delta p_1}{c(p_1 - p_2)}, \quad \text{and} \quad a = \frac{\Delta p_2}{p_1 - p_2}.$$

Note first that $\lim_{\pi \rightarrow 0} f'(\pi) > 0$. It then suffices to show that $f'(\pi) = 0$ at most at one value of π . From the above, $f'(\pi) = 0$ if and only if $\left(A + \frac{1}{\pi^2}\right) / \left(\frac{1}{(\pi+a)^2}\right) = B$. However, the derivative of $\left(A + \frac{1}{\pi^2}\right) / \left(\frac{1}{(\pi+a)^2}\right)$ with respect to π is $\frac{2(\pi+a)}{\pi^2} \left(A\pi^2 - \frac{a}{\pi}\right)$, which is negative because $a > 0$ and $A < 0$ due to Assumption 2. Therefore, $\frac{\partial Z_D}{\partial \pi} = \frac{\partial Z_C}{\partial \pi}$ at most at one value of π as desired. ■

Proof of Proposition 8: Denote centralized contracts by a payment $s \geq 0$ to the manager and $w \geq 0$ to the worker if x is realized, and 0 otherwise. Since the owner cannot induce different work decisions from the worker in different states, the worker is induced to work in both states or shirk in both states. If the worker shirks in both states, then there is no use of the manager's information. Thus the owner chooses proprietorship and her expected payoff is rx .

Suppose the manager gathers information and reports truthfully. For the owner to prefer this to proprietorship, she should necessarily induce the worker to work in both states. Given the prescribed action by the two agents, the owner's project choice should be $C(\theta_i) = \psi_i$, $i = 1, 2$ due to Assumption 2. Below we solve for the equilibrium that leads to the above outcome.

Let $d_m \in \{0, 1\}$ denote the manager's information gathering decision where $d_m = 1$ if he gathers information, and $d_m = 0$ otherwise. Similarly let $d_w \in \{0, 1\}$ denote the worker's work decision where $d_w = 1$ if he works, and $d_w = 0$ otherwise.

Let $V(d_m, d_w)$ be the manager's expected payoff given (d_m, d_w) and the project choice described above. If the manager gathers information and reports truthfully, then $V(1, 1) = (\pi p_1 + (1 - \pi)q_2)s - c$. Given the project choice described above, it is not optimal for the manager to make untruthful reports if he gathered information. This is due to Assumption 2. When $d_m = 0$, let $V_i(0, d_w)$ be the manager's expected payoff when he always reports θ_i , $i = 1, 2$. That is, $V_1(0, 1) = (\pi p_1 + (1 - \pi)p_2)s$ and $V_2(0, 1) = (\pi q_1 + (1 - \pi)q_2)s$. The manager could also randomize, but we can ignore this since randomization will be dominated by either of the above two. Given $d_w = 1$, the manager's incentive compatibility constraint is then

$$V(1, 1) \geq \max\{V_1(0, 1), V_2(0, 1)\} \iff s \geq \max\left\{\frac{c}{(1 - \pi)(q_2 - p_2)}, \frac{c}{\pi(p_1 - q_1)}\right\}.$$

Due to Assumption 1, $(1 - \pi)(q_2 - p_2) < \pi(p_1 - q_1)$. Thus the optimal contract for the manager is given by $s = \frac{c}{(1 - \pi)(q_2 - p_2)}$.

Let $U(d_m, d_w)$ be the worker's expected payoff given (d_m, d_w) and the project choice described above. Given that the manager gathers information and reports truthfully, the worker's incentive compatibility constraint is

$$\begin{aligned} U(1, 1) \geq U(1, 0) &\iff (\pi p_1 + (1 - \pi)q_2)w - \ell \geq rw \\ &\iff w \geq \frac{\ell}{\pi \Delta p_1 + (1 - \pi) \Delta q_2}. \end{aligned}$$

Thus the optimal contract for the worker is $w = \frac{\ell}{\pi \Delta p_1 + (1 - \pi) \Delta q_2}$.

The expected payoff for the owner is then

$$Z \equiv (\pi p_1 + (1 - \pi)q_2) \left(x - \frac{c}{(1 - \pi)(q_2 - p_2)} - \frac{\ell}{\pi \Delta p_1 + (1 - \pi) \Delta q_2} \right).$$

and the described equilibrium exists if $Z \geq rx$. ■

Proof of Proposition 9: For worker delegation to benefit the owner relative to centralization, the worker should work in at least one of the two states. We show below that worker delegation cannot induce the manager to gather information. Therefore the worker cannot make different work decisions depending on states: he either works in both states or shirks in both

states. This leads to the same outcome and the same expected payoff for the owner as in centralization.

Let ω be the owner's payment to the worker in case of success, and σ_i be the worker's payment to the manager in case of success when ψ_i is chosen, $i = 1, 2$. Suppose the manager gathers information and reports truthfully. Then it is not in the worker's interest to work in θ_2 . Suppose he does. Then his expected payoff is $p_2(\omega - \sigma_1) - \ell$ if he chooses ψ_1 , and $q_2(\omega - \sigma_2) - \ell$ if he chooses ψ_2 . The worker's IC requires these expected payoffs to be no less than $r\omega$. But this is impossible due to Assumption 2. Thus we can focus on the case where the worker works only in θ_1 .

Consider now the four possible cases of project choice the worker makes based on the manager's report: (i) $C(\theta_i) = \psi_1$ for $i = 1, 2$; (ii) $C(\theta_i) = \psi_2$ for $i = 1, 2$; (iii) $C(\theta_i) = \psi_j$ for $i \neq j$; (iv) $C(\theta_i) = \psi_i$ for $i = 1, 2$. We consider the manager's IC constraints in each of these cases. In (i), they are $p_1\sigma_1 \geq r\sigma_1 \geq p_2\sigma_1$, which is impossible since $p_2 > r$. In (ii), they are $q_1\sigma_2 \geq r\sigma_2 \geq q_2\sigma_2$, which is again impossible since $q_2 > r$. In (iii), the manager's IC requires $q_1\sigma_2 \geq r\sigma_1 \geq q_2\sigma_2$, which is impossible since $q_2 > q_1$. In (iv), the manager's IC dictates $p_1\sigma_1 \geq r\sigma_2 \geq p_2\sigma_1$, which implies $\sigma_2 \geq \frac{p_2}{r}\sigma_1 > \sigma_1$. Then, in θ_2 , the worker is better off choosing ψ_1 rather than ψ_2 . In sum, there cannot be an equilibrium under worker delegation in which the manager gathers information.

Consequently the owner induces the same action from the worker regardless of states. If she induces work from the worker, then it is optimal for her to induce the worker to choose ψ_1 since ψ_1 is better than ψ_2 given the prior belief. In this case, the optimal payment to the worker is $\omega = \frac{\ell}{\pi\Delta p_1 + (1-\pi)\Delta p_2}$. Given ω , it is not in the worker's interest to choose ψ_2 . Thus worker delegation results in the same outcome and the same expected payoff for the owner as in centralization. ■

Proof of Proposition 10: It is clear that, for either regime to implement (MD2), the lowest wage for the worker in case of success is $w_1 = \frac{\ell}{\Delta p_1}$ in θ_1 and $w_2 = \frac{\ell}{\Delta q_2}$ in θ_2 . Let σ denote the lowest equilibrium salary for the manager under delegation that induces (MD2). Then, the manager's IC implies, in particular,

$$\pi p_1(\sigma - w_1) + (1 - \pi)q_2(\sigma - w_2) - c \geq (\pi p_1 + (1 - \pi)p_2)(\sigma - w_1) \quad [A3]$$

where the LHS of [A3] is the manager's equilibrium expected payoff and the RHS is his expected payoff when he selects project 1 without gathering information and induces work.

Let s_1 and s_2 be a pair of salaries for states 1 and 2 that induces (MD2) if offered to the manager under centralization. Then, they satisfy the following equilibrium conditions:

- i) $p_1 s_1 \geq q_1 s_2, q_2 s_2 \geq p_2 s_1 \iff \frac{q_2}{p_2} \geq \frac{s_1}{s_2} \geq \frac{q_1}{p_1}$;
- ii) $\pi p_1 s_1 + (1 - \pi) q_2 s_2 - c \geq \max\{(\pi p_1 + (1 - \pi) p_2) s_1, (\pi q_1 + (1 - \pi) q_2) s_2\}$;
- iii) $p_1(x - s_1 - w_1) \geq \max\{q_1(x - s_2 - w_2), r(x - s_1), r(x - s_2)\}$;
- iv) $q_2(x - s_2 - w_2) \geq \max\{p_2(x - s_1 - w_1), r(x - s_1), r(x - s_2)\}$.

In the above, i) and ii) are the manager's interim and ex ante IC constraints, respectively, and iii) and iv) are the owner's ex post IC constraints for project choice. Conversely, if these conditions are satisfied, s_1 and s_2 would induce (MD2) if offered to the manager under centralization.

Given s_1 and s_2 that induce (MD2) under centralization, the expected payment to the manager in this equilibrium is $P(s_1, s_2) \equiv \pi p_1 s_1 + (1 - \pi) q_2 s_2$. If this is smaller than that under delegation, $P(\sigma) \equiv \pi p_1(\sigma - w_1) + (1 - \pi) q_2(\sigma - w_2)$, the claim of the proposition is proved because the expected payment to the worker is the same under the two regimes. Hence, we consider the other possibility below.

If $P(s_1, s_2) > P(\sigma)$, then $s_1 > \sigma - w_1$ or $s_2 > \sigma - w_2$. Below we consider three such possibilities one by one, and construct another pair, \hat{s}_1 and \hat{s}_2 , that satisfy the conditions i) - iv) above and $P(\hat{s}_1, \hat{s}_2) \leq P(\sigma)$. Since the latter pair would implement (MD2) if offered under centralization, this completes the proof.

First, suppose $s_1 > \sigma - w_1$ and $s_2 > \sigma - w_2$. Let $\hat{s}_i = \sigma - w_i$, $i = 1, 2$, so that $P(\hat{s}_1, \hat{s}_2) = P(\sigma)$. Then, i) and ii) hold for \hat{s}_i because they are part of the manager's interim and ex post IC constraints under delegation with salary σ . In addition, iii) and iv) also hold for \hat{s}_i : Since $\hat{s}_i + w_i = \sigma$ and $\hat{s}_1 > \hat{s}_2$, violation of iii) or iv) would necessarily mean that $q_2(x - \hat{s}_2 - w_2) < r(x - \hat{s}_2)$ which, in turn, would mean $q_2(x - s_2 - w_2) < r(x - s_2)$ because $q_2 > r$ and $s_2 > \hat{s}_2$. But this contradicts iv) for s_1 and s_2 .

Next, suppose $s_1 > \sigma - w_1$ and $s_2 \leq \sigma - w_2$. Let $\hat{s}_1 = \sigma - w_1$ and $\hat{s}_2 = s_2$, so that $P(\hat{s}_1, \hat{s}_2) \leq P(\sigma)$. Then, i) holds for \hat{s}_i because $\frac{q_2}{p_2} \geq \frac{s_1}{s_2} \geq \frac{\hat{s}_1}{\hat{s}_2} \geq \frac{\sigma - w_1}{\sigma - w_2} \geq 1 \geq \frac{q_1}{p_1}$; ii) holds because the RHS is equal to $(\pi p_1 + (1 - \pi) p_2) s_1$ due to Assumption 1, which decreases more than the LHS as \hat{s}_1 replaces

s_1 ; iii) holds because the LHS increases more than the RHS as \hat{s}_1 replaces s_1 ; iv) holds because $q_2(x - s_2 - w_2) > p_2(x - \sigma) = p_2(x - \hat{s}_1 - w_1)$, and $q_2(x - s_2 - w_2) \geq r(x - s_2)$ from iv) for s_i and $r(x - s_2) > r(x - \hat{s}_1)$.

Finally, suppose $s_1 \leq \sigma - w_1$ and $s_2 > \sigma - w_2$. Let $\hat{s}_1 = s_1$ and \hat{s}_2 be such that $P(\hat{s}_1, \hat{s}_2) = P(\sigma)$. Note $s_2 > \hat{s}_2 \geq \sigma - w_2$. Then, i) holds for \hat{s}_i because $\frac{q_2}{p_2} \geq \frac{\sigma - w_1}{\sigma - w_2} \geq \frac{\hat{s}_1}{\hat{s}_2} \geq \frac{s_1}{s_2} \geq \frac{q_1}{p_1}$; ii) holds because the LHS is $P(\hat{s}_1, \hat{s}_2) - c = P(\sigma) - c \geq (\pi p_1 + (1 - \pi)p_2)(\sigma - w_1) \geq (\pi q_1 + (1 - \pi)q_2)s_2$ decreases more than the LHS as \hat{s}_2 replaces s_2 ; iv) holds because the LHS increases more than the RHS as \hat{s}_2 replaces s_2 ; iii) holds because $p_1(x - s_1 - w_1) > q_1(x - \sigma) \geq q_1(x - \hat{s}_2 - w_2)$, and $p_1(x - s_1 - w_1) > q_2(x - \sigma) \geq q_2(x - \hat{s}_2 - w_2) \geq \max\{r(x - s_1), r(x - \hat{s}_2)\}$ where the last inequality follows from iv).

Thus if the owner can implement (MD2) under centralization and manager delegation, she can implement it under centralization at no larger cost. Since the same outcome is implemented in both regimes, the owner weakly prefers centralization to manager delegation. ■

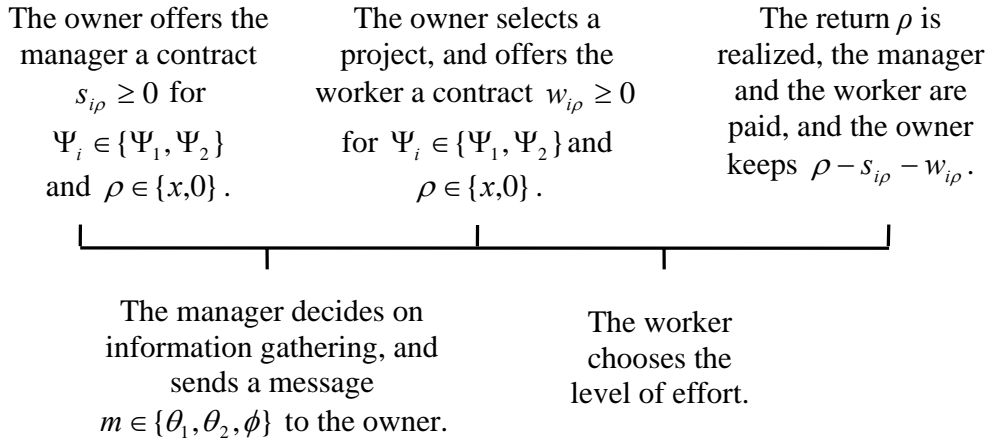
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Time-line under Centralization



Time-line under Delegation

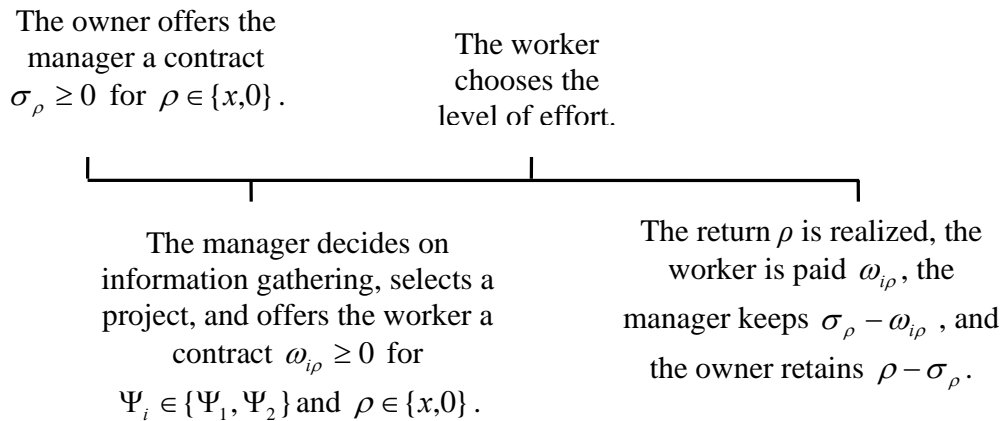


Figure 1: Time-line under Centralization and Delegation

Figure 2.1: Changes in c

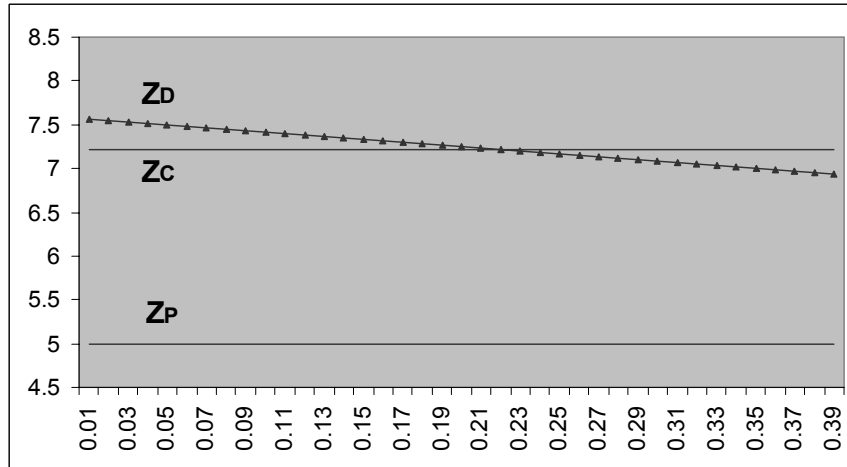


Figure 2.2: Changes in l

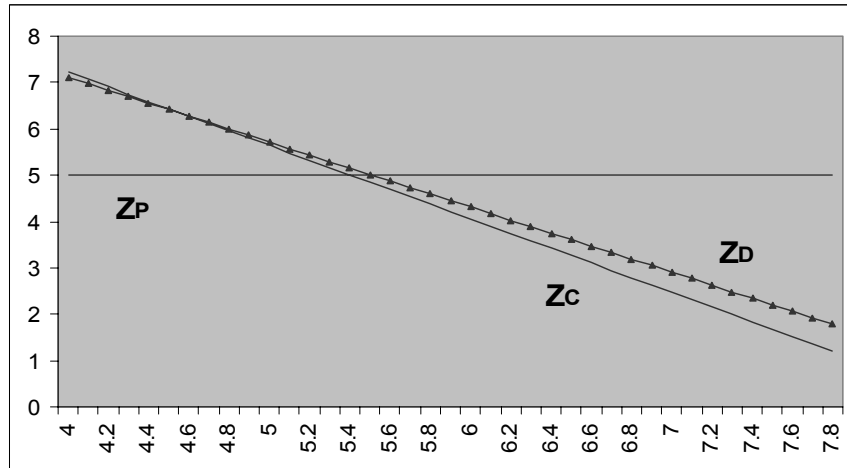


Figure 2.3: Changes in π

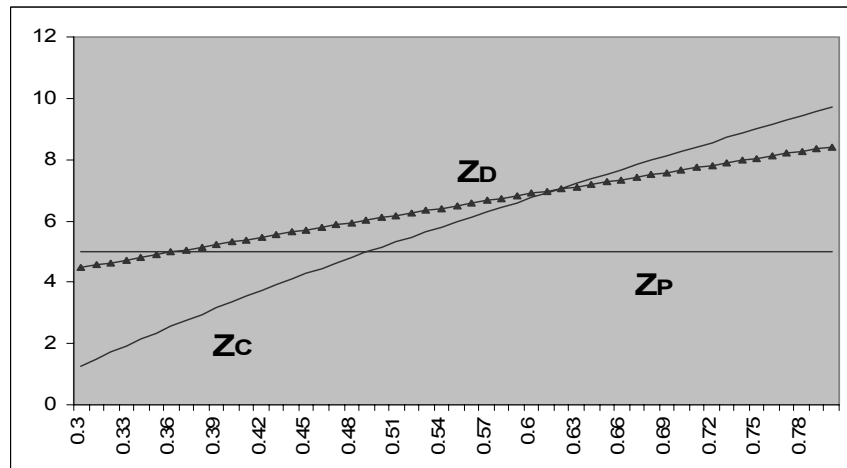


Figure 2: The Owner's Expected Payoffs