Information, Authority, and Corporate Hierarchies

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Abstract

In a typical corporate hierarchy, the manager is delegated the authority to make strategic decisions, and to contract with other employees. By studying a model with one principal and two agents where one agent can gather information that is valuable for the principal's project choice and the other agent provides effort to the chosen project, we study when the principal can benefit from such delegation relative to centralization. We show that beneficial delegation is possible when complete contracts cannot be written, and delegation of authority should necessarily be to the information gatherer. The benefits of delegation stem from either efficiency gains or reduction in rent to the information gatherer.

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I. 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 structure of modern 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 where managers are placed between owners and other stakeholders.(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?

The first step to answering the questions above is to understand the manager's role. In his classic work, Simon (1977) argues that the most important role of manager is gathering, processing information, and making decisions based on this.(2) He writes:

> Executives and their staffs spend a large fraction of their time surveying the economic, technical, political and social environment to identify new conditions that call for new actions. They probably spend an even larger fraction of their time [...], seeking to invent, design, and develop possible courses of action for handling situations where a decision is needed (Simon, 1977, p. 40).

Radner (1992, 1993) also treats information processing and decision making as the manager's main task, distinct from the roles played by other employees. According to him, managing is a specialized activity, synonymous to decision making, distinct from 'production'. The manager's role as a decision maker is legitimized by authority, which can be defined as the 'power to make decisions which guide the actions of another' (Simon, 1997, p. 179).

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(1) Separation 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).

(2) Case studies by Mintzberg (1973) provide rich supporting evidence for this.

Granted that the manager's role is information gathering and decision making, a natural question is why owners *voluntarily* delegate authority to the manager. On efficiency grounds at least, it seems that the authority to make decisions should rest with the party who can gather or has necessary information and the ability to use it.(3) Indeed, a typical explanation for delegation in corporations is based on the manager's expertise and the ensuing benefits of specialization. Jensen and Murphy (1990) 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 (Jensen and Murphy, 1990, p. 251).

Underlying the above explanation is the supposition that communicating the manager's information is costly, or that shareholders or boards do not have necessary expertise to process the information for decision-making even if communication is costless.(4) For, otherwise, shareholders or boards will be able to make decisions based on the manager's information, which is the central insight from the revelation principle. While the efficiency benefits from delegation are reasonable to expect, it is less clear whether or how the efficiency benefits can flow back to shareholders. Specifically if delegation results in too much rent dissipated to the manager, then shareholders would be worse off despite overall efficiency gains.

This paper proposes a model that highlights the manager's role as information gatherer and decision maker, and formalizes when and why owners can benefit from delegating authority to the manager. The existing literature has studied hierarchical delegation either by adopting the conventional adverse selection or moral hazard models, or by using an incomplete contracting approach.(5) In the former approach, the manager's information is about the hidden cost parameter or actions of other agents within the organization, rather than about the conditions external to the organization that call for new actions. The manager's role in this case is akin to that of supervisor or monitor, rather than what is described by Simon or Radner. In the latter approach, the manager's information is relevant for decision making and the focus is on the allocation of decision authority, but the issues of contracting are largely left untouched. The main innovation of our paper is two-fold. First, we focus on the two most salient aspects of authority within the firm, the authority to make decisions and the authority to design and offer contracts to other parties. Thus we complement the incomplete contracting literature on organization design by

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(3) See, for example, Milgrom and Roberts (1992), or Baron and Kreps (1999).

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

(5) This literature is reviewed in Section II.

considering both decision authority and contracting authority. Second, we provide conditions under which a multi-tier hierarchy emerges as an optimal organizational structure where the manager, not other parties, is at the center of the hierarchy. The multi-tier hierarchy thus identified may be regarded as a reasonable portrayal of corporate hierarchy. We sketch below the key features of our model and the intuition behind the main result.

Consider a firm that consists of an owner and two heterogenous agents. The owner has two investment projects and the return from each project depends on the state of nature. One agent can, at some costs, acquire private information about the state of nature, which can be used for project choice. We call this agent the manager. The other agent, whom we call the worker, can exert effort that can increase the likelihood that the chosen project is successful. An organizational structure specifies allocation of authority. We consider two types of authority, one related to contract design and the other related to project choice. In any organizational structure, the owner retains the authority to contract with at least one agent. We will call this contract the primary contract. So the first type of authority, called the contracting authority, specifies who designs and makes a take-it-or-leave offer of contract to the agent who does not hold the primary contract. The second type of authority, called the decision authority, refers to the right to make a project choice decision. In exercising the decision authority, the party can demand communication of information from the manager if, of course, the manager is not the party with decision authority. Our focus is on the owner's problem of choosing an organizational structure that maximizes her expected payoff.

In centralization, the owner has both types of authority while in delegation, one or both types of authority is delegated to the agents. Of particular interest is when both types of authority are delegated to the manager. In this case, the organizational structure can be described as a three-tier hierarchy where the manager is at the center of the hierarchy. We consider two contracting environments. In the first environment called complete contracting, the communication of manager's information, project choice, and the return from the chosen project are all contractible upon.[(6)] In the second environment called partial contracting, only the return is contractible upon.

We first show that, in the complete contracting environment, the owner cannot benefit from any forms of delegation, hence centralization is her preferred organizational structure. This is a direct consequence of the revelation principle although our model has elements of post-contractual information asymmetry and moral hazard. With costless communication of manager's information, the owner can centrally implement any outcome that can be implemented when the manager is delegated

[(6)] In the model we study, the case where only project choice and return are contractible upon is equivalent to the case of complete contracting, as explained in Section III.

authority. Thus centralization is equivalent to any organizational structures where the manager is delegated one or both types of authority. If authority is delegated to the worker, however, the owner is strictly worse off due to limited liability. This is because the worker's incentive problem conditional on the manager's information is the same under centralization and delegation, whence conferring the contracting authority to the worker results in double marginalization of rent (McAfee and McMillan, 1995; Mookherjee, 2006).

In the partial contracting environment, centralization continues to dominate any organizational structures in which the worker is delegated authority. However, delegating authority to the manager, the contracting authority in particular, can benefit the owner. The benefits from delegating authority to the manager come from two sources.

First, if the two projects are sufficiently different in their return distributions, then the manager may find it optimal not to acquire information but send a message to the owner that would result in his preferred project to be chosen. This is because, in centralization in the partial contracting environment, the manager's contract is independent of the worker's contract, depending only on the return from the chosen project, not on his information communicated to the owner. The manager's communication, of course, carries no information content and the owner optimally bypasses the manager. In this case, centralization results in a suboptimal investment decision and inefficient effort provision by the worker. Delegating authority to the manager can change this as it makes him a residual claimant in the subcontracting stage. Thus the manager's payoff in delegation is dependent on the worker's contract he would offer, and indirectly on project choice as well. This motivates the manager to acquire information since proper exercise of authority requires information acquisition, which, albeit at cost, can pay off since it can increase his residual claim. Thus delegation can result in an optimal investment decision and efficient effort provision by the worker. Such efficiency gains from delegation are weighed against the costs of motivating the manager. We show that delegation is more likely to dominate centralization 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.

Second, even when centralization can induce information acquisition and implement an optimal investment decision, delegation of authority to the manager can benefit the owner as it can reduce the rent that the owner needs to pay the manager to motivate him to acquire and communicate information truthfully. Once again, the residual claim given to the manager in the subcontracting stage enables the owner to provide tighter incentives to the manager, thereby reducing the cost of observing the manager's incentive constraints under centralization.

Our work differs from and complements the existing literature at least in three ways. First, the manager is not endowed with private information in our model.

Rather, he needs to incur private costs to acquire information. Because of costly information acquisition, there are benefits from delegating authority to the manager. In the existing studies on hierarchy, there is no a priori reason why a particular agent should be at the center of the multi-tier hierarchy.(7) 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 gatherer 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. As stressed in the aforementioned quotes by Simon (1977), Radner (1992, 1993), and Jensen and Meckling (1990), the manager's information acquisition and subsequent decision making are what distinguish managerial inputs from those of other employees in corporations. Roughly speaking, the manager's decision 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. 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)

Third, our results show that beneficial delegation to the manager is possible only when complete contracts cannot be written due to either complexity or contracting costs. This is consistent with managerial contracts in the real world, which are almost all output-based and other information such as the manager's report or project choice is hardly used. Thus the dominance of delegation over centralization in our partial contracting environment seems to square well with reality. Finally, the only information-related cost in our model is that of information gathering by the manager. For clarity of exposition and tractability of analysis, we leave out other information-related costs. Any additional costs of communicating information (e.g., Laffont and Martimort, 1998) or processing it (e.g., Radner, 1993; Van Zandt, 1999)

(7) Baliga and Sjöström (1998) is a notable exception, although the agent at the center of the hierarchy in their model is the one who can observe the other agent's effort, rather than acquire external information that can be used for decision making.

(8) One 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.).

would only strengthen the case for delegation to the information gatherer.

The rest of the paper is organized as follows. Section II reviews the related literature. Section III describes the model. The case of complete contracting is studied in Section IV while Section V is on the partial contracting environment. Section VI compares centralization with delegation to the manager. Section VII concludes the paper. The appendix contains the proofs of the results that are not central to the exposition of our main ideas.

II. Related Literature

The main focus of this paper, namely an optimal multi-tier hierarchy, is directly related to a large body of literature on incentive-based explanations of hierarchy.(9) We refer the readers to Mookherjee (2006) for an excellent review and discuss only briefly where our paper stands relative to the existing studies. For convenience, we divide the literature broadly into two categories.

First, many studies adopt the conventional adverse selection model with one principal and at least two agents, where each agent has private information about his production cost. In an environment where the revelation principle applies, centralization cannot be dominated by any other mechanisms. Thus hierarchy can be equivalent to centralization at best. The equivalence of centralization and hierarchy under some conditions is shown, among others, by Baron and Besanko (1992), Gilbert and Riordan (1995), and Melumad, Mookherjee and Reichelstein (1995). Faure-Grimaud, Laffont and Martimort (2003) also show the equivalence when one of the agents is replaced by a supervisor, whose primary role is to observe the productive agent's cost information. When conditions for the revelation principle do not hold, hierarchy can dominate centralization. This is shown by Laffont and Martimort (1998) when there are limits on communication and the possibility of collusion between agents, and by Melumad, Mookherjee and Reichelstein (1992, 1997) under restrictions on message space. On the other hand, Mookherjee and Tsumagari (2004) generalize the model in Laffont and Martimort (1998) to show that hierarchy is in general strictly dominated by centralization due to double marginalization of rents.(10) The latter is also shown by McAfee and McMillan (1995) when contracts are subject to limited liability.

Second, a number of papers study the standard moral hazard setting with one

(9) Other strands of literature on multi-tier hierarchy are concerned with the issue of monitoring and loss of control (Williamson, 1967; Calvo and Wellisz, 1978; Qian, 1994), or the information-processing capacity of hierarchy (Radner, 1993; Van Zandt, 1999). Hart and Moore (2005) focus on the allocation of authority within hierarchies but without the element of incentives.

(10) The 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.

principal and two agents where each agent takes hidden action. Baliga and Sjöström (1998), and Macho-Stadler and Pérez-Castrillo (1998) show the equivalence of hierarchy and a centralized mechanism subject to the possibility of collusion. An additional conclusion of Baliga and Sjöström relates to the pattern of hierarchical delegation: when one agent can freely observe the other agent's action but not vice versa, the agent with superior information should be delegated the contracting authority. While not directly concerned with multi-tier hierarchies, Itoh (1992, 1993) also studies a multiple-agent moral hazard environment to examine conditions under which the principal can benefit by allowing coalition of agents, when agents can monitor each other. These findings can also be regarded as supportive of delegation over centralization when agents have informational advantages over the principal.

Our paper shares common interest with the above studies, but differs from them in motivation and modelling approach. Our goal is to understand the emergence of corporate hierarchy where decision maker and input supplier are linked in a hierarchical fashion. This led us to introduce two heterogeneous agents, an information gatherer and an input supplier. In line with the manager's role as described by Simon (1977), Radner (1992, 1993), and Jensen and Murphy (1990), we show that an optimal hierarchy should necessarily have the information gatherer at the middle tier of the hierarchy. In an optimal hierarchy, the information gatherer has both decision making authority and contracting authority. In contrast, a hierarchy in the above studies is delineated by and large by the contracting authority only. The agent in the middle tier of the hierarchy is not a decision maker but only observes other agent's hidden cost parameter or action, which he communicates to the principal or uses in designing the contract for the other agent. Such a role is akin to monitoring or supervision. As the earlier quotation from Simon (1997) suggests, the manager's role is to gather information external to the firm and make strategic decisions, going beyond that of monitoring or supervising subordinates.

A number of recent studies have been concerned with the allocation of authority within an organization in tackling coordination problems (Athey and Roberts, 2001; Friebel and Raith, 2006; Dessein, Garicano and Gertner, 2007; Alonso, Dessein and Matouschek, 2008; Rantakari, 2008). For example, Alonso, Dessein and Matouschek (2008) and Rantakari (2008) show that coordination can be achieved through cheap talk communication between division managers when they are given the decision authority, the benefits of which increase with decentralization. However, these studies are not directly concerned with multi-tier hierarchies. On the other hand, Choe and Ishiguro (2008) show that, in the absence of such communication, hierarchical delegation can be another way to improve coordination relative to complete decentralization. These studies typically follow the control rights literature initiated by Aghion and Tirole (1997). Thus there is no formal contract except for the allocation of decision authority. Our paper is also concerned with the allocation of authority but it incorporates both the decision and contracting authority.

With formal contracts and no limit on communication, the decision authority turns out not to have much bite but the contracting authority does matter. In particular, we show how delegation of contracting authority can benefit the principal when it is to the information gatherer, but hurts it is to the input supplier.

Finally, the aspect of information gathering by the manager in our model can be related to several studies on strategic information gathering. Crémer and Khalil (1992) allow the possibility for the agent to gather information after the contract is offered but before it is signed. In case unfavorable states are observed, the agent can reject the contract. They show that the principal offers a contract that induces the agent not to gather information, hence information remains symmetric. In related papers, Crémer and Khalil (1994), and Crémer, Khalil and Rochet (1998) consider a situation where the agent can gather costly information before a contract is offered. Information does not have social value in these studies, as it will become known at no cost once the parties sign a contract. Therefore, the main reason for socially wasteful information gathering is for the agent to improve his bargaining position. A general message from these studies is that such pre-contractual information gathering leads to deviation from the first-best efficient allocation. Information gathering in our paper is quite different from that in these studies: the manager's information is valuable for project choice and subsequent contracting with the worker, hence the optimal contract for the manager is structured to provide incentives for information gathering.

III. The Model

A. Players, Technology and Outcomes

There are three parties, a principal and two heterogeneous agents, whom we call the manager and the worker.(11) The principal has two projects, called A and B. The return from either project is random with a binary support $X := \{x, 0\}$ where $x > 0$. We call the event of positive return a success. The probability of success from project A depends on the underlying state, θ, and the worker's action which is a binary choice between "work" or "shirk". The monetary cost of work is $\ell > 0$ and that of shirk is normalized to 0. The state θ is a binary random variable assuming θ_1 and θ_2 with probabilities $\pi \in (0, 1)$ and $1 - \pi$, respectively. The probability of success from project A is $p_i \in (0, 1)$ in state θ_i if the worker chooses work; If the worker chooses shirk, the probability of success is 0 in both states.(12) Project B does not require the worker's input and has a success probability of $q \in (0, 1)$ regardless of state.

(11) We will use the female gender pronoun for the principal and the male gender pronoun for the manager and the worker.

(12) This simplifies notation and analysis. Our main qualitative results are robust to different success probabilities when the worker shirks, as long as they are sufficiently small.

That the return from project B has the same support as project A is to ensure that the return does not reveal which project was chosen.[13] Also the assumption that project B does not require the worker's input is for the sake of simplicity. What is essential is that the worker's optimal action is necessarily state-dependent, of which the simplest case is where only project A requires the worker's input.

The return from either project is publicly observable and verifiable, while the worker's action is private information. After a state $\theta \in \{\theta_1, \theta_2\}$ is realized, the manager is the only party that can observe a signal that is correlated with the state, which will be called information gathering. Information gathering is costly to the manager, and its monetary equivalent cost is $c > 0$. For simplicity we assume that the signal is a perfect predictor of the state, i.e., the manager observes the true state θ if he gathers information. If the manager does not gather information, then he observes nothing and we denote this null signal by $\emptyset$, so the set of all possible signals is $\Theta := \{\theta_1, \theta_2, \emptyset\}$.

The precise order of events differs depending on organizational structures, which will be described in the next subsection. In any organizational structure, each agent is offered a contract that specifies compensation contingent on contractible variables. We assume that both agents are risk-neutral and maximize the expected compensation net of any cost. The principal is also risk-neutral and maximizes the expected return net of compensation payments. The aforementioned structure of the game is common knowledge. Our focus is on the principal's problem of choosing an organizational structure that is best for her.

Next, we introduce restrictions on parameter values that would make the problem of contracting with multiple agents interesting and non-trivial. If $p_i x - \ell \geq qx$ for $i = 1, 2$, it is optimal to undertake project A and induce work regardless of state. If $p_i x - \ell \leq qx$ for $i = 1, 2$, on the other hand, it is optimal to undertake project B regardless of state, in which case worker's input is irrelevant. In both cases the manager's information is not valuable and the solution to the principal's problem is trivial. An interesting case of multi-agent contracting thus arises when the worker's optimal action depends on the manager's information. Therefore, we assume that the manager's information is valuable, i.e., without loss of generality,

ASSUMPTION 1: $p_1 x - \ell > qx > p_2 x - \ell$.

Then, the *ex post* efficiency is obtained in the following outcome:

(C1) Project A is chosen and the worker works in θ_1, and project B is undertaken in θ_2. The total expected surplus is $V_1 := \pi(p_1 x - \ell) + (1 - \pi)qx - c$.

For this outcome to be implemented, the manager should gather information, so that project A (B, resp.) is chosen in θ_1 (θ_2, resp.), followed by the worker choosing

(13) As will become clear, this assumption of 'no moving support' limits the set of feasible contracts the principal can use when only return is contractible.

work if $\theta = \theta_1$. This outcome is indeed socially optimal if the extra surplus from the use of manager's information exceeds the cost of his gathering information, c. However, whether the principal would wish to implement (C1) depends on the cost of inducing the manager to gather information and report truthfully, which may be larger than c due to limited liability. If it is too high, then the principal will implement an alternative outcome.

To see what other outcomes the principal needs to consider, notice first that, whenever the manager's information is used, the worker should be induced to work for project A only in θ_1 since $qx > p_2x - \ell$. That is, any outcome in which the manager's information is used should necessarily be (C1). Thus the only other outcomes the principal needs to consider in addition to (C1) are the ones in which the manager's information is not used. There are two such outcomes that are not dominated:

(C2) Project A is undertaken regardless of the state and the worker works. The total expected surplus is $V_2 := [\pi p_1 + (1-\pi)p_2]x - \ell$.

(C3) Project B is undertaken regardless of the state, in which case the worker's input is irrelevant. The total expected surplus is $V_3 := qx$.

The principal can easily implement (C2), e.g., by offering a null contract to the manager, always choosing project A, and offering the worker a contract specifying a payment of $w = \ell/[\pi p_1 + (1-\pi)p_2]$ in case of success and $w = 0$ otherwise. Hence, the principal's expected payoff from implementing (C2) is equal to the entire surplus V_2. The principal can also implement (C3) trivially by always choosing project B without engaging either agent, whence again extracting the total surplus V_3. These two outcomes are the principal's fall-back options. Since (C3) is not an interesting case, we assume

ASSUMPTION 2: $V_2 > V_3 \iff \pi p_1 + (1-\pi)p_2 - q > \ell/x$.

Finally we assume $V_1 > V_2$ since, otherwise, the multi-agent contracting problem is reduced to the standard principal-agent problem between the principal and the worker. This is because V_1 is the maximum possible surplus the principal can attain by engaging the manager while she can always secure V_2 by directly contracting with the worker without the manager's information.

ASSUMPTION 3: $V_1 > V_2 \iff (1-\pi)(qx + \ell - p_2x) > c$.

The term $(1-\pi)(qx + \ell - p_2x)$ shows the potential benefits from using the manager's information: θ_2 is observed with probability $1-\pi$, in which case it is optimal to choose project B for the expected return of qx, instead of choosing project A and hiring the worker, which returns $p_2x - \ell$. Since the former is larger than the latter due to Assumption 1,(14) the value of manager's information can

(14) The first part of Assumption 1, $p_1x - \ell \geq qx$, is implied by Assumptions 2 and 3 since $V_1 > V_3$ implies $p_1x - \ell > qx + c/\pi$.

be measured as the difference between the two, $qx - (p_2x - \ell)$. Given that the manager's information gathering cost is c, Assumption 3 means that the manager's information is valuable.

Note that the above assumptions imply that π is neither too large nor too small. If it is so large that $\theta = \theta_1$ almost certainly, then there is no need for the manager's information and the principal is better off implementing (C2). Similarly, if π is too small, then $\theta = \theta_2$ almost certainly, in which case (C3) can be the best option for the principal.(15) Given Assumption 2, (C2) is the principal's fall-back option, which she can implement through centralized contracting. Therefore, in the sequel we focus on various organizational structures that the principal can adopt to implement (C1).

B. Authority and Organizational Structure

Based on the possible events described above, we now discuss various organizational structures that can be adopted to govern contracts among the three parties.

There are three public actions to be taken in our model: selecting a project between A and B, contracting with the manager, and contracting with the worker. An organizational structure specifies allocation of authority as to who takes which of these three actions. In each contracting, we assume that the party with the authority makes a take-it-or-leave offer to the other party. In making a project choice, the party with the authority can demand communication of information from the manager unless, of course, the manager has the authority.

By *centralization* we mean an organizational structure in which the principal takes all three actions. In terms of timing, the manager's contract should be offered before the manager gathers information since, otherwise, the manager would not gather information due to the hold-up problem (i.e., the cost of information gathering would be already sunk at the time of contracting). On the other hand, the worker's contract can be offered either before or after the principal makes a project choice decision. However, since the worker's input is needed only in project A and our focus is on (C1), it is easy to see that the worker's incentive problem turns out to be the same in both cases. So we assume that the worker's contract is offered after project choice. Thus events unfold in the following order. First, the principal offers a contract to the manager. Second, a state is realized and the manager makes a decision on information gathering. Third, the manager communicates his information to the principal, based on which the principal makes a project choice. If project A is chosen, then the principal offers a contract to the worker, who then chooses his action. Return from the chosen project realizes and payments are made according to the contracts.

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(15) To be precise, the lower bound of π implied by Assumption 2 is $[\ell - (p_2 - q)x]/(p_1 - p_2)x$ and the upper bound of π implied by Assumption 3 is $1 - c/[\ell - (p_2 - q)x]$.

Being the ultimate residual claimant, the principal always retains the authority to contract with at least one agent who we call the *primary agent*. By *delegation* we mean any organizational structure in which the primary agent is bestowed with the right to make a contract with the other agent, called the *contracting authority*, or the right to make a project choice decision, called the *decision authority*. Depending on whether one or both of these authorities are delegated, we subdivide delegation into partial delegation and full delegation.

Within *partial* delegation, the principal may retain the decision authority but delegates the contracting authority to the primary agent. We call this *MC-delegation* if the manager is the primary agent, and *WC-delegation* if the worker is. In either case, the contract between the two agents specifies payments from the primary agent, rather than the principal, to the other agent for various contractible contingencies. The key aspect in this type of partial delegation is hierarchical contracting: in MC-delegation, for example, the principal offers a contract to the manager, who in turn offers a contract to the worker. In MC-delegation, the timing of events is the same as in centralization except that, in the penultimate stage when the principal chooses the project, the manager rather than the principal offers a contract to the worker. In WC-delegation, the timing changes. First, the principal offers a contract to the worker. After this, the worker offers a contract to the manager, who then decides on information gathering. This is followed by the manager's communication with the principal, who then makes a project choice. Finally the worker chooses his action if project A is chosen.

Alternatively, the principal may retain the contracting authority but delegates the decision authority to the primary agent. We call this *MD-delegation* if the manager is the primary agent, and *WD-delegation* if the worker is. In MD-delegation, the principal offers a contract to the manager, who then decides on information gathering and chooses a project. If project A is chosen, then the principal offers a contract to the worker. In WD-delegation, a meaningful exercise of decision authority by the worker requires the worker's contract be offered before communication of the manager's information. Thus the timing of events changes. First, the principal offers contracts to both agents. This is followed by the manager's communication of information to the worker, who then makes a project choice and chooses his action.

In *full* delegation, either the manager is delegated with both types of authority, called *M-delegation*, or the worker is, called *W-delegation*. In M-delegation, the primary contract is between the principal and the manager, while in W-delegation, it is between the principal and the worker. The timing of events in M-delegation is the same as in MC-delegation except that the manager, rather than the principal, makes a project choice decision without communicating his information. Likewise, the timing of events in W-delegation is the same as in WC-delegation except that the worker replaces the principal in communicating with the manager and making the project choice decision.[16]

Which one of these organizational structures can be considered as a three-tier hierarchy depends on what we mean by a two-tier hierarchy. For example, if a two-tier hierarchy refers only to a contractual relation between two parties, then MC-delegation, WC-delegation, M-delegation and W-delegation all lead to three-tier hierarchies. If the party in the middle of the three-tier hierarchy should have the decision authority as well, then only M-delegation and W-delegation exhibit three-tier hierarchies. Figure 1 shows all possible organizational structures where the solid line connecting two parties represents the contracting authority held by the party in the upper box while the decision authority is indicated within the box.

— Figure 1 goes about here. —

At this point we introduce some notation that will facilitate subsequent analysis of various organizational structures described above. In doing so, we use subscript p for the principal, m for the manager, and w for the worker. We denote the manager's information gathering decision by $\delta_m \in \{0,1\}$ where $\delta_m = 1$ if the manager gathers information. If the decision authority is held by the manager (i.e., in MD-delegation and M-delegation), the project choice decision is denoted by a mapping $\psi_m : \Theta \to \{A, B\}$. In all other organizational structures, the communication of manager's information is denoted by a mapping $\gamma_m : \Theta \to \widetilde{\Theta}$ where $\widetilde{\Theta}$ denotes the message space, and the project choice decision by either the principal or the worker, depends on the manager's report and is denoted by a mapping $\psi_j : \widetilde{\Theta} \to \{A, B\}$ for $j = p, w$. The worker's action choice is relevant only when project A is chosen, which is denoted by $\delta_w \in \{0,1\}$ where $\delta_w = 1$ if the worker chooses work.

C. Contracting Environment

The outcome from each organizational structure depends on specific contracting environment. We consider two types of contracting environment depending on which variables are contractible upon. Since the manager's information gathering and the worker's action are both private, there are potentially three remaining variables that can be used for contracting purposes: the return from the project, the identity of chosen project, and the manager's report regarding the state he may have observed.

In the first environment, called *complete contracting*, all three variables are contractible. In the second environment, called *partial contracting*,[17] there are

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[16] There are other possibilities of full delegation, called mixed delegation, where one agent has the contracting authority while the other agent has the decision authority. As will become clear from our analysis, what matters is the contracting authority. Thus mixed delegation where the manager (worker, resp.) has the contracting authority is equivalent to M-delegation (W-delegation, resp.).

[17] We use the term 'partial' contracting instead of 'incomplete' contracting since the latter usually refers to the case where allocation of authority is the only contractible variable and explicit performance-based incentives are absent.

two cases to consider. The first case is where project choice and return are contractible but the manager's report is not, and the second case is where only return is contractible. As will become clear as we go on, optimal contracts in the first case lead to the same outcome and the same payoffs for all the parties as in the case of complete contracting. While this is due to the binary nature of the manager's information and project choice in our model, the equivalence continues to hold as long as the cardinality of the manager's information set is not less than the cardinality of project choice decision. For this reason, in the sequel we take it granted that partial contracting refers to the case that only return is contractible upon. Unless otherwise indicated, we focus on limited liability contracts that have a lower bound of zero for payments to the manager and the worker in each contingency.

In what follows we study the organizational structure and contracts that the principal can use to implement her preferred outcome in the two contracting environments. An organizational structure is said to dominate another organizational structure if the principal's equilibrium expected payoff from the former is larger than that from the latter.

IV. Complete Contracting

Since the principal can implement (C2) in centralization without leaving any rent to either agent as shown above, and the outcome (C3) is inferior due to Assumption 2, the principal's problem is the choice between outcomes (C1) and (C2). In particular, she does not need to consider organizational structures other than centralization if she wishes to implement (C2). Delegation may be beneficial only when it implements (C1) at a lower cost than in centralization. Thus, our focus below is on the organizational structure and contracts that implement (C1).

Unless the manager has the decision authority, implementing (C1) requires honest reporting by the manager. Therefore, it suffices to consider $\widetilde{\Theta} = \{\tilde{\theta}_1, \tilde{\theta}_2\}$ where $\tilde{\theta}_i$ is interpreted as the message the manager sends when $\theta = \theta_i$, $i = 1, 2$. Consequently, the equilibrium communication strategy that implements (C1) is $\gamma_m(\theta_i) = \tilde{\theta}_i$ for $i = 1, 2$, which we take as granted in the sequel. Note that this applies to the partial contracting environment as well.

In addition, unless the worker has any authority, implementing (C1) requires that either the principal or the manager contract with the worker to induce work, conditional on the knowledge that $\theta = \theta_1$ and project A is undertaken. Then the worker's contract that implements (C1) is simplified to (w_x, w_0) where w_r is the wage when return is $r \in X$. Since the worker chooses work if and only if $w_x - w_0 \geq \ell/p_1$, the optimal contract for the worker is $w_x = \ell/p_1$ and $w_0 = 0$, whether it is designed by the principal or by the manager. Clearly this contract does not leave any rent to the worker.

LEMMA 1. *In any organizational structure where the worker does not have any* *authority, the optimal contract for the worker when* $(C1)$ *is implemented is* $w_x = \ell/p_1$ *and* $w_0 = 0$ *when* $\theta = \theta_1$ *and project* A *is chosen, and a null contract, i.e.,* $w_x = w_0 = 0$*, when* $\theta = \theta_2$.

A. Centralization

Our focus is on perfect Bayesian equilibria that implement (C1), which necessarily requires honest reporting by the manager. In such an equilibrium, we have $\delta_m = 1$, $\gamma_m(\theta_i) = \tilde{\theta}_i$ for $i = 1, 2$, $\psi_p(\tilde{\theta}_1) = A$, $\psi_p(\tilde{\theta}_2) = B$, and $\delta_w = 1$ only in θ_1. By Bayes rule, the following beliefs are immediate: the principal believes the true state to be θ_i upon receiving a report $\tilde{\theta}_i$ from the manager; the worker believes the state to be θ_1 (θ_2, resp.) upon observing the project choice of A (B, resp.). Since the optimal contract for the worker is as in Lemma 1, it remains to identify the optimal contract for the manager that the principal would choose to implement the outcome specified above.

A manager's contract is represented by $s : \widetilde{\Theta} \times \{A, B\} \times X \to \Re_+$ where $s(\tilde{\theta}, k, r)$ specifies a non-negative payment to the manager when he reports $\tilde{\theta} \in \widetilde{\Theta} = \{\tilde{\theta}_1, \tilde{\theta}_2\}$, project $k \in \{A, B\}$ is chosen, and return from the project is $r \in X$. Denoting $s^i_{kr} = s(\tilde{\theta}_i, k, r)$ for brevity, we represent a manager's contract by $(s^i_{kx}, s^i_{k0})_{i=1,2;k=A,B} \in \Re^8_+$. Similarly, we denote the worker's contract by $(w^i_{kx}, w^i_{k0})_{i=1,2;k=A,B} \in \Re^8_+$.

Given a manager's contract $(s^i_{kx}, s^i_{k0})_{i=1,2;k=A,B}$ and the worker's contract as in Lemma 1 that implement (C1), the manager's expected payoff is

$$U_M := \pi[p_1 s^1_{Ax} + (1 - p_1)s^1_{A0}] + (1 - \pi)[q s^2_{Bx} + (1 - q)s^2_{B0}] - c, \tag{1}$$

the worker's expected payoff is $U_W = 0$, and the principal's expected payoff is

$$U_P := V_1 - U_M - U_W = V_1 - U_M. \tag{2}$$

We examine the principal choosing manager's contract to maximize U_P subject to implementing (C1) in centralization.

Let $u(\tilde{\theta}|\theta)$ denote the manager's interim expected payoff from reporting $\tilde{\theta} \in \{\tilde{\theta}_1, \tilde{\theta}_2\}$ when the true state is $\theta \in \{\theta_1, \theta_2\}$. That is, for $i = 1, 2$,

$$u(\tilde{\theta}_1|\theta_i) = p_i s^1_{Ax} + (1 - p_i)s^1_{A0} \quad \text{and} \quad u(\tilde{\theta}_2|\theta_i) = q s^2_{Bx} + (1 - q)s^2_{B0}.$$

Then the manager's expected payoff in (1) is $U_M = \pi u(\tilde{\theta}_1|\theta_1) + (1 - \pi)K - c$ where $K = q s^2_{Bx} + (1 - q)s^2_{B0}$. Since the manager first makes a decision on information gathering and then on his reporting strategy, there are two kinds of incentive compatibility (IC) constraints. Interim IC constraints ensure that, once the manager gathered information, he reports observed signals truthfully:

$$u(\tilde{\theta}_1|\theta_1) \geq K \geq u(\tilde{\theta}_1|\theta_2). \tag{3}$$

Ex ante IC constraint ensures information gathering: Since, without gathering information, the manager can report θ_1 and obtain an expected payoff $\pi u(\tilde{\theta}_1|\theta_1) + (1-\pi)u(\tilde{\theta}_1|\theta_2)$, or report θ_2 and obtain K, the ex ante IC constraint is

$$\begin{aligned} &U_M \geq \max\{\pi u(\tilde{\theta}_1|\theta_1) + (1-\pi)u(\tilde{\theta}_1|\theta_2),\ K\} \\ &\iff u(\tilde{\theta}_1|\theta_1) - \frac{c}{\pi} \geq K \geq u(\tilde{\theta}_1|\theta_2) + \frac{c}{1-\pi}. \end{aligned} \tag{4}$$

Since (4) implies (3), the principal's optimal contracting problem is:

$$\text{Max}_{(s^1_{Ar}, s^2_{Br})_{r=x,0} \in \Re^4_+} \quad U_P = V_1 - U_M \quad \text{subject to (4)} \tag{5}$$

and her own IC constraints, namely, it is indeed optimal for her to choose project A (B, resp.) if the manager reports $\tilde{\theta}_1$ ($\tilde{\theta}_2$, resp.). The principal's IC constraints are easily satisfied by setting $s^1_{Bx} = s^2_{Ax} = x$: the principal's deviation from (C1) does not pay off since the entire return goes to the manager. The next proposition provides the solution to (5) and the principal's choice of optimal outcome in centralization with complete contracting.

PROPOSITION 1: *In centralization in the complete contracting environment*:

(i) *The principal can optimally implement outcome* ($C1$) *with the worker's contract* $(w^1_{Ax}, w^1_{A0}) = \left(\frac{\ell}{p_1}, 0\right)$, *and the manager's contract such that* $(s^1_{Ax}, s^1_{A0}) = \left(\frac{c}{\pi(1-\pi)(p_1-p_2)},\ 0\right)$ *and* $(s^2_{Bx}, s^2_{B0}) \in \Re^2_+$ *satisfying* $qs^2_{Bx} + (1-q)s^2_{B0} = \frac{c[\pi p_1 + (1-\pi)p_2]}{\pi(1-\pi)(p_1-p_2)}$. *Then the manager's expected payoff is* $U_M = \frac{c[\pi p_1+(1-\pi)p_2]}{\pi(1-\pi)(p_1-p_2)}$ *and the principal's expected payoff is* $U_P = V_1 - U_M$.

(ii) *Alternatively, the principal can implement outcome* ($C2$) *by offering a null contract to the manager, and* $w = \frac{\ell}{\pi p_1 + (1-\pi)p_2}$ *to the worker in case of success and* $w = 0$ *otherwise. The principal's expected payoff is then* V_2.

(iii) *The principal prefers* ($C1$) *to* ($C2$) *if and only if* $(1-\pi)(qx + \ell - p_2 x) - c \geq U_M$.

PROOF: See the Appendix.

The intuition behind the manager's optimal contract that implements (C1) is as follows. The manager's contract needs to control the twin incentives of information gathering and truthful report. To provide incentives for truthful report, the principal needs to reward the manager when θ_2 is reported, which is denoted by $K = qs^2_{Bx} + (1-q)s^2_{B0}$. Since K can be chosen to satisfy (4) so long as $u(\tilde{\theta}_1|\theta_1) - \frac{c}{\pi} \geq u(\tilde{\theta}_1|\theta_2) + \frac{c}{1-\pi}$, the total compensation to the manager, $\pi u(\tilde{\theta}_1|\theta_1) + (1-\pi)K$, is minimized when this inequality holds as an equality at lowest possible level, which happens when $s^1_{A0} = 0$ and s^1_{Ax} is set to satisfy the equality. Note that the manager's equilibrium expected payoff is strictly positive: $U_M = K > 0$. As can be seen readily, the reason for the strictly positive expected payoff is limited liability. Without limited liability, the principal can set $K = 0$, make s^1_{Ax} positive and s^1_{A0} negative so that the manager's expected payoff becomes zero.

As discussed above, limited liability turns out to be crucial in the principal's choice of which outcome to implement. Limited liability raises the principal's cost of implementing (C1) by limiting the extent to which the manager can be penalized for lying. The information rent the principal has to pay to the manager given limited liability is $U_M = \frac{c[\pi p_1 + (1-\pi)p_2]}{\pi(1-\pi)(p_1-p_2)}$, which she does not need to bear when implementing (C2) since she does not use the manager's information then. The value of manager's information lies in implementing (C1), which is given by $(1-\pi)(qx+\ell-p_2x)-c$. Thus if $U_M > (1-\pi)(qx+\ell-p_2x)-c$, then the principal would bypass the manager and implement (C2). Otherwise, she would implement (C1). If there is no limited liability so that no information rent is needed, then the principal would implement (C1) under centralization due to Assumption 3, which cannot be improved upon in any other organizational structure.

Finally, we note that, as mentioned in the previous section, the above outcome can be also implemented when project choice and return are contractible but the manager's report is not. In this case, consider the manager's contract such that $s_{Ar} = s^1_{Ar}$ and $s_{Br} = s^2_{Br}$ for $r \in X$, where s^1_{Ar} and s^2_{Br} are as specified in Proposition 1. Then, it is clear that the manager's IC constraints are satisfied as before. Those of the principal, namely, $p_1(x - s_{Ax} - \ell/p_1) \geq qx - U_M \geq p_2(x - s_{Ax} - \ell/p_1)$, can be routinely verified from Assumption 1, (4), and $U_M = K$.

B. Delegation to the Manager

There are three ways in which the principal can delegate one or both types of authority to the manager, M-delegation, MD-delegation, and MC-delegation. We will establish that all three organizational structures are equivalent to centralization in implementing (C1) by showing that the effective IC constraints for the manager are the same as those in centralization. Consequently, the principal's cost of implementing (C1) is the same.

Let us start with M-delegation that implements (C1). Since there is no reporting by the manager in this case, the principal offers a contract contingent upon the project choice and return, denoted by $(s_{kx}, s_{k0})_{k=A,B}$, to the manager, who makes a project choice and offers a contract (w_{Ax}, w_{A0}) to the worker if he chooses project A. Recall from Lemma 1 that the optimal contract for the worker is $(w_{Ax}, w_{A0}) = (\ell/p_1, 0)$. Since the principal's IC constraints are irrelevant in the current case, we move on to the manager's IC constraints.

Given contracts $(s_{kx}, s_{k0})_{k=A,B}$ and (w_{Ax}, w_{A0}) that implement (C1) in M-delegation, the manager's expected payoff is

$$U'_M = \pi u(A|\theta_1) + (1-\pi)K - c. \tag{6}$$

where $u(A|\theta_1) = p_1(s_{Ax} - \ell/p_1) + (1-p_1)s_{A0}$ and $K = qs_{Bx} + (1-q)s_{B0}$.

To check interim IC constraints, we consider the following possible deviations by the manager. Upon observing θ_1, either he may select project A but induce shirk from the worker by offering $(w_{Ax}, w_{A0}) = (0, 0)$, thus obtaining a payoff of s_{A0}, or he may select project B without engaging the worker to obtain a payoff K. Thus, the first set of interim IC constraints is $u(A|\theta_1) \geq \max\{s_{A0}, K\}$. Upon observing θ_2, he may select project A and then either induce work from the worker and obtain an expected payoff $u(A|\theta_2) = p_2(s_{Ax} - \ell/p_1) + (1 - p_2)s_{A0}$, or induce shirk from the worker and obtain s_{A0}. So the second set of interim IC constraints is $K \geq \max\{u(A|\theta_2), s_{A0}\}$. Put together, interim IC constraints are

$$u(A|\theta_1) \geq K \geq \max\{u(A|\theta_2), s_{A0}\}. \tag{7}$$

Given the interim IC constraints in (7), ex ante IC constraints require that the manager cannot obtain a payoff exceeding (6) by not gathering information. Since the manager cannot take state-dependent action without information gathering, there are three deviations to consider: (i) $\psi_m(\theta_i) = A$ for $i = 1, 2$ and $\delta_w = 1$, which leads to his expected payoff $\pi u(A|\theta_1) + (1 - \pi)u(A|\theta_2)$; (ii) $\psi_m(\theta_i) = A$ for $i = 1, 2$ but $\delta_w = 0$, leading to his expected payoff s_{A0}; (iii) $\psi_m(\theta_i) = B$ for $i = 1, 2$, which results in his expected payoff K. Since $K \geq s_{A0}$ from (7), the IC constraint in case (ii) is satisfied if the constraint is satisfied in case (iii). Hence, ex ante IC constraints require that (6) exceeds the payoffs of (i) and (iii):

$$u(A|\theta_1) - \frac{c}{\pi} \geq K \geq u(A|\theta_2) + \frac{c}{1 - \pi}. \tag{8}$$

Since the inequalities in (8) imply all the inequalities in (7) except $K \geq s_{A0}$, the optimal implementation of (C1) in M-delegation is the solution to

$$\mathrm{Max}_{(s_{Ar}, s_{Br})_{r=x,0} \in \Re^4_+} \; V_1 + p_1\ell - U'_M \;\; \text{subject to (8) and } K \geq s_{A0}. \tag{9}$$

Observe from the discussions up to now that both (5) and (9) amount to minimizing $\pi u(A|\theta_1) + (1 - \pi)K$ by choosing $K > 0$ and $s_{Ar} \geq 0$ for $r = x, 0$, with one extra constraint for (9), namely, $K \geq s_{A0}$. However, since we have already shown that the solution to (5) satisfies this extra constraint (Proposition 1), it follows that the solutions to (5) and (9) are the same. That is, the IC constrains for implementing (C1) are effectively identical in centralization and in M-delegation and consequently, the principal's equilibrium expected payoff in M-delegation is the same as that in centralization. The only difference is that, in M-delegation, the payment to the manager includes the payment to the worker, which in equilibrium will be passed on to the worker when project A is chosen.

The case of MC-delegation is analogous to M-delegation. The only difference between the two is that the principal has the decision authority in the former. However, this difference does not change the manager's incentive problem. Even when the manager does not have the decision authority, he has the de facto decision authority in implementing (C1): through his report, he can induce the principal to choose the project he prefers. Moreover, the optimal contract for the worker is the same regardless of who has the contracting authority as per Lemma 1. Based on this, it is easy to verify that the manager's IC constraints in MC-delegation are equivalent to those in M-delegation. Therefore, the principal's optimal contracting problem has the same solution in the two cases.

Finally consider MD-delegation. As in M-delegation, denote the manager's interim expected payoff by $u(A|\theta_i)$ when he chooses project A in θ_i, and K when he chooses project B in either state. Then his interim IC constraints are $u(A|\theta_1) \geq K \geq u(A|\theta_2)$. For the manager's ex ante IC constraints, note that the manager has fewer ways of deviation in MD-delegation compared to M-delegation because, without the contracting authority, he is unable to induce different actions from the worker in different states. Once again, we can analyze the manager's ex ante IC constraints in two cases, with or without information gathering. With information gathering, it is easy to see that interim IC constraints imply ex ante IC constraints. This leaves only the cases without information gathering: (i) $\psi_m(\theta_i) = A$ for $i = 1, 2$; (ii) $\psi_m(\theta_i) = B$ for $i = 1, 2$. These ex ante IC constraints are equivalent to (4) with $u(\tilde{\theta}_1|\theta_i)$ replaced by $u(A|\theta_i)$. Consequently, the principal's optimal contracting problem is the same as in centralization, hence has the same solution.

PROPOSITION 2: *In the complete contracting environment, M-delegation, MC-delegation and MD-delegation are all equivalent to centralization in implementing the outcome (C1).*

C. Delegation to the Worker

The principal can also delegate one or both types of authority to the worker. In WC-delegation, the worker has the contracting authority while the principal retains the decision authority. In WD-delegation, the worker has the decision authority but not the contracting authority. In W-delegation, both types of authority are delegated to the worker. In all these delegation modes, the manager's communication is part of the game, which is written into contracts. Except in WD-delegation, the worker offers a contract to the manager and, therefore, the worker's net payoff in each contractible contingency is his payment from the principal less his payment to the manager.

Consider first WD-delegation. Note that the manager's incentive problem in WD-delegation is the same as in centralization. The only difference is whom he reports to, which is irrelevant for his incentives in equilibrium that implements (C1). For WD-delegation to implement (C1), the worker needs to be given incentives to choose project A and work given the manager's report of $\tilde{\theta}_1$, and choose project B given the manager's report of $\tilde{\theta}_2$. This is easily achieved by extending the same worker's contract as in centralization, i.e., that pays him ℓ/p_1 when project A is chosen and return is x and 0 in all other contingencies. Thus the principal can implement (C1) without leaving any rent to the worker. In sum, delegating only the decision authority to the worker does not raise the cost of implementing (C1) relative to centralization.

PROPOSITION 3: *In the complete contracting environment, WD-delegation is equivalent to centralization in implementing (C1).*

PROOF: See the Appendix.

When the worker is delegated the contracting authority, the equivalence result above no longer holds. The main reason for this comes from the cost of inducing the worker to choose project B when the manager reports $\tilde{\theta}_2$. In centralization, the worker is not engaged when the manager reports $\tilde{\theta}_2$, and the principal needs to satisfy only the manager's IC constraints to truthfully report $\tilde{\theta}_2$, which involves rewarding the manager by a positive payment when $\tilde{\theta}_2$ is truthfully reported. When the worker has the contracting authority, the same reward has to be made to the manager by the worker. Since this payment should be included in the primary contract the principal offers the worker, the worker can earn a positive rent by marginally inducing the manager to always report $\tilde{\theta}_2$ without gathering information, e.g., by offering a contract stipulating a small payment only when $\tilde{\theta}_2$ is reported. To counter such incentives, the worker's expected payoff when $\tilde{\theta}_1$ is reported should be made sufficiently positive as well. Since the worker enjoys no rent in centralization, it follows that the principal is strictly worse off in W-delegation and WC-delegation.

PROPOSITION 4: *In the complete contracting environment, centralization dominates W-delegation and WC-delegation in implementing (C1).*

PROOF: See the Appendix.

The above dominance result parallels what McAfee and McMillan (1995) called 'organizational diseconomies of scale', although their model is distinctly different from ours. In centralization, the principal needs to leave a positive information rent only to the manager. In W-delegation and WC-delegation, the worker replaces the principal in contracting with the manager. Without direct contact with the manager, the principal can motivate the manager only through motivating the worker. This requires leaving a positive rent to the worker as well. As in McAfee and McMillan, this 'double marginalization of rent' is due to limited liability. Without limited liability, the manager enjoys no information rent in centralization. Therefore, the principal does not need to leave a positive rent to the worker to motivate the manager. To see this, denote the manager's equilibrium contract in centralization without limited liability by $\tilde{s}^1_{Ax} > 0$, $\tilde{s}^1_{A0} < 0$ and $q\tilde{s}^2_{Bx} + (1-q)\tilde{s}^2_{B0} = \tilde{K} = 0$. We know that the worker's equilibrium contract in centralization leaves no rent to him, which is denoted by $\tilde{w}^1_{Ax} = \ell/p_1$, $\tilde{w}^1_{A0} = 0$. Then, it is straightforward to verify that

(C1) can be implemented in W-delegation or WC-delegation if the primary contract for the worker on the equilibrium path is the sum of the above two contracts,[(18)] rendering W-delegation and WC-delegation equivalent to centralization. Combined with the results so far, the above discussion implies that, without limited liability, centralization is equivalent to all delegated organizational structures.

V. Partial Contracting

In the partial contracting environment, contracts can be written only on the return. Neither the manager's report nor project choice can be used for contracting purposes. Hence, we denote a contract by $(s_x, s_0) \in \Re^2_+$ for the manager where s_r is the payment when return is $r \in \{x, 0\}$; and similarly, $(w_x, w_0) \in \Re^2_+$ for the worker. Nonetheless, there is communication of manager's information except when the manager has the decision authority. Such communication is observable, albeit not contractible, to all the parties. Our focus is again on the principal's expected payoff from implementing (C1) in alternative organizational structures.

A. Centralization

Suppose (C1) is implemented in centralization with contracts $(s_x, s_0) \in \Re^2_+$ for the manager and $(w_x, w_0) \in \Re^2_+$ for the worker, where $w_x = \ell/p_1$ and $w_0 = 0$ as in Lemma 1. The manager's ex ante IC constraints are

$$(q - p_2)(s_x - s_0) \geq \frac{c}{1-\pi} \quad \text{and} \tag{10}$$

$$(p_1 - q)(s_x - s_0) \geq \frac{c}{\pi} \tag{11}$$

where (10) ((11), resp.) ensures that the manager prefers information gathering and truthful reporting to always reporting $\tilde{\theta}_1$ ($\tilde{\theta}_2$, resp.) without gathering information. It is easily verified that the manager's interim IC constraints, $(p_1 - q)(s_x - s_0) \geq 0$ and $(q - p_2)(s_x - s_0) \geq 0$, are implied by (10) and (11).

Since $p_1 > q$ and $p_1 > p_2$ by Assumption 1, we divide analysis into two cases. First, if $p_2 \geq q$, then there does not exist (s_x, s_0) that satisfies (10) and (11). Thus centralization cannot implement (C1) and the principal's optimal choice is to implement (C2). Second, if $q > p_2$, then (10) and (11) imply the following optimal contract for the manager: $s_0 = 0$, $s_x = \max\{\frac{c}{(1-\pi)(q-p_2)}, \frac{c}{\pi(p_1-q)}\}$. However, Assumption 2 implies $\pi p_1 + (1-\pi)p_2 > q$, i.e., $\pi(p_1 - q) > (1-\pi)(q - p_2)$, which in turn implies $s_x = \frac{c}{(1-\pi)(q-p_2)}$ and (11) is slack. Then it is trivial to verify that the principal's IC constraints are satisfied for project choice in implementing (C1).

PROPOSITION 5: *In centralization in the partial contracting environment*:

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(18) It is easy to specify the contract off the equilibrium path that can satisfy the worker's IC constraints for (C1).

(i) *If $q \leq p_2$, then the principal cannot implement $(C1)$. The principal implements $(C2)$ instead and her expected payoff is $U_P = V_2$.*

(ii) *If $q > p_2$, then the principal can optimally implement $(C1)$ with the manager's contract $(s_x, s_0) = \left(\frac{c}{(1-\pi)(q-p_2)}, 0\right)$ and the worker's contract $(w_x, w_0) = \left(\frac{\ell}{p_1}, 0\right)$. The manager's expected payoff is $U_M = \frac{c[\pi p_1 + (1-\pi)p_2]}{(1-\pi)(q-p_2)}$ and the principal's expected payoff is $U_P = V_1 - U_M$. The principal prefers $(C1)$ to $(C2)$ if and only if $(1-\pi)(qx + \ell - p_2 x) - c \geq U_M$.*

The first part of Proposition 5 shows that, if $q \leq p_2$ then it is impossible to induce the manager to gather information in the partial contracting environment. The intuition is as follows. Given $q \leq p_2$ and that his compensation is based only on return, the manager would prefer to have project A undertaken regardless of the true state if $s_x > s_0$. On the other hand, he would prefer project B undertaken regardless of the true state if $s_x \leq s_0$. Thus the value of information is nil from the manager's point of view and, consequently, information gathering cannot be induced. Note that, with complete contracting, the principal has a much better handle on this since the manager's contract can be based on project choice as well. In particular, when compensation is more sensitive to return when A is undertaken than when B is, while the overall payoff from B is higher than when A is undertaken in the unfavorable state, information gathering can be induced.

If $q > p_2$, then the manager prefers project A when $\theta = \theta_1$ and B when $\theta = \theta_2$ so long as $s_x > s_0$. Therefore, information gathering can be induced by making $s_x - s_0$ large enough so that the value of information to the manager exceeds the cost of information gathering. Nonetheless, it is more costly for the principal to induce information gathering when she is unable to write complete contracts. How large is the loss to the principal from partial contracting, compared to complete contracting? Since this question is irrelevant if she implements (C2) in both contracting environments, we discuss the question in two other cases. First, (C1) is implemented with complete contracting but (C2) is with partial contracting. Such a possibility exists if $p_2 \geq q$. That the principal implements (C1) in the complete contracting environment implies that her expected payoff $V_1 - U_M^C$ is larger than V_2 where U_M^C denotes the manager's equilibrium expected payoff shown in Proposition 1. Since the principal's expected payoff from (C2) is V_2, her loss from partial contracting in this case is $V_1 - V_2 - U_M^C$. Second, (C1) is implemented in both contracting environments. The principal's expected payoff from (C1) is $V_1 - U_M^C$ with complete contracting and $V_1 - U_M^P$ with partial contracting where U_M^P is the manager's expected payoff shown in Proposition 5. As expected, the manager's expected payoff is larger in the partial contracting environment: $U_M^P > U_M^C$ can be verified easily from $\pi p_1 + (1-\pi)p_2 > q$. Thus the principal's loss from partial contracting in this case is $U_M^P - U_M^C$.

Finally, note that the positive rent to the manager when (C1) is implemented is once again due to limited liability. Without limited liability, the principal can set $s_0 < 0$ and $s_x > 0$ and make the manager's equilibrium expected payoff equal to zero. Such (s_x, s_0) can be found by substituting the binding IC constraint into the manager's expected payoff, which is then set equal to zero: $s_x = \frac{c[1-\pi p_1-(1-\pi)p_2]}{(1-\pi)(q-p_2)}$, $s_0 = -\frac{c[\pi p_1+(1-\pi)p_2]}{(1-\pi)(q-p_2)}$. Thus, as in the complete contracting environment, the principal would prefer centralization to any other organizational structures if limited liability is relaxed and (C1) can be implemented in centralization, i.e., $q > p_2$.

B. Delegation to the Manager

We continue to denote the manager's contract by $(s_x, s_0) \in \Re^2_+$ and the worker's contract by $(w_x, w_0) \in \Re^2_+$ where $(w_x, w_0) = (\ell/p_1, 0)$ by Lemma 1.

Let us consider M-delegation first. The manager's IC constraints are similar to those in the case of complete contracting except for the obvious differences in contractual form. So we omit the details. Corresponding to the IC constraints in (8) and (9), we have

$$p_1(s_x - \ell/p_1) + (1-p_1)s_0 - \frac{c}{\pi} \geq qs_x + (1-q)s_0 \geq p_2(s_x - \ell/p_1) + (1-p_2)s_0 + \frac{c}{1-\pi},$$

$$\text{and} \quad qs_x + (1-q)s_0 \geq s_0 \iff s_x \geq s_0.$$

Note that $s_x \geq s_0$ is implied by the first inequality since $p_1 > q$. Rearranging the first two inequalities, all the IC constraints for the manager are then reduced to

$$(q - p_2)(s_x - s_0) \geq \frac{c}{1-\pi} - \frac{p_2 \ell}{p_1}, \quad \text{and} \tag{12}$$

$$(p_1 - q)(s_x - s_0) \geq \frac{c}{\pi} + \ell. \tag{13}$$

Comparison of (10) and (11) with (12) and (13) shows how the manager's incentives change in M-delegation. Constraint (12) is a counterpart to (10) in centralization, which ensures that the manager prefers information gathering and optimal project choice to always choosing project A without gathering information. Since the worker is paid only when project A is chosen, the manager needs to pay the worker in both states if he chooses the latter option. Since the worker's payment increases in ℓ, larger ℓ makes (12) more likely to be satisfied. Note also that, if $q > p_2$, then (12) admits a larger set of (s_x, s_0) than (10).

Constraint (13) is a counterpart to (11), which leads the manager to prefer information gathering and optimal project choice to always choosing project B without gathering information. Since the manager does not need to pay the worker with project B, (13) is more likely to be satisfied if ℓ is smaller. While (13) admits a smaller set of (s_x, s_0) than (11), we also note that (11) is slack when (C1) is implemented in centralization. For future reference, we denote by ℓ^* the value of

ℓ that balances the above twin incentives, which is found by setting both (12) and (13) with equality and solving for ℓ that equates $s_x - s_0$ in (12) and (13):

$$\ell^* := \frac{cp_1[\pi p_1 + (1-\pi)p_2 - q]}{\pi(1-\pi)q(p_1 - p_2)}. \tag{14}$$

The reason for the difference in the manager's IC constraints between centralization and M-delegation is that the manager's contract in M-delegation includes the payment to the worker, which motivates the manager to gather information for optimal project choice and hire the worker only when doing so benefits him. Such a link between the worker's contract and the manager's incentives is missing in centralization. Authority, the contracting authority in particular, provides the manager with stronger incentives for information gathering and optimal project choice than in centralization. Thus, (C1) can be implemented in M-delegation for a larger set of parameter values than in centralization.

PROPOSITION 6: *In M-delegation in the partial contracting environment*:

(i) *Suppose* $q \le p_2$. *If* $\ell \ge \ell^*$, *then the principal can optimally implement* $(C1)$ *with the manager's contract* $(s_x, s_0) = \left(\frac{\pi\ell + c}{\pi(p_1 - q)}, 0\right)$. *If* $\ell < \ell^*$, *then the principal cannot implement* $(C1)$.

(ii) *Suppose* $q > p_2$. *If* $\ell \ge \ell^*$, *then the principal can optimally implement* $(C1)$ *with the same contract as in (i). If* $\ell < \ell^*$, *then the principal can optimally implement* $(C1)$ *with the manager's contract* $(s_x, s_0) = \left(\frac{cp_1 - (1-\pi)p_2\ell}{(1-\pi)p_1(q-p_2)}, 0\right)$.

PROOF: See the Appendix.

In the discussion that led to Proposition 6, it was implied that the difference in the manager's incentive problem between centralization and M-delegation is primarily due to the contracting authority, rather than the decision authority. The manager's IC constraints for truth-telling in centralization are equivalent to his IC constraints for project choice when he has the decision authority. However, the manager's IC constraints when he has the contracting authority cannot be replicated in centralization, as Proposition 6 shows. Consequently, we may expect MD-delegation to be equivalent to centralization but MC-delegation to be equivalent to M-delegation. Indeed, it is not difficult to show that the manager's IC constraints in MD-delegation are equivalent to those in centralization while his IC constraints in MC-delegation are the same as those in M-delegation. So, the proof of the following proposition is omitted.

PROPOSITION 7: *In the partial contracting environment, MD-delegation is equivalent to centralization, and MC-delegation is equivalent to M-delegation in implementing (C1).*

C. Delegation to the Worker

When authority is delegated to the worker, the manager's incentive problem does not change from that in centralization. This is the same as in the case of complete contracting. Once again, the only difference from centralization is whom the manager reports to. Then Proposition 5 implies that, when $q \le p_2$, (C1) cannot be implemented in any organizational structure where the worker is delegated one or both types of authority. So, we focus on the case where $q > p_2$.

We start with WD-delegation. In the complete contracting environment, it was shown to be equivalent to centralization primarily because complete contracts allow the principal to design the worker's contract in a way to decouple his incentives for project choice in the two states. Such decoupling is not possible in the partial contracting environment. For example, the worker cannot be penalized for wrongly selecting project B in θ_1 since project choice is not contractible; whichever project is chosen, the worker needs to be paid when return is x. This increases the worker's incentive to choose project B unless the reward from success is large enough when he chooses project A in θ_1. In particular, if his (interim) expected payoff from choosing project A and work in θ_1 is zero as in centralization, he would always opt for project B. What this implies is that the principal should leave a positive rent to the worker in order to implement (C1) in WD-delegation. Since the manager's expected payoff remains the same but the worker's expected payoff is larger in WD-delegation than in centralization, the principal is worse off in WD-delegation. The analysis of W-delegation and WC-delegation is similar to the case of complete contracting. In addition to the problem identified above, double marginalization of rent continues to be present as long as the worker has the contracting authority. Thus, centralization should again dominate these organizational structures.

PROPOSITION 8: *In the partial contracting environment, centralization dominates W-delegation, WC-delegation, and WD-delegation in implementing (C1).*

PROOF: See the Appendix.

VI. Centralization vs. Delegation to the Manager

This section returns to our central question of when the principal can benefit by delegating authority. We first summarize the main findings from the previous sections. Section IV has shown that there is no reason for the principal to delegate either type of authority to any agent if she can write complete contracts. Centralization dominates all organizational structures where the worker has the contracting authority, and is equivalent to all other organizational structures. Centralization is therefore the preferred organizational structure in this case. In Section V, it was shown that, in the partial contracting environment, centralization continues to dominate all organizational structures in which the worker is delegated either type of authority. However, delegating the contracting authority to the manager can potentially benefit the principal compared to centralization. There are two sources of such potential benefits. First, delegation allows the principal to implement an outcome that cannot be implemented in centralization. Specifically, if $q \leq p_2$, then (C1) cannot be implemented in centralization but it can be in M-delegation and MC-delegation. Second, delegation implements the same outcome as in centralization but possibly at lower costs. The latter is the case if $q > p_2$. By analyzing these two cases, this section shows when delegation to the manager can dominate centralization. Since MC-delegation is equivalent to M-delegation, our discussion below proceeds by comparing centralization with M-delegation. In what follows, we denote the expected payoff from (C1) in centralization by U_M^C for the manager and U_P^C for the principal. The expected payoff from (C1) in M-delegation is denoted by U_M^D for the manager and U_P^D for the principal.

A. Partial Contracting When $q > p_2$

This is the case where (C1) can be implemented in both centralization and M-delegation. From Proposition 5, in centralization, the principal's expected payoff from (C1) is

$$U_P^C = V_1 - U_M^C = V_1 - \frac{c[\pi p_1 + (1-\pi)p_2]}{(1-\pi)(q-p_2)}, \tag{15}$$

and the principal prefers (C1) to (C2) if and only if $U_P^C \geq V_2$, or equivalently,

$$(q-p_2)x + \ell \geq \frac{c[\pi p_1 + (1-\pi)q]}{(1-\pi)^2(q-p_2)}. \tag{16}$$

Thus (C1) is more likely to be implemented if x and ℓ are larger, and c and π are smaller. Larger x and ℓ imply more benefits to using the manager's information for project choice because (C2) involves a suboptimal project choice and inefficient effort provision by the worker in θ_2. Smaller c implies less cost of using the manager's information. Finally, smaller π implies that the manager's information is more valuable. If π is so large that choosing project A and inducing work is almost certainly optimal, then the principal is best off implementing (C2) without the manager's information.

In M-delegation, there are two possibilities as shown in Proposition 6. Since the manager's expected payoff is $U_M^D = \pi p_1(s_x - \ell/p_1) + (1-\pi)qs_x - c$, the principal's expected payoff when $\ell < \ell^*$ is

$$U_P^D = V_1 - U_M^D = V_1 - \frac{[\pi p_1 + (1-\pi)q][cp_1 - (1-\pi)p_2\ell]}{(1-\pi)p_1(q-p_2)} + \pi\ell + c \tag{17}$$

as is evident from Proposition 6 (ii). If $\ell \geq \ell^*$, the principal's expected payoff is

$$U_P^D = V_1 - U_M^D = V_1 - \frac{q(\pi\ell + c)}{\pi(p_1 - q)}, \tag{18}$$

which again follows from Proposition 6 (ii) for $\ell \geq \ell^*$.

If (16) is satisfied so that (C1) is implemented in centralization, then we can say that M-delegation dominates centralization if and only if $U_P^D \geq U_P^C$ or, equivalently, $U_M^D \leq U_M^C$. If (16) is not satisfied, then the principal implements (C2) in centralization. This case is the same as when $q \leq p_2$, which is analyzed in the next section.

PROPOSITION 9: *Suppose $q > p_2$ and that the principal implements (C1) in centralization, i.e., (16) holds. Then there exists $\ell' > \ell^*$ such that M-delegation dominates centralization for all $\ell \leq \ell'$.*

PROOF: See the Appendix.

The above dominance result can be understood from how delegation changes the manager's incentives. Specifically, the contracting authority entrusts the manager with the payment to the worker thereby creating two opposing incentives for the manager in M-delegation, which are not present in centralization. On the one hand, the option of always choosing project B without information gathering becomes more attractive because it means that he need not pay the worker. On the other hand, the option of always choosing project A without gathering information becomes less attractive because it means that he will have to pay the worker regardless of the state. Compared to centralization, the former makes the deviation of not gathering information more attractive while the latter makes it less attractive. These effects can be seen by comparing the manager's IC constraints in M-delegation with those in centralization, namely, (13) with (11) and (12) with (10), respectively. These effects are proportional to ℓ because larger ℓ means larger payment to the worker. When $q > p_2$, (11) is slack in centralization and (13) is slack in M-delegation. Thus the difference in the cost of implementing (C1) in the two organizational structures essentially hinges on the comparison of (12) and (10). Both constraints ensure that the manager prefers (C1) to always choosing project A without gathering information. As argued above, delegation makes the latter option less attractive: (12) is easier to satisfy than (10). Therefore, if (C1) is implementable in centralization for some (s_x, s_0) that satisfies (10), then it is implementable in M-delegation with a lower (s_x, s_0) when ℓ is not too large.

The cost reduction is a result of a lower rent for the manager, which is possible because delegation allows the principal to provide more effective incentives to the manager. It is worth noting that, although the manager's contract does not depend on project choice in the partial contracting environment, his payoff in M-delegation depends on project choice through his decision to exercise the contracting authority. Such a link between the manager's payoff and project choice is possible in M-delegation but not in centralization, which the principal can utilize to better design the manager's contract.

Figure 2 shows an example in which we plot the principal's expected payoffs in M-delegation and centralization for a set of parameter values that satisfy Assumptions 1 to 3, $q > p_2$, and (16). We set parameter values at $p_1 = 0.9, p_2 = 0.2, q = 0.3, \pi = 0.3$, $c = 0.5$, and $x = 100$. Then $\ell^* = 1.61$ and the upper bound for ℓ as implied by Assumption 2 is $[\pi p_1 + (1-\pi)p_2 - q]x = 18$. In centralization, the principal's expected payoff decreases in ℓ. In M-delegation, it increases up to $\ell = \ell^*$, and then decreases thereafter. As shown in Proposition 9, M-delegation dominates centralization for all values of $\ell \leq \ell^* = 1.61$. When $\ell > 1.61$, M-delegation continues to dominate centralization until ℓ reaches $\ell' \approx 7.9$. Thereafter centralization dominates M-delegation until ℓ reaches its upper bound of 18.

— Figure 2 goes about here. —

B. Partial Contracting When $q \leq p_2$

We showed above that if $q > p_2$, delegation may benefit the principal because it allows her to implement (C1) at a lower cost than in centralization. We now show that if $q \leq p_2$ and $\ell \geq \ell^*$, the principal may benefit from M-delegation because it allows her to implement (C1), which is not feasible in centralization. Not being able to implement (C1) in centralization, the principal implements (C2) instead. Since (C2) involves suboptimal project choice and inefficient effort by the worker in θ_2, the benefit of delegation in this case comes primarily from efficiency. The cost of delegation is the rent that needs to be paid to the manager. We discuss below when the benefit outweighs the cost.

The principal's expected payoff in centralization is V_2. In M-delegation, Proposition 6 shows that the principal's expected payoff is the one given in (18). Thus the net benefit from M-delegation is

$$\Delta := U_P^D - V_2 = -(1-\pi)(p_2 - q)x + \left[1 - \pi - \frac{q}{p_1 - q}\right]\ell - \left[1 + \frac{q}{\pi(p_1 - q)}\right]c. \quad (19)$$

The first and the third terms on the right hand side of (19) are negative while the sign of the second term is indeterminate. It is routinely verified that Δ can be positive at some parameter values that satisfy Assumptions 1 to 3, $q \leq p_2$, and $\ell \geq \ell^*$. For example, when $p_1 = 0.9, p_2 = 0.2, q = 0.19, \pi = 0.5, c = 0.12, x = 100$, and $\ell = 3$, we have $\ell^* \approx 1.17$ and $\Delta \approx 0.013$. To provide an illustration on how Δ may change for different parameter values, Figure 3 plots U_P^D and V_2 as we change c, ℓ, and π from the above example. The observed pattern is that $\Delta > 0$ when c is low and when ℓ and π are neither too large nor too small. We establish below that this pattern is indeed general.

— Figure 3 goes about here. —

A parameter profile is a 7-tuple $\mathbf{z} = (c, \ell, x, \pi, p_1, p_2, q) \in \Re^3_{++} \times (0,1)^4$. Let $\Xi \subset \Re^3_{++} \times (0,1)^4$ be the interior of the set of parameter profiles such that Assumptions

1-3 are satisfied, $q \leq p_2$, $\ell \geq \ell^*$, and $\Delta > 0$. The above example shows $\Xi \neq \emptyset$. Given $\mathbf{z} \in \Xi$, we use $\mathbf{z}_{z/z'}$ to denote $\mathbf{z}$ with its z-component replaced by z' for $z = c, \ell, \pi$. For $z = \ell$, Assumption 2 places an upper bound $\bar{\ell}_{\mathbf{z}} := [\pi p_1 + (1-\pi)p_2 - q]x$ on ℓ' for $\mathbf{z}_{\ell/\ell'} \in \Xi$ to hold.

Let $\mathbf{z} \in \Xi$ and consider changes in c, the manager's cost of gathering information. Since Δ decreases in c, we must have $\Delta > 0$ for all $\mathbf{z}_{c/c'}$ such that $c' < c$. This is intuitively clear because higher c means higher cost of inducing the manager to gather information in M-delegation. Next, consider changes in ℓ, the worker's cost of effort. Centralization leads to suboptimal effort choice by the worker since in (C2) the worker works in θ_2 even if his marginal product is less than the cost of work. An increase in ℓ magnifies this inefficiency of centralization. Thus, the efficiency benefit of M-delegation can be measured as $V_1 - V_2$, which increases as ℓ increases: $\frac{\partial(V_1-V_2)}{\partial \ell} = 1 - \pi > 0$. On the other hand, an increase in ℓ also increases the manager's compensation in M-delegation: $\frac{\partial U_M^D}{\partial \ell} = \frac{q}{p_1 - q} > 0$. It is possible to show that if $\mathbf{z} \in \Xi$, the efficiency benefit outweighs the compensation cost for all $\mathbf{z}_{\ell/\ell'}$ such that $\ell' \geq \ell$. Finally, it can be easily verified from (19) that Δ is strictly concave in π. This implies that the information rent to the manager is large relative to the value of information to the principal when π is either too small or too large. In these cases, obtaining information has a limited value and thus, the manager is reluctant to gather information. The value of manager's information is larger when π has an intermediate value. In implementing (C2), on the other hand, manager's rent is irrelevant. These observations lead to the next proposition.

PROPOSITION 10: $\Xi \neq \emptyset$. *Furthermore, for each* $\mathbf{z} \in \Xi$:

(i) *There is* $\bar{c}_{\mathbf{z}} > 0$ *such that* $\mathbf{z}_{c/c'} \in \Xi$ *if and only if* $c' \in (0, \bar{c}_{\mathbf{z}})$*;*
(ii) *There is* $\underline{\ell}_{\mathbf{z}} \geq \ell^*$ *such that* $\mathbf{z}_{\ell/\ell'} \in \Xi$ *if and only if* $\ell' \in (\underline{\ell}_{\mathbf{z}}, \bar{\ell}_{\mathbf{z}})$*; and*
(iii) *There is* $(\underline{\pi}_{\mathbf{z}}, \bar{\pi}_{\mathbf{z}}) \subset (0,1)$ *such that* $\mathbf{z}_{\pi/\pi'} \in \Xi$ *if and only if* $\pi' \in (\underline{\pi}_{\mathbf{z}}, \bar{\pi}_{\mathbf{z}})$.

PROOF: See the Appendix.

We summarize the main findings of this section. In centralization, the principal is unable to motivate the manager to gather information. This results in suboptimal project choice and inefficient effort provision by the worker. M-delegation corrects this inefficiency but at the cost of manager's rent necessary to motivate him to gather and use information for efficient decision-making. Choosing M-delegation instead of centralization, the principal thus trades off the benefits of manager's information against the compensation cost for the manager. The benefits of delegation increase as the manager's information becomes more valuable and the worker's cost of effort increases. The cost of delegation increases as it becomes more costly for the manager to gather information. As a consequence, M-delegation is more likely to dominate centralization if the manager's cost of information gathering is smaller, the worker's effort cost is larger, and the manager's information becomes more valuable. This is in contrast to the case in the previous section. When $q > p_2$, there is no efficiency loss in centralization. Thus the comparison of centralization and M-delegation was based primarily on how much rent the manager should be given in the two organizational structures.

VII. 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. Dividing authority into two types, namely, decision-making authority and contracting authority, and focusing on the allocation of authority, we have studied the equilibria of different organizational structures in two contracting environments. In the complete contracting environment, all the publicly observable variables can be used for contracting purposes while, in the partial contracting environment, only the return from the project is contractible. Under centralization, the principal retains both types of authority while delegation confers one or both types of authority to the agents.

The central question of this paper is when the principal can benefit from delegation compared to centralization. Our main results can be summarized as follows. First, the principal cannot benefit from delegation in the complete contracting environment: she is strictly worse off under some forms of delegation when contracts are subject to limited liability constraints; without limited liability constraints, any form of delegation is payoff-equivalent to centralization, which is a direct consequence of the revelation principle. Second, delegation can benefit the principal in the partial contracting environment when authority, the contracting authority in particular, is delegated to the manager, but not to the worker.

The benefits from delegating authority to the manager come from two sources. First, when centralization cannot induce the manager to acquire information and hence results in a suboptimal investment decision, delegating authority to the manager can motivate him to acquire information, thereby implementing an optimal investment decision. These efficiency gains from 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. Second, even when centralization can induce information acquisition and implement an optimal investment decision, manager delegation can benefit the principal as it can reduce the rent that the principal needs to pay the manager under centralization. Conferred with the authority to contract with the worker, the manager is made a residual claimant in the subcontracting stage. This enables the principal to disentangle the interlocked incentives between the manager and the worker, thereby reducing the cost of observing the manager's incentive constraints under centralization.

In our model, we did not assume any costs in communicating and processing information; the only information-related cost was that of information gathering by the manager. If there were additional costs of communicating information (e.g., Laffont and Martimort, 1998) or processing it (e.g., Radner, 1993; Van Zandt, 1999), the case for manager delegation will only be strengthened. 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 fruitfully elucidate the nature of incentive pay in multi-tier corporate hierarchies is left for future research.

Appendix

PROOF OF PROPOSITION 1: The principal's optimal contracting problem is equivalent to minimizing the manager's expected payoff subject to (4). In any solution to the principal's problem, the second IC constraint in (4), $K \geq u(\tilde{\theta}_1|\theta_2) + c/(1-\pi)$, should be necessarily binding. Otherwise, K can be reduced until it is binding without violating the first IC constraint. Substituting $K = u(\tilde{\theta}_1|\theta_2) + c/(1-\pi)$ into the first IC constraint and rearranging terms, we have

$$(p_1 - p_2)(s^1_{Ax} - s^1_{A0}) \geq \frac{c}{\pi(1-\pi)}. \qquad (A1)$$

Since $s^1_{Ax}, s^1_{A0} \geq 0$, the least costly way to meet $(A1)$ is to set $s^1_{Ax} = \frac{c}{\pi(1-\pi)(p_1-p_2)}$ and $s^1_{A0} = 0$. Then any nonnegative s^2_{Bx} and s^2_{B0} can be chosen to satisfy $qs^2_{Bx} + (1-q)s^2_{B0} = p_2 s^1_{Ax} + (1-p_2)s^1_{A0} + c/(1-\pi) = \frac{c[\pi p_1 + (1-\pi)p_2]}{\pi(1-\pi)(p_1-p_2)}$. This leads to the manager's expected payoff $U_M = qs^2_{Bx} + (1-q)s^2_{B0}$. Since $U_W = 0$, the principal's expected payoff from (C1) is then $U_P = V_1 - [qs^2_{Bx} + (1-q)s^2_{B0}]$. This proves (i). Proof of (ii) was already given. To show (iii), note that the principal prefers (C1) to (C2) if and only if $V_1 - [qs^2_{Bx} + (1-q)s^2_{B0}] \geq V_2$, which is equivalent to $(1-\pi)(qx + \ell - p_2 x) - c \geq \frac{c[\pi p_1 + (1-\pi)p_2]}{\pi(1-\pi)(p_1-p_2)}$. ∎

PROOF OF PROPOSITION 3: Since the manager's incentive problem in WD-delegation is the same as that in centralization, it suffices to show that the principal can implement (C1) without leaving any rent to the worker. For WD-delegation to implement (C1), the worker's contract $(w^i_{kx}, w^i_{k0})_{i,k}$ needs to satisfy two sets of IC constraints for the worker's project choice. First, given the manager's report of $\tilde{\theta}_1$, the worker has three options: (i) $\psi_w(\tilde{\theta}_1) = A$ and $\delta_w = 1$, which results in his expected payoff $p_1 w^1_{Ax} + (1-p_1)w^1_{A0} - \ell$; (ii) $\psi_w(\tilde{\theta}_1) = A$ but $\delta_w = 0$, leading to the expected payoff w^1_{A0}; (iii) $\psi_w(\tilde{\theta}_1) = B$, leading to the expected payoff $qw^1_{Bx} + (1-q)w^1_{B0}$. To implement (C1), the worker's expected payoff from option (i) should not be smaller than that from the other two. In equilibrium that implements (C1), the worker infers θ_i from the manager's report of $\tilde{\theta}_i$. Thus the first set of IC constraints can be written as:

$$p_1 w^1_{Ax} + (1-p_1)w^1_{A0} - \ell \geq \max\{w^1_{A0},\ qw^1_{Bx} + (1-q)w^1_{B0}\}. \qquad (A2)$$

Given the manager's report of $\tilde{\theta}_2$, the worker again has the same three options, leading to the second set of IC constraints:

$$qw^2_{Bx} + (1-q)w^2_{B0} \geq \max\{p_2 w^2_{Ax} + (1-p_2)w^2_{A0} - \ell,\ w^2_{A0}\}. \qquad (A3)$$

Clearly (A2) and (A3) are independent. Thus $(w^1_{Ar}, w^1_{Br})_{r=x,0}$ can be chosen to satisfy (A2), and $(w^2_{Ar}, w^2_{Br})_{r=x,0}$ to satisfy (A3). The least costly way to do so is to set all payments equal to zero except $w^1_{Ax} = \ell/p_1$. This is the same as in centralization. ∎

PROOF OF PROPOSITION 4: Denote the worker's contract by $(w^i_{kr})_{i,k,r}$ and the manager's contract by $(s^i_{kr})_{i,k,r}$. The worker's net payoff in contingency (i,k,r) is $w^i_{kr} - s^i_{kr}$. As noted before, the manager's incentive problem in either delegation mode is the same as in centralization. Therefore, if the worker is to induce information gathering and truth-telling from the manager, then he would offer exactly the same contract as that offered by the principal in centralization: $s^1_{Ax}, s^2_{Bx}, s^2_{B0}$ are as in Proposition 1, and $s^1_{A0} = 0$. Henceforth, we denote these payments by $\tilde{s}^1_{Ax}$ and $\tilde{K} := q\tilde{s}^2_{Bx} + (1-q)\tilde{s}^2_{B0}$. When (C1) is implemented, the worker's expected payoff is

$$U_W := \pi[p_1(w^1_{Ax} - \tilde{s}^1_{Ax}) + (1-p_1)w^1_{A0} - \ell] + (1-\pi)[qw^2_{Bx} + (1-q)w^2_{B0} - \tilde{K}]. \quad (A4)$$

Consider now the following deviation by the worker. Suppose the worker offers the manager a contract that induces him not to gather information and always report $\tilde{\theta}_2$. An example of such a contract is $s^1_{kr} = s^2_{Ar} = 0$ for $k = A, B$ and $r = x, 0$, and any nonnegative (s^2_{Bx}, s^2_{B0}) such that $qs^2_{Bx} + (1-q)s^2_{B0} = \varepsilon < c$ for sufficiently small $\varepsilon > 0$. Given the manager's report of $\tilde{\theta}_2$, suppose the worker chooses project B in W-delegation. In equilibrium that implements (C1) in WC-delegation, the principal chooses project B given $\tilde{\theta}_2$. In either case, the worker's ex ante expected payoff from this deviation is $qw^2_{Bx} + (1-q)w^2_{B0} - \varepsilon$. For W-delegation or WC-delegation to implement (C1), U_W in (A4) should not be less than the above expected payoff. Moreover we must have $qw^2_{Bx} + (1-q)w^2_{B0} \geq \tilde{K}$ for the manager's contract to be feasible for the worker to offer. Thus $U_W \geq qw^2_{Bx} + (1-q)w^2_{B0} - \varepsilon \geq$

$\tilde{K} - \varepsilon$. Since $\tilde{K} > 0$, there is $\varepsilon > 0$ such that the worker's expected payoff is strictly positive in equilibrium that implements (C1). Therefore to implement (C1) in W-delegation or WC-delegation, the worker should necessarily be given a strictly positive rent. Recall that the worker's expected payoff is zero in centralization when (C1) is implemented. Since the manager's equilibrium expected payoff is the same in centralization, W-delegation and WC-delegation when (C1) is implemented, the principal is strictly worse off in W-delegation and WC-delegation. ∎

PROOF OF PROPOSITION 6: In equilibrium that implements (C1), the principal chooses (s_x, s_0) to minimize the manager's expected payoff subject to (12) and (13). Suppose $q \leq p_2$. Then (12) and (13) become

$$s_x - s_0 \leq \frac{1}{q - p_2}\Big(\frac{c}{1-\pi} - \frac{p_2 \ell}{p_1}\Big), \tag{$A5$}$$

$$s_x - s_0 \geq \frac{1}{p_1 - q}\Big(\frac{c}{\pi} + \ell\Big). \tag{$A6$}$$

Note that $\frac{1}{q-p_2}\big(\frac{c}{1-\pi} - \frac{p_2\ell}{p_1}\big) \geq \frac{1}{p_1-q}\big(\frac{c}{\pi} + \ell\big)$ if and only if $\ell \geq \ell^*$. Thus the intersection of the two constraints is nonempty if $\ell \geq \ell^*$. In this case, $(A6)$ is binding at the solution to the principal's optimal contracting problem with the manager. This leads to $s_0 = 0$ and $s_x = \frac{\pi\ell + c}{\pi(p_1 - q)}$. If $\ell < \ell^*$, then the intersection of the above two constraints is empty. Thus (C1) cannot be implemented.

Suppose now $q > p_2$. Then the inequality in $(A5)$ is reversed. Moreover we have $\frac{1}{q-p_2}\big(\frac{c}{1-\pi} - \frac{p_2\ell}{p_1}\big) \leq \frac{1}{p_1-q}\big(\frac{c}{\pi} + \ell\big)$ if and only if $\ell \geq \ell^*$. Therefore, if $\ell \geq \ell^*$, then only $(A6)$ is binding and, therefore, the principal's optimal offer to the manager is the same as above. If $\ell < \ell^*$, then $(A5)$ is binding. Solving it for s_x with $s_0 = 0$ gives us $s_x = \frac{cp_1 - (1-\pi)p_2\ell}{(1-\pi)p_1(q-p_2)}$. ∎

PROOF OF PROPOSITION 8: For the cases of W-delegation and WC-delegation the proof is similar to that of Proposition 4 and is omitted. We consider WD-delegation below.

Since the manager's incentive problem in WD-delegation is the same as that in centralization and the worker's expected payoff in centralization is zero, it suffices to show that the worker's expected payoff in WD-delegation is strictly positive. For WD-delegation to implement (C1), the worker's contract (w_x, w_0) needs to satisfy two sets of IC constraints for the worker's project choice. First, given the manager's report of $\tilde{\theta}_1$, the worker has three options: (i) $\psi_w(\tilde{\theta}_1) = A$ and $\delta_w = 1$, which results in his expected payoff $p_1 w_x + (1 - p_1) w_0 - \ell$; (ii) $\psi_w(\tilde{\theta}_1) = A$ but $\delta_w = 0$, leading to the expected payoff w_0; (iii) $\psi_w(\tilde{\theta}_1) = B$, leading to the expected payoff $q w_x + (1 - q) w_0$. To implement (C1), the worker's expected payoff from option (i) should not be smaller than that from the other two. Thus the first set of

IC constraints can be written as:

$$\begin{aligned} & p_1 w_x + (1-p_1)w_0 - \ell \geq \max\{w_0,\ q w_x + (1-q)w_0\} \\ \iff\ & w_x - w_0 \geq \ell/(p_1 - q). \end{aligned} \tag{A7}$$

Given the manager's report of $\tilde{\theta}_2$, the worker again has the same three options, leading to the second set of IC constraints:

$$\begin{aligned} & q w_x + (1-q)w_0 \geq \max\{p_2 w_x + (1-p_2)w_0 - \ell,\ w_0\} \\ \iff\ & (q - p_2)(w_x - w_0) + \ell \geq 0,\ w_x \geq w_0. \end{aligned} \tag{A8}$$

Since $p_1 > q > p_2$, (A7) implies (A8). Thus the optimal contract for the worker is $w_x = \ell/(p_1 - q)$, $w_0 = 0$. Then the worker's expected payoff is $\pi(p_1 w_x - \ell) + (1 - \pi)q w_x = q\ell/(p_1 - q) > 0$. ∎

PROOF OF PROPOSITION 9: Suppose $\ell < \ell^*$. Denote the manager's expected payoff in this case by U_M^{D1}, which is given in (17). Direct calculation shows

$$U_M^C - U_M^{D1} = \frac{p_2[\pi p_1 + (1-\pi)q]\ell}{p_1(q - p_2)} + \pi\ell > 0. \tag{A9}$$

Thus M-delegation dominates centralization for all values of $\ell < \ell^*$. Suppose next $\ell \geq \ell^*$. Then the relevant expected payoff for the manager is given in (18), which we denote by U_M^{D2}. Recall that ℓ^* was defined as the value of ℓ, at which the manager's IC constraints (12) and (13) are equivalent and both hold with equality. Thus $U_M^{D2}|_{\ell=\ell^*} = lim_{\ell \to \ell^*} U_M^{D1} < U_M^C$. Since U_M^{D2} is continuous and increasing in ℓ while U_M^C is independent of ℓ, there is $\ell' > \ell^*$ such that $U_M^D \leq U_M^C$ for all $\ell \in (\ell^*, \ell']$. Combining the two cases gives us the proposition. ∎

PROOF OF PROPOSITION 10: We have already shown $\Xi \neq \emptyset$. Take an arbitrary $\mathbf{z} \in \Xi$. Note that (19) decreases in c. It is trivial to verify that Assumptions 1-3 and $\ell \geq \ell^*$ continue to hold when c decreases. Hence, setting $\bar{c}_{\mathbf{z}}$ as the minimum of the upper bounds of c determined by Assumption 3, $\ell \geq \ell^*$, and $\Delta > 0$, proves part (i) of the Proposition.

Since the first and the third terms of the RHS of (19) are negative, $\mathbf{z} \in \Xi$ implies that $1 - \pi - \frac{q}{p_1 - q} > 0$, which in turn implies that Δ increases in ℓ. It is easy to verify that Assumptions 1-3 and $\ell \geq \ell^*$ continue to hold when ℓ increases up to $\bar{\ell}_{\mathbf{z}}$, but Assumption 2 is violated if it increases above $\bar{\ell}_{\mathbf{z}}$. Hence, setting $\underline{\ell}_{\mathbf{z}}$ as the maximum of the lower bounds of ℓ determined by Assumption 1, Assumption 3, $\ell \geq \ell^*$, and $\Delta > 0$, proves part (ii) of the Proposition.

Finally, it is easy to check that $\frac{\partial^2 \Delta}{\partial \pi^2} < 0$, hence Δ is strictly concave in π. Since $\Delta > 0$ at $\mathbf{z}$, $\Delta > 0$ also holds as π changes within an interval, say $I \subset (0,1)$. By the same token, the condition $\ell \geq \ell^*$ holds as π changes within an interval, say $J \subset (0,1)$. Let $\underline{\pi}_{\mathbf{z}}$ be the maximum of $\inf I$, $\inf J$, and the lower bound on

π determined by Assumption 2. Let $\bar{\pi}_{\mathbf{z}}$ be the minimum of $\sup I$, $\sup J$, and the upper bound on π determined by Assumption 3. This establishes part (iii) of the Proposition. ∎

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