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Disagreement and Informal Delegation in Organizations*

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Abstract

To investigate delegation decisions within organizations, we develop a principal-agent model in which the principal can only informally delegate authority to the agent and the parties openly disagree with each other in the sense of differing prior beliefs about the optimal course of action. Our main analysis shows that the degree of disagreement determines what kind of delegation policy the principal can commit to and this, in turn, alters the agent's effort for information acquisition. In an extension, we consider the principal's incentives to provide the agent with training, which reduces the cost of acquiring information. The analysis reveals that training provision is higher under delegation and that training facilitates delegation. We use a cross section of matched employer-employee data to examine the extent to which the empirical implications of this extension are consistent with data.

Keywords: Delegation of authority; Differing priors

JEL Codes: L2; M0

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1 Introduction

As having access to expertise and local knowledge is critical to success, the allocation of decision rights to employees continues to be a fundamental challenge for organizations.[1] Aghion and Tirole (1997) show in their seminal work that delegating authority involves a trade-off between increased initiative and loss of control. That is, the employee to whom authority is delegated may have stronger incentives to collect information useful for the organization; yet, delegation provides the same employee with an opportunity to pursue his or her own interests at the expense of those of the organization. Besides this "double-edged-sword" nature of the delegation of authority, certain features of organizations render the design of delegation policies even more challenging.

First, it is not uncommon that the organization and the employee disagree about the right course of action. In other words, despite having access to the same information as the organization, the employee may have a different intuition and therefore disagree with the organization on which actions are more likely to lead to a successful outcome. As differences of opinion alter the employee's incentives for collecting information (Van den Steen, 2002; Che and Kartik, 2009), organizations should adjust their delegation policies accordingly. Second, as discussed by Bolton and Dewatripont (2013), delegation of formal authority within organizations may not be credible due to the so-called business judgment rules, which induce courts not to enforce any contracts written between parties in a single organization.[2] This means that even though certain decisions may be informally delegated to the employee, the organization (that is, the party endowed with the formal authority) can choose to overrule the employee's decision.

In this paper, we investigate the organization's incentives to allocate decision rights in a setting in which the delegation decision is noncontractible, and the organization and the employee openly disagree on the optimal course of action. After exploring the organization's delegation decision under such circumstances, we introduce training decision to examine how the organization's incentives to facilitate information acquisition interact with the incentives to delegate authority.

To explore these issues, we develop a single-period principal-agent model whereby the goal of the employment relationship is to take an action in order to implement a given project (or, more generally, to maximize the firm's profits). The action taken then determines the payoff of each party depending on the state of the world initially unknown to either player. In the spirit of

[1] Besides the utilization of employees' information, other rationales for delegating authority include the efficient use of scarce resources such as time or attention, reducing the compensation cost and motivating the employees (Gibbons et al., 2013). See Aghion et al. (2013) and Bolton and Dewatripont (2013) for recent surveys of the literature on the allocation of decision rights.

[2] Exceptions to this business judgment rule include contracts with financial investors and employment contracts within universities. Related to the latter case, Aghion et al. (2008) argue that academia serves as a commitment mechanism in which scientists retain the decision rights regarding the specifics of their projects, whereas the same rights reside with the employer as far as the scientists working in the private sector are concerned. Lacetera (2009) provides supporting evidence for this argument.

Aghion and Tirole (1997), the principal can delegate authority to the agent whose primary role is to collect information about the state of the world. Regardless of being granted authority, the agent exerts costly effort to generate a signal, which is, if generated, publicly observed. After the agent's investigation is over, the principal decides whether to stick to her initial delegation decision and then the party with authority chooses an action to implement the project.

Central to our analysis is the disagreement between the principal and the agent concerning the right course of action. Along the lines of Van den Steen (2008) and Che and Kartik (2009), the players disagree openly by having different prior beliefs about the state.[3] Differing priors not only result in different *ex ante* preferred actions but also lead the players to interpret any information about the state differently—even though they observe exactly the same information—and therefore to have differing *ex post* preferred actions. Hence, in our setup, the conflict of interest between the principal and the agent arises not because they have different underlying preferences but because they have differences of opinion.[4] The other key ingredient of our model is noncontractible decision rights as in Baker et al. (1999). That is, even though the principal can informally delegate authority to the agent, before the agent exercises his authority, the principal can revoke it, at a cost, if it is in her interest to do so. The cost of retracting the agent's authority consists of the direct cost of revoking the delegation decision (which may arise, for example, from the principal's reputational concerns) and the cost of implementing an action.

We begin our analysis with a benchmark case in which the principal has the ability to commit to a delegation policy.[5] This benchmark provides key insights. The disagreement between the players concerning the optimal action is mitigated with additional information. In other words, the party with no authority is better off if the decision is made (by the party with authority) after a signal is observed than when the decision is made without observing any additional information. The fact that any signal that may be generated by the agent is publicly observed generates additional effort incentives when decision-making is centralized. This follows because by generating a signal the agent can persuade the principal to take an action closer to his own preferred action. Since persuasion incentives arise only when the principal retains authority, the agent's effort provision is higher under centralization than under delegation. This difference is decisive for the principal's choice of organizational mode observed in equilibrium: as long as the implementation cost is not large, the principal retains authority regardless of the degree of disagreement.

In our second analysis of this model, we assume that the principal's delegation is not credible in the sense that she takes authority back from the agent when it is in her interest to do so. In this case,

[3] See Morris (1995) for a detailed discussion of the rationale for using differing priors, instead of a common prior, in economic analysis. For concrete examples drawn from the management literature, see Van den Steen (2010c).

[4] Throughout the analysis, we use the terms "difference of opinion" and "disagreement" interchangeably.

[5] Technically, we assume a sufficiently high cost of retracting authority so that the principal never finds it optimal to take authority back from the agent.

the degree of *ex ante* disagreement between the players and the informational setting determine what kind of delegation policy the principal can commit to. In the one extreme case in which the degree of disagreement is high, the principal finds it optimal to retract the agent's authority regardless of whether the agent has generated additional information. This follows because the principal's cost of allowing the agent to choose his preferred action is higher than the cost of reneging on her promise by taking back the agent's authority. In the other extreme case, in which the degree of disagreement is low, the principal can commit to not taking authority back from the agent since the cost of retracting authority exceeds the cost of being exposed to the agent's biased (from the principal's point of view) decision-making. At moderate levels of disagreement, the principal can commit to partial delegation in the sense that the agent is allowed to exercise his authority (i.e., to choose his preferred action) if and only if he generates additional information before making a decision. Intuitively, the principal's cost of retracting authority is lower than the disutility caused by the agent's biased decision only when the agent chooses an action after observing a signal. The signal's role in mitigating the degree of disagreement is essential to partial delegation.

When granted authority, the agent determines his effort provision according to whether he will be able to exercise it. The agent's effort is the lowest when the degree of disagreement is low. The logic is the same as the logic in the case of delegation considered in the benchmark case. Because the agent can choose his preferred action independently of the outcome of his investigation, he has no incentives to persuade the principal and therefore has weak effort incentives. Interestingly, the agent exerts higher effort when the disagreement is severe even though he knows that his authority will be retracted before exercising it. The reason is that the agent behaves as if decision-making is centralized and therefore exerts higher effort to persuade the principal by generating a signal. Finally, when the disagreement is moderate, in which case the principal can commit to partial delegation, the agent's effort provision is the highest. The logic is that because retaining authority is tied to the outcome of the agent's investigation, the agent's marginal benefit from generating a signal is the highest.

The organizational mode observed in equilibrium depends primarily on the level of effort exerted by the agent, which is, in turn, determined by the degree of *ex ante* disagreement. In extreme cases of disagreement (either low or high), the principal retains authority because delegation does not lead the agent to exert higher effort but brings a cost from the agent's biased decision (or, in the terminology of Aghion and Tirole (1997), a cost due to loss of control). At moderate levels of disagreement, the principal may delegate authority because, as indicated, she elicits higher effort from the agent under partial delegation than under centralization. In particular, the principal opts for partial delegation when the uncertainty in the environment is sufficiently high or the agent's signal is sufficiently precise. Intuitively, as either the environment becomes more volatile or the agent's signal becomes more informative, the value of acquiring additional information increases for the principal, and therefore, the rents from partial delegation increase.

In our third analysis of the model, we incorporate training to investigate the principal's incentives to be involved in the information acquisition process. Departing from the literature in which the principal's involvement takes the form of conducting her own investigation to figure out the optimal course of action (e.g., Aghion and Tirole, 1997; Rantakari, 2012), we focus on the principal's incentives to provide training which is treated as a cost-reducing investment in the agent's human capital. More specifically, before deciding whether to delegate authority, the principal chooses a level of training to provide to the agent and additional training reduces the worker's marginal cost of effort in information acquisition.[6]

Our analysis yields two main results. First, there is a positive relationship between training and delegation. That is, given the level of disagreement, the principal provides a higher level of training under delegation than under centralization. Intuitively, because the principal's marginal benefit of becoming informed is higher under delegation and training fosters effort (which in turn increases the agent's probability of generating a signal), the principal provides higher levels of training under delegation. Second, training facilitates delegation. For moderate levels of disagreement, because the level of training provided under (partial) delegation is higher than under centralization, the benefits from delegating authority, as opposed to retaining it, are even higher relative to the no-training case, and this reduces the threshold level of initial uncertainty above which partial delegation is optimal.[7] In other words, partial delegation becomes more likely to be optimal when training is possible than when it is not. Interestingly, the principal facing a low level of disagreement with the agent may switch from centralization to delegation. The logic is that the principal provides higher levels of training under delegation than under centralization and this may translate into higher effort provision under delegation, relative to under centralization, if the degree of complementarity between training and effort is sufficiently high. In other words, the principal uses training to elicit higher effort from the agent and this may result in delegation being the optimal organizational mode. Clearly, the switch is more likely to be observed when the disagreement is lower.

In the last part of the paper, we investigate the extent to which the implications of the third analysis are supported by the data. We investigate the following three predictions: i) delegation and training are positively related; ii) firms are more likely to delegate authority as the uncertainty in the environment increases; iii) firms are more likely to delegate authority as the worker's signal becomes more precise. To test these predictions, we use data drawn from a large, nationally-representative cross-section of British workplaces, the 2004 wave of the Workplace Employee Relations Survey

[6]Because we focus on the interaction between decisions concerning the delegation of authority and the provision of training, our analysis abstracts away from how transferability of human capital alters the principal's incentives to provide training. For analyses along those lines, see, for example, Acemoglu and Pischke (1998).

[7]Note that the same effect is also observed for the threshold value of signal precision.

(WERS).[8] The empirical results are broadly consistent with the model's implications.

The outline for the paper is as follows. The next section discusses the related work in the literature. Section 3 presents our theoretical analysis. In the subsections, we first present the setup of our model and then examine a benchmark case in which the principal can commit to delegation. Next, we derive the equilibrium behavior when the principal lacks the ability to commit to delegation. In the last part of the analysis, we incorporate training and then discuss the testable implications yield by this extension. Section 4 presents the data and discusses the empirical results. Section 5 presents concluding remarks.

2 Related Literature

Our paper falls into the extensive literature examining various aspects of delegation of authority within organizations. Starting with the seminal work of Aghion and Tirole (1997), a growing number of papers have examined the interplay between delegation and incentives for information acquisition (e.g., Zabojnik, 2002; Bester and Krähmer, 2008; Rantakari, 2012; Shin and Strausz, 2014). As in these papers, the question of how delegating authority alters the agent's incentives for information acquisition is essential to our analysis; however, our setting differs from those considered in the literature in two important ways. First, in our setting the conflict of interest between the principal and the agent does not arise from differences in their preferences but because they have differences of opinion. Second, we consider an environment in which decision rights are noncontractible.

In terms of modeling differences of opinion between the principal and the agent, our paper is closest to that of Che and Kartik (2009). These authors investigate how differences of opinion affect the agent's incentives to acquire information and the strategic disclosure of any information he has acquired. Their main result is that differences of opinion generate additional incentives for information acquisition but also worsen the agent's information disclosure. In a part of their analysis, Che and Kartik (2009) modify the Aghion-Tirole model to consider how differences of opinion alter the principal's decision to allocate authority. However, the delegation decision in their setting is irreversible—thus, the principal has no commitment problem. Other papers that examine the delegation decision in a setting with differing priors include Van den Steen (2008) and Omiya et al. (2017). Van den Steen (2008) examines the allocation of both decision rights and income rights, meaning that firm boundaries may change in his setup, whereas Omiya et al. (2017) follow an approach closer to ours by considering only the decision rights. However, in Omiya et al. (2017), the agent has private information about the state of the world and the principal can write a contract (on the message sent by the agent) to extract the agent's private information. In both

[8] Other studies that examine the delegation of authority and employ the same data source include Acemoglu et al. (2007), DeVaro and Kurtulus (2010), DeVaro and Prasad (2015) and Bilanakos et al. (2018).

of these papers, the principal can credibly delegate authority so that the agent is not concerned about his authority being retracted. Further, none of these three papers considers the principal's training provision.

As in Baker et al. (1999), our model is built on the assumption that the principal's delegation decision is not credible, but it differs from theirs in the following ways. First, our focus is on how differences of opinion are related to the delegation of authority when the delegation decision is non-contractible. Second, we examine how the principal's commitment problem affects her delegation decision (and her training provision) in a single-period model, whereas Baker et al. (1999) study an infinitely repeated game and show that the principal can informally delegate authority through self-enforcing contracts. Finally, there is no asymmetric information in our setting, whereas they consider an uninformed principal, who may not have the same information as the agent concerning the benefits from implementing the project proposed by the agent, and examine if informal delegation can be sustained through repeated interactions. Similarly, Alonso and Matouschek (2007) consider an infinitely repeated game in which the agent is better informed than the principal; but, they examine the agent's incentives to reveal information under different organizational modes the principal can commit to.[9] Finally, Aghion et al. (2008) focus on the allocation of decision rights to discuss the tradeoff between conducting research in academia or in the private sector. Their main assumption is that the delegation decision is credible only in academia in which case the scientists can freely choose their research strategies.[10]

Finally, Bilanakos et al. (2018) examine the relationship between delegation and training by extending the Aghion-Tirole framework. As in our analysis, they assume that training and worker effort are complementary; however, because our setup differs significantly from the one considered by Aghion and Tirole (1997), the implications of our model are different from those of Bilanakos et al. (2018). First, even though their model also predicts a positive relationship between delegation and training, the rationale for this prediction is different from ours. Specifically, they show that the firm opts for delegation and then provides more training than it would provide under centralization if its preferences are sufficiently congruent with those of the worker. By contrast, we show that the firm has an incentive to delegate authority if the disagreement is sufficiently pronounced. Second, their model is silent about the effects of uncertainty in the environment and the precision of the worker's information on the firm's incentives to delegate.[11]

[9] This strand of the literature in which the agent communicates his information strategically stems from the seminal work by Dessein (2002). See Bolton and Dewatripont (2013) or Gibbons et al. (2013) for a more detailed discussion.

[10] Another interesting paper in this strand of the literature is by Marino et al. (2009). These authors examine the allocation of authority when the principal's ability to centralize decision-making is limited by the agent's willingness to disobey the order made by the principal. In related work, Van den Steen (2010b) considers a setting with differing priors and examines the role of asset ownership in imparting interpersonal authority.

[11] Also, even though they employ the same dataset as we do, they do not test our second and third hypotheses.

3 Theoretical Framework

This section presents our theoretical framework we build upon Che and Kartik (2009). We first provide the setup of our model and then analyze the equilibrium behavior in a benchmark setting in which the principal can credibly commit to delegation. Next, we assume that the principal's delegation decision is not credible and then derive the equilibrium behavior under this assumption. In the last part, we analyze the principal's incentives to provide the agent with training and then discuss the empirical implications of this extension. All proofs are presented in the Appendix.

3.1 Model Setup

We consider a one-period game with two players: the principal ("P", "she" and "firm") and the agent ("A", "he" and "worker"). In this game, the party with authority takes an action, $a \in \mathbb{R}$, to implement a given project (or to maximize the firm's profits) and the players' payoffs depend on both the chosen action and the unknown state of the world, $\theta \in \mathbb{R}$.[12] More specifically, when action a is implemented, the utility of player i from implementing the project is given by

$$u_i(a,\theta) = -(a-\theta)^2 \tag{1}$$

where $i = P, A$.[13] As indicated, the true value of the state variable is initially unknown; importantly, players openly disagree on which action is the best for the firm, i.e., each player has his or her own priors concerning the state variable. In particular, player i's prior belief about the state variable is given by $\theta \sim N\left(\mu_i, \sigma_0^2\right)$. Without loss of generality, we assume that $\mu_A > \mu_P = 0$ and $\mu_A \in \left[\underline{\mu_A}, \overline{\mu_A}\right]$. Note that μ_A (hereafter referred to as the agent's "type") measures the degree to which the principal and the agent have differences of opinion about the state of the world. As we discuss below, this alters how each player interprets any signal about the state, and consequently, determines their preferred actions.

As in Aghion and Tirole (1997), information acquisition plays a central role on the delegation decision. Because the agent has expertise in the tasks assigned to him, he can exert costly effort to acquire a signal informative about the state. In particular, he exerts effort ψ to observe signal s with probability ψ, where $s \sim N\left(\theta, \sigma_s^2\right)$. The cost of exerting effort ψ, $\psi \in \left[\underline{\psi}, \overline{\psi}\right]$, is given by function $g(\psi)$, which is strictly increasing and convex and satisfies the Inada conditions (i.e., $g'\left(\underline{\psi}\right) = 0$ and $g'\left(\overline{\psi}\right) = \infty$). The agent's effort choice is not observed by the principal but the outcome of her investigation is publicly observed. That is, the principal observes the signal if the agent's efforts generate one.[14]

[12] Throughout the analysis, we use "action" and "decision" interchangeably.

[13] This preference structure is commonly used in the delegation literature (e.g., Alonso and Matouschek, 2007; Che and Kartik, 2009).

[14] This feature of our model contrasts with that of Che and Kartik (2009) who assume that the agent can withhold

We adopt the incomplete contracting approach (Grossman and Hart, 1986) by postulating that the principal cannot write contracts contingent on the agent's actions, the signal or payoffs.[15] Further, along the lines of Baker et al. (1999), decision rights are noncontractible. Thus, the principal may delegate authority to the agent; however, her delegation decision is not credible because she can revoke it before the agent takes any action. Conditional on having granted authority to the agent, the principal incurs a cost of R, $R > 0$, if she chooses to retract the agent's authority. The cost of revoking the delegation decision may arise, for example, from the firm's reputational concerns (Baker et al., 1999), or it may arise because the agent, whose authority is revoked, may engage in activities harmful to the principal (Hart and Holmstrom, 2010). Finally, the principal also incurs an implementation cost κ, $\kappa > 0$, when she, rather than the agent, chooses an action to implement the project.[16]

The timing of the events is as follows. The type of the agent is determined and observed by all players. Next, the principal decides whether to delegate authority to the agent. The agent then decides how much effort to exert in acquiring information. Afterwards, the outcome of the agent's investigation is publicly observed. If the agent was initially granted delegation, the principal then decides whether to retract authority from the agent. Finally, the player with authority takes an action and payoffs are determined according to the chosen action and the realized value of the state variable.

3.2 Benchmark: Equilibrium under Formal Delegation

This section considers what happens when the principal's delegation decision is credible. To investigate this issue, we assume $R = \infty$, that is, the cost of retracing the agent's authority is infinitely high, so that the principal can commit to delegation since it is not optimal to take the authority back from the agent.

To derive the equilibrium behavior, we first derive each player's preferred action that they would choose had they have the authority to do so. Given that the players' utility decreases with the distance between the action taken and the realized value of the state variable, they use all information available to update their beliefs concerning the state of the world and then decide about their preferred actions accordingly. When player i observes signal s, his or her posterior concerning the state variable, θ, is normally distributed with mean $\widetilde{\mu}_i = \rho s + (1-\rho)\mu_i$ and variance $\widetilde{\sigma}^2 = \frac{\sigma_0^2\sigma_s^2}{\sigma_0^2+\sigma_s^2}$, where $\rho = \frac{\sigma_0^2}{\sigma_0^2+\sigma_s^2}$ (DeGroot, 2004). Note that because each player interprets the signal

a signal strategically.

[15]For an analysis of the relationship between incentive pay and delegation, see, for instance, Prendergast (2002), DeVaro and Kurtulus (2010), DeVaro and Prasad (2015) or Lo et al. (2016).

[16]This cost arises, for example, if the agent has a lower opportunity cost of time than the principal (Van den Steen, 2010a). Alternatively, the principal may incur a monitoring cost when she requests the agent to implement a specific action.

according to his or her opinion (i.e., his or her own prior belief), their posterior means differ. Let Ω denote the information available to players, where $\Omega = s$ if signal s is generated by the agent and $\Omega = \emptyset$ if not. Using state-dependent utilities on (1), one can write each player's expected utility conditional on the information available as follows:

$$\mathbb{E}\left[u_i(a,\theta)|\Omega\right] = -\left(a - \mathbb{E}\left[\theta|\Omega\right]\right)^2 - \mathbb{V}\left[\theta|\Omega\right]. \quad (2)$$

Let $\alpha_i(\Omega)$ denote the optimal action of player i conditional on information set Ω. From (2), it is easy to see that $\alpha_i(\Omega) = \mathbb{E}_i\left[\theta|\Omega\right]$, where $\mathbb{E}_i\left[.\right]$ indicates that the expectation is taken according to the belief of player i.

Differences of opinion between the players result in a conflict of interest concerning the optimal action even though their underlying preferences are the same. Indeed, the conflict arises regardless of whether any additional information about the state is generated by the agent, but its severity is dependent upon whether a decision is made after observing an informative signal. To see this, suppose that the agent's efforts do not generate any signal, i.e., $\Omega = \emptyset$. In this case, the optimal action is 0 for the principal (since her prior mean is normalized to zero) and μ_A for the agent. The preferred actions upon observing signal s, i.e., when $\Omega = s$, are ρs and $\rho s + (1-\rho)\mu_A$ for the principal and the agent, respectively. Thus, the difference between the players' preferred actions is $(1-\rho)\mu_A$ when a decision is made after observing signal s. Note that the signal appears in the optimal action of both players with the same weight. Therefore, the exact value of the signal does not cause any additional incongruity between the players.[17]

To summarize the discussion, let the agent's bias from the principal's standpoint be denoted by $B_s = (1-\rho)\mu_A$ if the agent's efforts generate a signal and $B_\emptyset = \mu_A$ if not. We make two observations here. First, an informative signal reduces the bias (i.e., $B_s < B_\emptyset$ as long as $\sigma_s^2 < \infty$). Second, the magnitude of the bias upon observing a signal is decreasing in the initial uncertainty in the environment and the precision of the signal, that is, B_s decreases with σ_0^2 and increases with σ_s^2.[18]

After deriving the players' preferred actions under each informational setting, we consider the principal's delegation decision. Suppose that the principal does not delegate authority to the agent, i.e., decision making is centralized. Since the principal has the authority over the decision to be made, the agent anticipates that the principal will choose $\alpha_P(s)$ if she observes signal s and $\alpha_P(\emptyset)$ if not. Therefore, the agent chooses a level of effort, ψ, to maximize his expected payoff given by

[17]This result depends on the assumption that players' priors beliefs have the same variance, σ_0^2. See Che and Kartik (2009) who employ the same assumption.

[18]This result hinges on how much weight is assigned to the signal in predicting the state. Because the principal and the agent assign the same weight to the signal in forming their preferred actions, the disagreement is mitigated as the weight of the signal increases. For example, the signal is assigned a higher weight in the posterior mean as it becomes more precise. Indeed, in the extreme case in which the signal is perfectly informative about the state, the difference in the players' optimal actions disappears (since $\widetilde{\mu}_H - \widetilde{\mu}_A \to 0$ as $\sigma_s^2 \to 0$).

the following:

$$U_A^c(\psi) = \psi \mathbb{E}[u_A(\alpha_P(s))] + (1-\psi)\mathbb{E}[u_A(\alpha_P(\emptyset))] - g(\psi). \tag{3}$$

The agent's optimal effort, ψ^c, is then characterized by

$$\mathbb{E}[u_A(\alpha_P(s))] - \mathbb{E}[u_A(\alpha_P(\emptyset))] = g'(\psi^c). \tag{4}$$

Note that even though the agent has no power to make any decisions, his optimal effort for information acquisition is strictly higher than the minimum feasible effort. The agent's effort incentives stem from two sources: by generating a signal, he not only achieves lower uncertainty about the state but also reduces the difference of opinion between the principal and himself. That is, since the agent will definitely be exposed to the principal's biased decision, he prefers that the decision be based upon a signal—recall that the difference of opinion is mitigated when a signal is observed by the party with authority. In other words, by generating a signal the agent persuades the principal to make a decision that is closer to his own preferred decision. These persuasion incentives result in the agent exerting a higher level of effort provision for information acquisition. Given that the worker's effort is uniquely determined by (4), the firm perfectly anticipates its expected payoff under centralization, $U_P^c(\psi^c)$.

Next, we consider the principal's payoff under delegation. Suppose that the agent was initially given authority to choose an action and consider the principal's decision to retract the agent's authority. Since the cost of doing so is very high (as, by assumption, $R = \infty$), the principal always allows the agent to exercise his authority. Anticipating that he will be able to choose his preferred action under delegation, the agent chooses a level of effort, ψ, to maximize his expected payoff:

$$U_A^d(\psi) = \psi \mathbb{E}[u_A(\alpha_A(s))] + (1-\psi)\mathbb{E}[u_A(\alpha_A(\emptyset))] - g(\psi). \tag{5}$$

Therefore, the agent's optimal effort, ψ^d, is characterized by

$$\mathbb{E}[u_A(\alpha_A(s))] - \mathbb{E}[u_A(\alpha_A(\emptyset))] = g'\left(\psi^d\right). \tag{6}$$

It follows from equations (4) and (6) that the agent's effort provision is higher under centralization than under delegation.

Lemma 1. *The agent's effort level is higher under centralization than under delegation, i.e.,* $\psi^c > \psi^d$*. Also,* ψ^c *is increasing in* μ_A *while* ψ^d *does not depend on it.*

Because the agent with authority chooses his preferred action, the persuasion incentives are lacking under delegation. This means that effort incentives for information acquisition stems only from the reduction in the uncertainty that occurs when the decision is made after observing a signal. This is in stark contrast to the case of centralization, in which the agent's additional incentives arise from the persuasion effect. Hence, when the principal has the ability to commit to delegation, the agent's effort choice is higher under centralization than under delegation (i.e., $\psi^c > \psi^d$). An implication of this result is that the degree of *ex ante* disagreement strengthens the worker's effort incentives under centralization, whereas it has no impact on the incentives under delegation. This follows because the persuasion incentives, which exist only under centralization, become stronger as the difference of opinion between the players becomes more pronounced.

Using (6), the principal anticipates the agent's effort provision, ψ^d, and her expected payoff, $U_P^d(\psi^d)$, under delegation. The following result describes the equilibrium behavior.

Proposition 1. *Suppose the principal can commit to delegation. In equilibrium, the principal retains authority and the agent exerts effort* ψ^c.

In equilibrium, the principal finds it optimal to retain authority regardless of the agent's type.[19] The intuition behind this result is simple. For the principal, the cost of delegating authority to the agent consists of the disutility from the agent's biased decision while the cost of centralization consists of the implementation cost. The decisive factor determining the principal's choice of organizational mode is the level of effort exerted by the agent for information acquisition. Since centralization, rather than delegation, leads to a higher effort level and the principal is better off when the decision is made after a signal is observed, centralization is the optimal organizational mode for the principal when she has the ability to commit to delegation.

3.3 Equilibrium under Informal Delegation

This section focuses on the equilibrium behavior when the principal's delegation decision is not credible (i.e., when $R < \infty$). In other words, the principal can informally delegate authority to the agent but she cannot commit not to take back the authority before the agent exercises it. Not surprisingly, introducing the principal's lack of commitment ability does not alter the players' optimal behavior under centralization. Thus, as in the benchmark analysis, under centralization the agent exerts effort ψ^c and the principal's expected payoff is $U_P^c(\psi^c)$. By contrast, the players' optimal behavior under delegation is altered.

To investigate this, suppose that the agent was initially given authority to choose an action and consider the principal's decision to retract the agent's authority. As this decision is made after the outcome of the agent's investigation is publicly observed, it is dependent upon what information is available (either $\Omega = \emptyset$ or $\Omega = s$) to predict the state of the world. If the agent retains authority and takes his preferred action, the principal incurs disutility that equals either $B_\emptyset^2$ or B_s^2 depending on

[19]The boundary conditions for this result to hold are stated in the Proof of Proposition 1.

whether the agent has generated a signal before making a decision. The principal finds it optimal to revoke her delegation decision if doing so is less costly than letting the agent make a decision. In other words, the principal retracts authority as long as the disutility from the agent's biased decision making is lower than the cost of revoking authority plus the cost of implementing an action, $R + \kappa$. The principal's revoking decision depends on the agent's type (conditional on the cost of retracting authority and the cost of implementation), which ultimately determines the magnitude of the principal's disutility from the agent's decision making.

Lemma 2. *Suppose that the principal initially delegates authority to the agent. There exist $\widetilde{\mu_A}(s)$ and $\widetilde{\mu_A}(\emptyset)$ such that $\widetilde{\mu_A}(s) > \widetilde{\mu_A}(\emptyset)$. If $\mu_A > \widetilde{\mu_A}(s)$, the principal takes the agent's authority back. If $\widetilde{\mu_A}(s) > \mu_A > \widetilde{\mu_A}(\emptyset)$, she retracts the agent's authority if and only if the agent does not generate a signal. Finally, the principal allows the agent to exercise his authority if $\mu_A < \widetilde{\mu_A}(\emptyset)$.*

The intuition behind this result is simple. If the degree of disagreement is sufficiently low, the principal allows the agent to make a decision—regardless of whether he has generated a signal—because the agent's biased decision results in disutility that is lower than the cost of taking his authority back. In other words, because the disutility the agent may inflict on the principal is limited, the principal can commit to not taking the agent's authority back. Therefore, the analysis of the "low bias" case is the same as the analysis of delegation considered in the benchmark case. In the other extreme case, in which the difference of opinion is sufficiently high, the principal retracts the agent's authority, regardless of the outcome of his investigation, because the disutility caused by the agent's biased decision exceeds the cost of revoking the delegation decision. The intermediate case, in which the difference of opinion is moderate, is the interesting one: the principal retracts the agent's authority if and only if he has not generated a signal. The agent is allowed to take his preferred action if his investigation generates additional information about the state because, from the principal's standpoint, the disutility from the agent's biased decision is lower than the cost of retracting authority only if the decision is made after observing a signal (recall that the disagreement concerning the optimal action is mitigated with additional information).

After characterizing the principal's decision about retracting authority, we turn to the agent's effort provision in information acquisition. Since the degree of disagreement is public information, the agent perfectly anticipates if the principal will retract his authority before exercising it. Thus, the agent's optimal effort choice depends on his own type, μ_A. For notational convenience, let $\psi_k^d(\mu_A)$ be the agent's optimal effort choice when the degree of disagreement is k, $k = L, M, H$. Specifically, $k = H$ when the degree of disagreement is high (i.e., $\mu_A > \widetilde{\mu_A}(s)$), $k = M$ when it is moderate (i.e., $\widetilde{\mu_A}(s) > \mu_A > \widetilde{\mu_A}(\emptyset)$), and $k = L$ when it is low (i.e., $\mu_A < \widetilde{\mu_A}(\emptyset)$). Anticipating the conditions under which his authority will be retracted by the principal, the agent chooses a level of effort, ψ_k^d, to maximize his expected payoff:

$$U_A^d\left(\psi_k^d;\mu_A\right)=\begin{cases}\psi_H^d\mathbb{E}\left[u_A(\alpha_P(s))\right]+\left(1-\psi_H^d\right)\mathbb{E}\left[u_A(\alpha_P(\emptyset))\right]-g\left(\psi_H^d\right), & \text{if } \mu_A>\widetilde{\mu_A}(s)\\ \psi_M^d\mathbb{E}\left[u_A(\alpha_A(s))\right]+\left(1-\psi_M^d\right)\mathbb{E}\left[u_A(\alpha_P(\emptyset))\right]-g\left(\psi_M^d\right), & \text{if } \widetilde{\mu_A}(s)>\mu_A>\widetilde{\mu_A}(\emptyset)\\ \psi_L^d\mathbb{E}\left[u_A(\alpha_A(s))\right]+\left(1-\psi_L^d\right)\mathbb{E}\left[u_A(\alpha_A(\emptyset))\right]-g\left(\psi_L^d\right), & \text{if } \mu_A<\widetilde{\mu_A}(\emptyset)\end{cases}$$

As in the case of centralization, attaining lower uncertainty is a source of incentives for any agent type. Thus, whether or not the agent can exercise his authority is the decisive factor determining the relative size of effort exerted by each type of agent.

Lemma 3. *The agent's optimal effort choices satisfy* $\psi_M^d>\psi_H^d=\psi^c>\psi_L^d$.

To see the intuition behind this result, consider the agent's marginal benefit of effort in each case. When the degree of disagreement is low, incentives for information acquisition are the weakest because the agent always exercises his authority and therefore has no incentives to persuade the principal. In the other extreme case, in which the agent's authority is always retracted, the size of incentives are the same as under centralization. Even though the agent is initially granted authority, he knows that the principal will make the decision (as if decision-making is centralized); however, by generating a signal the agent induces the principal to make a decision closer to his preferred decision. Hence, the agent has stronger incentives for information acquisition than the case in which his authority is never retracted by the principal. Finally, the agent has the strongest effort incentives when the degree of disagreement is moderate. In this case, the agent anticipates that he will be able to exercise his authority only if he generates a signal. In other words, the agent will be exposed to the principal's biased decision if he loses the authority before exercising it, whereas he will be able to choose his own preferred action if he retains authority. Hence, the risk of losing authority and the disagreement with the principal concerning the optimal action provide the agent with additional incentives for information acquisition.

Overall, observing the agent's type, μ_A, the principal anticipates that under delegation the agent's effort provision would be ψ_k^d and her expected payoff would be $U_P^d\left(\psi_k^d;\mu_A\right)$, where $k=L,M,H$. The following result describes the equilibrium behavior.

Proposition 2. *Suppose the principal cannot commit to delegation. Equilibrium behavior is described by (i) and (ii):*

(i) If $\mu_A>\widetilde{\mu_A}(s)$ *or* $\mu_A<\widetilde{\mu_A}(\emptyset)$*, the principal retains authority and the agent exerts effort* ψ^c.

(ii) If $\widetilde{\mu_A}(s)>\mu_A>\widetilde{\mu_A}(\emptyset)$*, the principal opts for partial delegation if either* σ_0^2 *is sufficiently large or* σ_s^2 *is sufficiently small. The agent exerts effort* ψ_M^d *if he is granted authority and* ψ^c *if not.*

As indicated by (i), the principal finds it optimal to retain authority if the difference of opinion is either low or high. On the benefit side, delegation does not strengthen the agent's incentives in either case. Indeed, the level of effort exerted by the agent under delegation is, at best, the same as under centralization (see Lemma 3). On the cost side, delegation results in additional disutility for the principal because either she incurs the cost of retracting the agent's authority (when the difference of opinion is high) or she is exposed to the agent's biased decision making (when the difference of opinion is low). Hence, the principal retains authority to avoid these costs which arise without any benefits.

By contrast, partial delegation may be optimal for the principal if the difference of opinion is moderate (see (ii)). As discussed, the risk of losing authority generates additional incentives for the agent and this results in a higher likelihood of a decision being made upon observing a signal. Thus, facing a moderate level of disagreement with the agent increases the principal's benefits from delegation, which include reducing the uncertainty about the state of the world and avoiding the costs of implementation and the cost of revoking authority. Importantly, the benefits dominate the costs if either the initial uncertainty in the environment is sufficiently high or the agent's signal is sufficiently precise. Note that in either case the conflict of interest between the players is mitigated as the difference in their posterior means diminishes (that is, as B_s decreases).[20]

3.4 Firm-Provided Training under Informal Delegation

In this section, we maintain the assumption concerning the principal's lack of commitment ability and analyze the principal's incentives to provide the agent with training. The objective of the analysis is twofold. First, we provide insights into the principal's incentive to facilitate information acquisition by investing in the agent's human capital. Second, we examine the interaction between the principal's delegation and training decisions.

We incorporate training into our model as follows. Before deciding about delegating authority, the principal chooses how much training to provide to the agent. The rest of the moves is the same as in the previous analysis in which the principal can informally delegate authority to the agent. The principal chooses level of training t, $t \in \left[0, \bar{t}\right]$, at cost $c\left(t\right)$, where $c\left(t\right)$ is strictly increasing and convex. The agent's cost of exerting effort ψ is given by $g\left(\psi, t\right)$, where t is the amount of training provided by the principal. As before, $g(.)$ is strictly increasing and convex with respect to ψ. By design, training renders the agent more productive by reducing the cost of acquiring additional information about the state. More specifically, additional training reduces the marginal cost of effort, i.e., $\frac{\partial^2 g(\psi,t)}{\partial\psi\partial t} < 0$ for any ψ.[21]

[20]In the next section, we discuss in detail how the initial uncertainty and the signal precision alter the principal's incentives to delegate authority.

[21]We assume that both $g\left(.\right)$ and $c\left(.\right)$ satisfy the Inada conditions, i.e., $g\left(.\right)$ satisfies $\frac{\partial g\left(\underline{\psi},t\right)}{\partial\psi} = 0$ and $\frac{\partial g\left(\overline{\psi},t\right)}{\partial\psi} = \infty$

We begin our analysis with the optimal behavior under centralization. Different from the analysis above, the agent takes his level of training into account when choosing how much effort to exert for acquiring information. To this end, the agent who received training t chooses $\psi^c(t)$ to maximize $U_A^d(\psi)$, given by (3).[22] The first-order condition that characterizes the optimal effort choice is the following:

$$\mathbb{E}\left[u_A(\alpha_P(s))\right] - \mathbb{E}\left[u_A(\alpha_P(\emptyset))\right] = \frac{\partial g\left(\psi^c(t), t\right)}{\partial \psi}. \tag{7}$$

As in the earlier analysis, the agent has incentives to exert effort because generating a signal reduces both the uncertainty about the state and the disagreement with the principal concerning the action to be taken. In addition, because the cost function is strictly convex with respect to effort and the marginal cost of effort decreases with training, the agent's effort choice is increasing in the level of training provided by the principal. This enables the principal to alter the agent's effort choice through her training provision. Anticipating $\psi^c(t)$, the principal chooses a level of training, t, to maximize her expected payoff:

$$U_P^c\left(t; \psi^c(t)\right) = \psi^c(t)\,\mathbb{E}\left[u_P(\alpha_{Pq}(s))\right] + \left(1 - \psi^c(t)\right)\mathbb{E}\left[u_P(\alpha_P(\emptyset))\right] - \kappa - c(t). \tag{8}$$

The principal's optimal training choice, t^c, equates the marginal benefit of training to the marginal cost:

$$\frac{\partial \psi^c(t^c)}{\partial t}\left[\mathbb{E}\left[u_P(\alpha_P(s))\right] - \mathbb{E}\left[u_P(\alpha_P(\emptyset))\right]\right] = c'(t^c). \tag{9}$$

As reflected on (9), the marginal benefit of providing an additional level of training is determined by the product of two terms: the first term measures how additional training alters the agent's optimal effort choice while the second term shows how much the principal's payoff changes if the decision is made (by the principal herself) upon observing a signal (i.e., it measures the principal's marginal benefit from becoming informed while making a decision). In sum, under centralization, the principal provides training t^c, described by (9), and the agent exerts effort $\psi^c(t^c)$, described by (7).

Next, we derive the optimal behavior when the principal initially delegates authority to the agent. Since training does not alter the agent's opinion regarding the state variable—consequently, the degree of disagreement between the players is not affected—the principal's decision to retract the agent's authority does not depend on how much training is provided to the agent. Therefore, the principal's optimal behavior after observing the outcome of the agent's investigation is as

for any t, and $c(.)$ satisfies $c'(0) = 0$ and $c'(\bar{t}) = \infty$. In addition, to derive comparative statics results, we assume that the third-order partial derivatives of $g(.)$ are zero and that $c'''(.) \leq 0$.

[22] To be more precise, $g(\psi)$ is replaced by $g(\psi, t)$ on (3).

described by Lemma 2. This implies that the expected utility of the agent with type μ_A is given by $U_A^d\left(\psi_k^d;\mu_A\right)$, except that the cost of exerting effort ψ_k^d depends on the level of both training provided by the principal and the effort exerted by the agent. Importantly, this means that the agent's marginal benefit from exerting an additional level of effort does not depend on training and therefore is the same as in the previous analysis, whereas the marginal cost of effort is a function of both the level of effort and the level of training.

Given the agent's type, the principal anticipates his effort provision and calculates the expected payoff accordingly. Thus, the principal chooses training level t_m^d, $m = L, M, H$, to maximize her expected payoff given by the following:

$$U_P^d\left(t_k^d;\mu_A\right) = \begin{cases} \psi_H^d\left(t_H^d\right)\mathbb{E}\left[u_P(\alpha_P\left(s\right))\right] + \left(1-\psi_H^d\left(t_H^d\right)\right)\mathbb{E}\left[u_P(\alpha_P\left(\emptyset\right))\right] - c\left(t_H^d\right) - R - \kappa, & \text{if } \mu_A > \widetilde{\mu_A}\left(s\right) \\ \psi_M^d\left(t_M^d\right)\mathbb{E}\left[u_P(\alpha_A\left(s\right))\right] + \left(1-\psi_M^d\left(t_M^d\right)\right)\left(\mathbb{E}\left[u_P(\alpha_P\left(\emptyset\right))\right] - R - \kappa\right) - c\left(t_M^d\right), & \text{if } \widetilde{\mu_A}\left(s\right) > \mu_A > \widetilde{\mu_A}\left(\emptyset\right) \\ \psi_L^d\left(t_L^d\right)\mathbb{E}\left[u_P(\alpha_A\left(s\right))\right] + \left(1-\psi_L^d\left(t_L^d\right)\right)\mathbb{E}\left[u_P(\alpha_A\left(\emptyset\right))\right] - c\left(t_L^d\right), & \text{if } \mu_A < \widetilde{\mu_A}\left(\emptyset\right) \end{cases}$$

As under centralization, the principal's marginal benefit from providing an additional level of training depends on the product of two factors: how much the agent's effort provision increases with additional training and how much the principal's expected payoff increases if a decision is made (by the party with authority) upon observing a signal. Because the agent's marginal benefit of effort does not depend on the level of training provided by the principal, the first factor does not depend on the agent's type either. That is, the degree to which additional training increases the agent's effort provision is the same regardless of the degree of initial disagreement between the players.[23] This means that how different the level of training given to each type of agent is determined solely by the latter factor.

Lemma 4. *Optimal training and effort choices satisfy the following conditions:*

(i) $t_M^d \geq t_L^d > t_H^d = t^c > 0$.

(ii) $\psi_M^d\left(t_M^d\right) > \psi_H^d\left(t_H^d\right) = \psi^c\left(t^c\right)$.

(iii) $\psi_L^d\left(t_L^d\right) > \psi^c\left(t^c\right)$ *if* $g_{\psi t}$ *is sufficiently large in absolute value.*

When decision-making is centralized or when the difference of opinion is high (in which case the agent's authority is eventually retracted by the principal), the principal's incentive to provide training arises only because making a decision upon observing a signal reduces the uncertainty concerning the state of the world. Thus, the level of training provided by the principal in these cases is positive but the lowest.

[23]Note that because additional training reduces the marginal cost of effort, the agent's effort provision increases with training. A sufficient condition for the magnitude of this effect to be the same for all agent types is to have the third-degree derivatives of $g(.)$ equal to zero (see Remark 1 in the Appendix). Even though this is not required for the results of the model, it simplifies the algebra and the corresponding discussion.

By contrast, the principal has additional incentives to provide training when the agent, rather than the principal herself, may make the decision. For example, the principal provides a higher level of training when the agent is always allowed to make a decision (a situation that arises when the difference of opinion is low) than when decision-making is centralized. Given that the principal will definitely be exposed to the agent's biased decision, she is better off if the decision is made after observing a signal—recall that the difference of opinion is mitigated when additional information about the state is observed by the party who makes the decision. This generates additional incentives for the principal since the agent's probability of generating a signal, conditional on his type, increases with the level of training he received. Finally, the principal's incentives to provide training are the strongest when the difference of opinion is moderate. The logic is the following. Because the principal avoids the cost of retracting the agent's authority—recall that this cost exceeds the disutility the principal would incur if the agent was allowed to make a decision (see Lemma 2)—she has an incentive to encourage the agent to exert higher levels of effort. Thus, the principal provides the highest level of training under partial delegation (i.e., when the agent's authority is tied to the outcome of his investigation).

To understand the logic behind the agent's effort choice, recall that training alters the agent's effort provision only through its effect on the marginal cost of effort (as noted, the marginal benefit of effort is not affected by training). Because the level of training provided under centralization is the same as the one provided when the degree of disagreement is high (that is, $t_H^d = t^c$), the agent's effort in these cases is the same. Importantly, the agent who has a moderate level of disagreement with the principal exerts a higher level of effort than these two cases both because the agent's marginal benefit from increased effort is higher (see the corresponding discussion after Lemma 3) and because this type of agent is provided a higher level of training. Finally, recall that in the absence of training the agent who has a low level of disagreement with the principal exerts a lower level of effort under delegation than under centralization (see Lemma 3). This result may be reversed when training is taken into account because this type of agent receives a higher level of training under delegation than under centralization (i.e., $t_L^d > t^c$). In particular, if $g_{\psi t}$ is sufficiently large in absolute value (in which case the increase in effort caused by additional training is larger), then the agent's provision will be higher under delegation.

The following result describes the equilibrium behavior when the principal cannot commit to delegation but she can provide training to the agent.

Proposition 3. *Suppose the principal cannot commit to delegation. The equilibrium behavior is described by (i) through (v):*

(i) Whenever decision-making is centralized, the principal provides training t^c and the agent exerts effort $\psi^c(t^c)$.

(ii) *If* $\mu_A > \widetilde{\mu_A}(s)$*, the principal retains authority.*

(iii) *If* $\widetilde{\mu_A}(s) > \mu_A > \widetilde{\mu_A}(\emptyset)$*, the principal opts for partial delegation as long as either* σ_0^2 *is sufficiently large or* σ_s^2 *is sufficiently small. Under partial delegation, the principal provides training* t_M^d *and the agent exerts effort* $\psi_M^d\left(t_M^d\right)$*.*

(iv) *If* $\mu_A < \widetilde{\mu_A}(\emptyset)$ *and* $g_{\psi t}$ *is small (in absolute value), the principal retains authority.*

(v) *If* $\mu_A < \widetilde{\mu_A}(\emptyset)$ *and* $g_{\psi t}$ *is sufficiently large (in absolute value), there exists* μ_A^+ *such that* $\mu_A^+ \leq \widetilde{\mu_A}(\emptyset)$ *and*

- *if* $\mu_A > \mu_A^+$*, the principal retains authority.*
- *if* $\mu_A \leq \mu_A^+$ *and either* σ_0^2 *is sufficiently large or* σ_s^2 *is sufficiently small, the principal delegates authority and provides training* t_L^d *while the agent exerts effort* $\psi_L^d\left(t_L^d\right)$*.*

When faced a high level of disagreement with the agent, the principal's decision to delegate authority is not affected by the introduction of training: the principal retains authority (even though she provides a positive level of training) because, as discussed, she cannot elicit higher effort from the agent by granting authority and then taking it back.

Training facilitates delegation of authority when the degree of disagreement is moderate. As discussed in the previous section, the principal facing a moderate level of disagreement opts for partial delegation if either the initial uncertainty is sufficiently high or the agent's signal is sufficiently precise. The ability to train the agent increases the principal's rents from delegation since this type of agent is provided with a higher level of training under delegation than under centralization. This difference in the amount of training, in turn, induces the agent to further increase his effort provision under delegation, as opposed to under centralization, as training reduces the cost of acquiring information. Hence, the possibility of training the agent increases the probability of partial delegation being optimal.[24]

Training may alter the principal's delegation decision when the degree of disagreement is low. As (iv) indicates, if the complementarity between effort and training is low (in which case the worker's effort provision is lower under delegation, i.e., $\psi_L^d\left(t_L^d\right) < \psi^c(t^c)$), the principal retains authority. Thus, the principal does not change her choice of organizational mode even though she would provide higher training under delegation than under centralization. A more interesting result is observed if the complementarity between training and effort is sufficiently high so that higher training provision under delegation, relative to centralization, also translates into higher effort provision (see (v)). In this case, full delegation may be optimal for the principal. More specifically, for sufficiently low levels of disagreement (i.e., for $\mu_A \leq \mu_A^+$), the principal allows the

[24]Note that the threshold value of σ_0^2 above which partial delegation is optimal is lower when training is possible than when it is not. The same result but in the reversed direction holds for σ_s^2.

agent to exercise his authority, regardless of whether he generates a signal. The intuition is simple. Because the disagreement on the optimal action is low, the principal is willing to be exposed to the agent's biased decision in order to benefit from higher effort provision. Clearly, these benefits are outweighed by the costs when the disagreement reaches a certain threshold, at which point the principal switches to centralization as the optimal organizational mode.

Before closing the discussion of the equilibrium behavior, we discuss how the principal's rents from delegation change with the initial uncertainty in the environment (σ_0^2) and the variation in the agent's signal (σ_s^2). For convenience, we focus on the case of moderate level of disagreement between the players.[25]

To examine how the initial uncertainty in the environment affects the principal's delegation decision, we make three observations. First, as the environment becomes more uncertain (i.e., as σ_0^2 increases), the principal's marginal benefit from becoming informed increases not only because the reduction in the uncertainty concerning the state is larger (that is, $\sigma_0^2 - \widetilde{\sigma}^2$ increases with σ_0^2) but also because the degree of disagreement with the agent is less pronounced (since B_s decreases with σ_0^2). Hence, since the agent exerts higher effort under delegation (i.e., $\psi_M^d\left(t_M^d\right) > \psi^c\left(t^c\right)$ as indicated by (ii) of Lemma 4), the principal's rents from delegation increases with σ_0^2, holding effort and training levels constant. Second, as σ_0^2 increases, the principal increases her training provision more under delegation than under centralization. Third, higher initial uncertainty has two effects on the agent's effort choice. On the one hand, the agent has stronger effort incentives under delegation because, as indicated, the principal increases training provision more when she opts for partial delegation. On the other hand, because the persuasion effect becomes stronger, the agent's effort incentives increase more under centralization than under delegation. As discussed in the Appendix, the former effect dominates the latter effect as long as the complementarity between training and effort is sufficiently large. Taken together, these three observations imply that the principal's rents from delegation increase with the initial uncertainty.[26]

Not surprisingly, the principal's rents from delegation decrease as the agent's signal becomes less informative (i.e., as σ_s^2 increases). To see why σ_0^2 and σ_s^2 affect the returns from delegation in opposite directions, consider how these parameters alter the degree of disagreement between the players' preferred actions after a signal is observed, B_s. As σ_s^2 increases, the players assign a lower weight to the signal in their posteriors. This also means that the weight on their priors, over which the principal and the agent have a disagreement, increases. Thus, the magnitude of the *ex post* disagreement increases with the variance of the signal. By contrast, the effect of the initial

[25]With small modifications, a similar reasoning applies to the case of low level of disagreement assuming the principal opts for delegation.

[26]We should also note that because the principal increases her training provision more under delegation than under centralization, the cost of training also increases more in the former case. Clearly, this effect reduces the principal's rents from delegation. As discussed in the Appendix, we always assume that the effect of training cost is not sufficiently large to alter the principal's optimal choice of organizational mode.

uncertainty is the opposite: as σ_0^2 increases, the weight on the signal increases, and consequently, B_s decreases. This explains why the effects of σ_0^2 and σ_s^2 on delegation rents act in opposite ways. In sum, as the signal becomes less informative, the principal reduces training provision more under delegation than under centralization, whereas the agent lowers his effort more under delegation than under centralization.[27] Hence, the principal earns lower rents from delegation as the signal becomes less informative.

Finally, it is worth summarizing the empirical implications of this analysis since we are interested in assessing how consistent the model's implications are with data. The main prediction of our theory is that delegation is associated with higher levels of training. Our analysis shows that even though the firm provides training in any organizational mode, it provides a higher level of training under delegation than under centralization (see Lemma 4). Hence, we expect a positive correlation between delegation and training. Our analysis also yields testable predictions concerning how the uncertainty in the environment and the precision of the worker's information are related to the firm's propensity to delegate authority. In particular, we show that the rents from delegation increase with the uncertainty in the environment and the precision of the worker's signal (see (iii) and (v) of Proposition 3).

In summary, we test the following hypotheses: i) delegation and training are positively related; ii) holding other factors constant, a firm is more likely to delegate as the uncertainty in the environment increases; iii) holding other factors constant, a firm is more likely to delegate as the worker's signal becomes more informative. To take these predictions to the data, in the next section we discuss how we proxy for the uncertainty in the environment and the precision of the worker's signal.

4 Empirical Analysis of Delegation and Training

This section presents an empirical analysis based on the empirical implications of the model analyzed in Section 3.4. We first describe our data and the key variables used in the regression analyses and then discuss the empirical results.

4.1 Description of Data and Key Variables

Our data is drawn from the 2004 wave of the Workplace Employee Relations Survey (WERS), a large, nationally-representative cross-section of British workplaces.[28] In each wave of the survey, a sample of workplaces is randomly drawn from the Interdepartmental Business Register, maintained

[27]In addition to increasing the degree of the *ex post* disagreement, B_s, lower signal precision also decreases the reduction in the uncertainty about the state. This effect also reduces the principal's incentive to delegate authority.

[28]In our discussion of the empirical analysis, we use "workplace", "establishment" and "firm" interchangeably.

by the Office of National Statistics. The surveys are stratified by workplace size and industry with larger workplaces and some industries being overrepresented (Chaplin et al., 2005). The survey population is all British workplaces (with 5 or more employees) except those in primary industries and private households with domestic staff. This dataset is suitable for our empirical analysis because it includes information about delegation and training while providing information on a wide range of employee and employer characteristics that can not only serve as important controls but also be used to proxy for the uncertainty in the environment and the signal precision.

The survey comprises three main sections: the 'Management Questionnaire', the 'Worker Representative Questionnaire' and the 'Employee Questionnaire'. We use information from both the management and the employee questionnaires. The management questionnaire is administered by a face-to-face interview with the most senior manager who has day-to-day responsibility for industrial relations or personnel matters. For the employee questionnaire, a sample of 25 employees (or all employees if the total number of the employees in the workplace is fewer than 25) is randomly selected at all workplaces participating in the management survey.[29] This questionnaire is self-administered by the employee without an interviewer's direct involvement. The response rate is 64% in the management questionnaire and 60% in the employee questionnaire. Throughout the analysis we use employee weights which correct for the non-response bias and render our working sample representative of the sampling population.

Our delegation measure comes from the employee questionnaire. At each workplace, the surveyed employees are asked: "*In general, how much influence do you have about the range of tasks you do in your job?*" Responses are recorded on a four-point scale: 'None', 'A little', 'Some' and 'A lot'.[30] Despite being subjective, this measure is employed to proxy for the delegation of authority to workers (e.g., DeVaro and Kurtulus, 2010; DeVaro and Prasad, 2015; Bilanakos et al., 2018).[31] Our main delegation measure takes on a value of one if the worker's response is 'A lot', 'Some' or 'A little' and zero if the worker's response is 'None'. To measure the amount of training a worker has received at his or her workplace, we use the following question from the employee questionnaire: "*During the last 12 months how much training have you had, either paid for or organized by your employer: include only training away from your normal place of work, but it could be on or off the premises*". The potential responses are "None", "Less than one day", "1 to less than 2 days", "2 to less than 5 days", "5 to less than 10 days" and "10 days or more".

To test the model's implications, we need to proxy for the uncertainty in the environment

[29] Due to the nature of the multistage sampling procedure used to survey employees, employee questionnaires were distributed only in those workplaces where a management interview had taken place.

[30] The distribution of responses to this question (after applying employee weights) is as follows: 'None' 12.7%, 'A little' 14.9%, 'Some' 36.9%, and 'A lot' 35.4%.

[31] Even though Acemoglu et al. (2007) use data from the same source in a part of their empirical analysis, their unit of analysis is workplace and they measure delegation using a question concerning the manager's autonomy from headquarters in making employment decisions.

(σ_0^2) and the precision of the worker's signal (σ_s^2). For the uncertainty in the environment, we use binary indicators capturing the current state of the market in which the employee's firm is operating. Specifically, the manager's response indicates whether the market is growing, declining, turbulent or mature. We expect the firm's environment to be more uncertain if the market is either growing, declining or turbulent than if it is mature. To proxy for the precision of the worker's signal, we use variables correlated with the worker's productivity. In our model, the worker could be regarded as more productive either as he becomes more likely to acquire a signal (holding the cost of acquiring the signal constant) or as his signal becomes more informative. We conjecture that the worker's age, tenure at the firm, and education level are positively correlated with the precision of the signal he may acquire. In addition, we proxy for the match quality between the worker's skills and his current job using the following question from the employee questionnaire: "*How well do the work skills you personally have match the skills you need to do your present job?*". The worker is categorized as overqualified if his response is either "Much higher" or "A bit higher", as qualified if his response is "About the same", and as underqualified if his response is either "A bit lower" or "Much lower". We conjecture that the worker's signal is more precise if he is either overqualified or qualified.

Our empirical analysis excludes workplaces not in the trading sector (government and non-profit establishments) and those observations for which any variables used in the analysis are missing. Merging the employee questionnaire with the management questionnaire, and treating the data at the worker level leaves us with a sample consisting of 10,983 workers clustered in 920 workplaces. Summary statistics are reported in Table 1.

4.2 Results

To test the predictions of the model, we first estimate probit models where the dependent variable is an indicator variable that takes a value of one if the worker is granted authority and zero if not.[32] Results are reported in Table 2.

Our baseline specification, reported in column 1, includes a binary variable for training, the worker's age and tenure (both with squared terms), indicator variables for education (the omitted category is 'no academic qualifications or other qualification'), job-skill match (the omitted category is underqualified), and indicators capturing the current state of the market in which the firm is operating (the omitted category is operating in a mature market). In addition to these key variables, the baseline specification includes the following controls: firm size (the log of the number of employees), indicators for how many years the workplace has been operating (the omitted category is 'more than 25 years'), if the worker has a permanent or a temporary job with no agreed end date (the omitted category is having a fixed-period job with an agreed end date), whether the

[32]Throughout the empirical analysis, standard errors are clustered at the workplace level.

workplace is a part of a larger organization (the omitted category is 'sole UK establishment of a foreign organization'), and finally indicators for industry and region.

In column 2, we add indicators for the worker's occupation (manager, professional, associate professional and technical, clerical and secretarial, craft and skilled service, personal and protective service, sales, plant and machine operatives, where the omitted category is 'other occupation'). In column 3, we add indicator variables capturing the occupational composition of the workforce (i.e., the percentage of: managers, professional staff, technical staff, clerical staff, craft (skilled) staff, service staff and sales staff, where the omitted category is the share of 'other occupations'). The specifications in columns 4 through 6 are the same as those in columns 1 through 3, respectively, except in the latter set of specifications, we use six categories, rather than a binary variable, for the amount of training received by the worker. In these richer specifications, the omitted category for training is "None".

We first discuss the relationship between delegation and training. As column 1 indicates, the coefficient for training is positive and statistically significant at the one percent level. When we control for the worker's occupation and the occupational composition at the workplace, the coefficient for training decreases by 31 percent (from 0.228 to 0.155) but remains statistically significant at the one percent level. To get a sense of the magnitude of the effect, consider the coefficient reported in the baseline specification. Accordingly, providing training with a worker is associated, on average, with a 2.8 percentage points increase in the predicted probability that the same worker is delegated authority. Once indicators for occupations are added, the positive effect of training on the predicted probability of being delegated authority decreases from 2.8 percentage points to 1.9 percentage points.

As indicated, we use a more flexible specification for training in columns 4 through 6, where six mutually exclusive categories measure the intensity of training provided by the firm. From these results, we observe three patterns. First, the effect of receiving training less than one day is not statistically different from the effect of not receiving training at all. Even though the coefficients for obtaining training less than a day are positive, they are not estimated with precision. Second, the probability of delegation monotonically increases with training up to training equal to 5 days, but the coefficients for higher training categories are smaller. However, according to the results in column 4, the coefficients for adjacent training categories for levels of training higher than 5 days are not statistically different from each other. Therefore, a more precise statement to describe the observed relationship is that the probability of delegation monotonically increases with training for levels of training between 1 day and 5 days, and then the positive effect flattens out with additional training. Third, in comparison to the baseline results, coefficient estimates for training categories become smaller as controls for occupations and the occupational composition of the workplace are added to the estimating equation.[33]

We now turn to the model's second prediction, that is, a firm becomes more likely to delegate authority as the uncertainty in the environment increases. We consider three binary variables indicating whether the market at which the firm currently operates is growing, declining or turbulent (recall that the benchmark category is market being mature). The results provide mixed support for the prediction. The results from the baseline specifications (columns 1 and 4) show that operating in a turbulent market, as opposed to operating in a mature market, is positively associated with the probability of delegating authority. The coefficients slightly increase and remain statistically significant (at the five percent level) when controls for occupations are added (see columns 2 and 5). In contrast, the coefficients decrease (by 21 percent) but remain positive and statistically significant at the ten percent level when controls for occupational composition are added (see columns 3 and 6). The coefficients in columns 1 and 3 indicate that operating in a turbulent market, as opposed to operating in a mature market, is associated with 2.1 and 1.7 percentage points, respectively, higher likelihood of delegation. The coefficients for growing markets are positive in all specifications, but statistically significant (at the ten percent level) only in columns 2 and 5. These coefficients indicate that operating in a growing market, as opposed to in a mature market, is associated with 1.4 percentage points higher probability of delegation. Finally, even though the coefficients for declining markets are positive in all specifications, they are not statistically different from zero at conventional levels.

Turning to the third prediction, we first consider the effect of educational level on delegation. Column 1 and 4 show that there is no monotonic relationship between the worker's highest educational attainment and the probability of delegation. More specifically, holding an A-level degree and lower has no effect on delegation (coefficients are small and not statistically different from zero), whereas holding either a college degree or a postgraduate degree, as opposed to holding either a lower educational qualification or no degree at all, is associated with a higher likelihood of delegation. Also, even though the coefficient for postgraduate degree is larger than the coefficient for college degree, the difference is not statistically different from zero. These effects, however, turn insignificant when the worker's occupation is controlled for (see, for example, columns 2 and 3). The reasoning behind this result is simple. Because the variation in educational attainment for a given occupation is not large, the positive effect of holding a college or a postgraduate degree disappears once indicators for occupations enter the specification. Consistent with this reasoning, we also observe that coefficients for certain occupations, such as manager, professional, technical and clerk, are positive and estimated with high precision (all these coefficients are statistically significant at the one percent level).

[33]The only exception to this pattern is training category for 5 to 10 days. This coefficient decreases from 0.292 to 0.149 when controls for occupations are included and then increases to 0.150 when controls for workforce composition are added.

The results concerning the effect of age and tenure provide support for the third prediction. Since in our specifications we include both age and age squared (divided by 100 for convenience) as explanatory variables, the effect of age on the probability of delegation depends on at what age level the marginal effect is evaluated. We observe qualitatively the same result in all specifications: the coefficient for age is positive and the coefficient for its squared term is negative (and both coefficients are statistically significant at the one percent level). This pattern indicates that the probability of delegation increases (at a decreasing rate) with age and the effect turns zero after a certain age. For example, according to the results from column 6, the effect of age on the probability of delegation becomes zero after around age 36. Similar to age, we include both tenure at firm and its squared term in our estimations. The results show that the coefficient for tenure is positive (and statistically significant at the one percent level) in all specifications, whereas the coefficient for its squared term is negative in all specifications but statistically significant (at the ten percent level) only in columns 2 and 4.[34] According to the coefficients in columns 2 and 4, the effect of tenure on delegation is positive up to tenure for 20 years.

As indicated, we conjecture that higher match quality between the worker's skills and his or her job is associated with higher probability of delegation. The results provide support for this hypothesis. In all specifications, the coefficients for overqualified and qualified are positive and statistically significant at the one percent level, and the difference between the marginal effects of being overqualified and qualified is statistically significant.[35] This implies that the effect of being qualified on the probability of delegation is greater than that of being overqualified. According to the coefficients reported in column 3, being qualified, as opposed to being underqualified, is associated with a 5.5 percentage points increase in the predicted probability of delegation, whereas being overqualified is associated with a 4 percentage points increase, with respect to the same benchmark, in the predicted probability of delegation.

As our delegation measure is derived from a question in which potential responses have a meaningful (ordinal) ranking, we also estimate an ordered probit model where the dependent variable describes the degree of delegation the worker has been granted with four distinct categories. The results are reported in Table 3. Note that specifications in columns 1 through 4 of Table 3 are analogous to those in columns 3 through 6 of Table 2, respectively.

The results concerning the relationship between training and delegation remain consistent with the theory. When training is measured by a binary variable, the coefficient is positive and statistically significant at the one percent level (see column 1). This means that the intensity of delegation (which is modelled as a latent variable) increases with training. The incremental effect of obtaining training (i.e., when training increases from 0 to 1) is associated with a 9.2 percentage points

[34]We also estimated our richest specification (column 6) by excluding tenure squared. In that case, the coefficient for tenure turns out to be 0.019 and statistically significant at the one percent level.

[35]The p-values associated with these tests are lower than 0.01 in all specifications.

decrease in the probability that delegation is not granted (i.e., the worker's response is 'None').[36] In columns 2 through 4, we observe that the relationship between obtaining training less than one day and delegation is not statistically significant, whereas obtaining training more than one day is positively related with training. Further, the coefficient for training equal to 1 to 2 days is smaller than the coefficient for training equal to 2 to 5 days in all specifications, but the difference is statistically significant only in columns 2 and 3.[37] Finally, adjacent training categories for levels of training higher than 5 days are not statistically different from each other.

Next, we look at the effect of the uncertainty in the environment, captured by indicators for the state of the market. Consistent with the earlier results, the coefficients for these indicator variables remain positive, as predicted by the theory, but not all of them are statistically significant. We observe the following differences between the results from Table 3 and those from Table 2. First, the coefficients for operating in a turbulent market remain positive, but become statistically not different from zero (this happens because the size of the coefficient decreases by approximately 50 percent, whereas the standard error decreases only marginally). Second, despite being marginally smaller than in the earlier set of results, the effect of operating in a growing market is positive and statistically significant (at the ten percent level in columns 1, 2, and 4 and at the five percent level in column 3).

Finally, we turn to how delegation is related to our proxies for the precision of the worker's signal. We observe that the qualitative results concerning age and tenure at the firm are the same. That is, the main effect is positive, whereas the coefficient for the quadratic term is negative (both coefficients are significant at the one percent level in all specifications). Concerning the effect of educational attainment, we observe the same pattern except for holding a GCSE degree (grades A-C). More precisely, we observe that holding a college degree and holding a postgraduate degree are associated with a higher likelihood of delegation (see column 1); these effects, however, disappear once we control for occupational dummies (as we observe in the probit model). The difference from the earlier set of results is that the coefficient for GCSE degree (grades A-C) turn significant (at the one percent level) in ordered probit models. Last, we obtain qualitatively the same results concerning the effect of the match quality between the worker's skills and his or her job. Overall, the results suggest that the correlation between being either qualified or overqualified and delegation is positive.[38]

[36] The incremental effect is statistically significant at the one percent level ($z = 3.33$).

[37] More specifically, the p-value for the difference between training categories "one to two days" and "two to five days" is 0.060 in column 2 and 0.630 in column 3.

[38] Note that the coefficient for qualified is greater than the coefficient for overqualified, but the difference is significant at modest levels. Specifically, the p-values from the corresponding tests are 0.122, 0.092 and 0.061 in columns 2, 3, and 4, respectively.

5 Conclusion

In this paper, we develop a theoretical model to investigate delegation decisions within organizations. Incorporating two aspects of organizations, namely the noncontractible nature of decision rights and the employees' disagreement with the organization on the optimal course of action, provides interesting insights into optimal delegation policies.

The presence of disagreement between the organization and the employee alters the latter's incentives to exert effort in information acquisition. In particular, because the degree of disagreement is mitigated with additional information, the employee has an incentive to persuade the organization by generating a signal. As the persuasion incentives arise only when the decision rights are retained by the organization, the presence of disagreement may lead to centralized decision-making in equilibrium.

When delegation decisions are not credible (that is, when the organization can retract authority before the agent exercises it), additional organizational forms may be observed in equilibrium. Our analysis shows that the degree of disagreement determines the delegation policies the organization can commit to, and this, in turn, affects the employee's effort choice. In particular, we show that at either low or high levels of disagreement, the organization retains authority because by delegating authority (and then retract it in the case of high disagreement) it cannot induce the employee to exert a level of effort higher than the level of effort he would exert under centralization. At moderate levels of disagreement, the organization can commit to partial delegation in the sense that the employee retains authority and exercises it only when he generates additional information before making a decision. Because the employee's ability to exercise his authority is contingent on whether he generates additional information, partial delegation provides the strongest incentives for effort. Our analysis shows that partial delegation may be optimal for the organization if either the uncertainty in the environment is high or the agent's additional information is sufficiently precise.

In addition to delegation decisions, we examine the organization's incentives to reinforce information acquisition by providing the employee with training. We treat training as an investment in the agent's human capital that reduces his cost of information acquisition. This analysis reveals that training provision is higher under delegation and that training facilitates delegation (that is, holding other factors constant, the possibility of training makes delegation more likely to be optimal). In addition to the positive correlation between training and delegation, comparative statics results yield testable predictions. Accordingly, the model predicts that firms should be more likely to delegate authority as the uncertainty in the environment increases and as the information the worker may acquire becomes more precise.

In the empirical part of the paper, we test the model's predictions and provide evidence broadly consistent with the model. First, we find strong evidence that providing higher levels of training is associated with higher likelihood of delegation. Second, we find evidence that firms operating in turbulent markets are more likely to delegate than firms operating in mature markets. Similarly, the effect of operating in a growing market, as opposed to operating in a mature market, is positive, but it is estimated with less precision. These findings provide support for the model to the extent that the state of the market measures the uncertainty faced by the firm. Finally, we proxy for the precision of the worker's signal using the worker's age, tenure at the firm, highest educational attainment and the quality of the match between the worker's skills and his or her job. In general, the empirical results concerning these variables are consistent with the model.

In terms of future research, it would be worthwhile to consider alternative functions of training. For example, the organization may provide training to reduce the disagreement with the employee concerning the optimal course of action. Another direction of interest would be to consider an asymmetric-information environment in which the degree of disagreement is privately observed by the employee and the organization uses training to learn about the degree of disagreement with the employee. Examining delegation decisions in these alternative settings would yield interest insights.

A Appendix

This Appendix contains the proofs omitted in the text. To simplify the notation, we let $\sigma_0^2 - \widetilde{\sigma}^2 = \Delta\sigma^2$, $\frac{\partial^2 g(\psi,t)}{\partial\psi^2} = g_{\psi\psi} > 0$ and $\frac{\partial^2 g(\psi,t)}{\partial\psi\partial t} = g_{\psi t} < 0$ for any ψ and t.

Proof of Lemma 1. *First-order conditions (4) and (6) imply that the marginal benefit of exerting an additional level of effort is* $\Delta\sigma^2 + \left[B_\emptyset^2 - B_s^2\right]$ *under centralization and* $\Delta\sigma^2$ *under delegation. Since* $\left[B_\emptyset^2 - B_s^2\right] > 0$ *and function* $g(.)$ *is strictly convex, the agent exerts a higher level of effort under centralization. To see the second part of the result, apply the implicit function theorem to the first-order conditions on (4) and (6) to write* ψ^c *and* ψ^d*, respectively, as functions of* μ_A*. This yields* $\frac{\partial\psi^c}{\partial\mu_A} = \frac{1}{g''}\frac{\partial\left(B_\emptyset^2 - B_s^2\right)}{\partial\mu_A} > \frac{\partial\psi^d}{\partial\mu_A} = 0$ *since* $\frac{\partial\left(B_\emptyset^2 - B_s^2\right)}{\partial\mu_A} > 0$*.*

Proof of Proposition 1. *Given that the agent's effort choices are uniquely determined by (4) and (6) under centralization and under delegation, respectively, the principal's payoff is* $U_P^c\left(\psi^c;\mu_A\right) = -\sigma_0^2 - \kappa + \psi^c\Delta\sigma^2$ *under centralization and* $U_P^d\left(\psi^d;\mu_A\right) = -\sigma_0^2 - B_\emptyset^2 + \psi^d\left[\Delta\sigma^2 + \left(B_\emptyset^2 - B_s^2\right)\right]$ *under delegation. Centralization is optimal for the principal if and only if the following condition is satisfied:*

$$\psi^d\left(B_\emptyset^2 - B_s^2\right) < B_\emptyset^2 - \kappa + \left[\psi^c - \psi^d\right]\Delta\sigma^2 \tag{A.1}$$

For given κ*, the right-hand side of (A.1) increases with* μ_A *faster than its left-hand side (this follows both because* ψ^c *increases with* μ_A *while* ψ^d *does not depend on it and because* $\frac{\partial\left(B_\emptyset^2 - B_s^2\right)}{\partial\mu_A} > \frac{\partial B_\emptyset^2}{\partial\mu_A} > 0$*). In other words, the returns to centralization increase with the agent type faster than the returns to delegation. This means that for given* κ*, one can choose the lower bound of agent types,* $\underline{\mu_A}$*, such* *that the condition on (A.1) holds for all types.*[39] *Hence, centralization is optimal for any agent type.*

Proof of Lemma 2. *Suppose that the principal initially delegates authority to the agent who then generates a signal, i.e., $\Omega = s$. The principal's payoff is $-\widetilde{\sigma}^2 - B_s^2$ if she allows the agent to exercise his authority and $-\widetilde{\sigma}^2 - R - \kappa$ if she takes the authority back from the agent and chooses her own preferred action. Therefore, conditional on observing a signal, the principal finds it optimal to retract the agent's authority if and only if $B_s^2 > R + \kappa$. Writing this condition more explicitly yields that revoking the delegation decision upon observing a signal is optimal if and only if $\mu_A > \widetilde{\mu_A}(s)$, where $\widetilde{\mu_A}(s) = \frac{\sqrt{R+\kappa}}{1-\rho}$. Similarly, when the agent does not generate a signal, the principal finds it optimal to revoke the delegation decision if and only if $B_\emptyset^2 > R + \kappa$. This condition is equivalent to $\mu_A > \widetilde{\mu_A}(\emptyset)$, where $\widetilde{\mu_A}(\emptyset) = \sqrt{R+\kappa}$. Finally, $\widetilde{\mu_A}(s) > \widetilde{\mu_A}(\emptyset)$ since $0 < \rho < 1$.*

Proof of Lemma 3. *The agent with type μ_A chooses ψ_k^d to maximize $U_A^d\left(\psi_k^d; \mu_A\right)$. Note that since the marginal cost of effort does not depend on the agent's type, the optimal effort choice is increasing with the marginal benefit of exerting an additional level of effort. Let MB^c denote the marginal benefit of effort under centralization and MB_k^d denote the marginal benefit of effort when the agent is initially granted authority and the degree of differences of opinion is k, $k = L, M, H$. The first-order conditions that characterize ψ_k^d imply that $MB_H^d = \Delta\sigma^2 + \left[B_\emptyset^2 - B_s^2\right]$, $MB_M^d = \Delta\sigma^2 + B_\emptyset^2$ and $MB_L^d = \Delta\sigma^2$. Since $\Delta\sigma^2 > 0$ and $B_\emptyset^2 > B_s^2$, we have $MB_M^d > MB_H^d > MB_L^d$. Therefore, $\psi_M^d > \psi_H^d > \psi_L^d$. Finally, it follows from (4) that $MB^c = MB_H^d$; thus, $\psi^c = \psi_H^d$.*

Proof of Proposition 2. *Suppose $\mu_A > \widetilde{\mu_A}(s)$. Substituting the agent's optimal effort choices into the principal's payoff yields $U_P^c(\psi^c; \mu_A) = -\sigma_0^2 - \kappa + \psi^c \Delta\sigma^2$ under centralization and $U_P^d\left(\psi_H^d; \mu_A\right) = -\sigma_0^2 - R - \kappa + \psi_H^d \Delta\sigma^2$ under delegation. Since $\psi_H^d = \psi^c$, we have $U_P^c(\psi^c; \mu_A) > U_P^d\left(\psi_H^d; \mu_A\right)$. Next, suppose $\mu_A < \widetilde{\mu_A}(\emptyset)$. The principal's payoff under delegation is given by $U_P^d\left(\psi_L^d; \mu_A\right) = -\sigma_0^2 - B_\emptyset^2 + \psi_L^d\left[\Delta\sigma^2 + \left(B_\emptyset^2 - B_s^2\right)\right]$. Condition $U_P^c(\psi^c; \mu_A) > U_P^d\left(\psi_L^d; \mu_A\right)$ is equivalent to the condition shown by (A.1) and it is therefore satisfied for any μ_A.*

Finally, consider the case $\widetilde{\mu_A}(s) > \mu_A > \widetilde{\mu_A}(\emptyset)$. Given that $U_P^d\left(\psi_M^d; \mu_A\right) = -\sigma_0^2 - R - \kappa + \psi_M^d\left[\Delta\sigma^2 + \left(R + \kappa - B_s^2\right)\right]$, the principal's expected rents from delegating authority equals $\Delta^d(\sigma_0^2, \sigma_s^2) = \left(\psi_M^d - \psi^c\right)\Delta\sigma^2 + \psi_M^d\left(R + \kappa - B_s^2\right) - R$. Since $\psi_M^d > \psi^c$, a sufficient (but not necessary) condition for $\Delta^d(\sigma_0^2, \sigma_s^2) > 0$ is κ being not very small or R being not very large. Applying the implicit function theorem to the first-order conditions that characterize ψ^c and ψ_M^d yields $\frac{\partial \psi^c}{\partial \sigma_0^2} = \frac{1}{g''}\frac{\partial\left(\Delta\sigma^2 + B_\emptyset^2 - B_s^2\right)}{\partial \sigma_0^2}$ and $\frac{\partial \psi_M^d}{\partial \sigma_0^2} = \frac{1}{g''}\frac{\partial\left(\Delta\sigma^2 + B_\emptyset^2\right)}{\partial \sigma_0^2}$, respectively. Therefore, $\frac{\partial \psi^c}{\partial \sigma_0^2} > \frac{\partial \psi_M^d}{\partial \sigma_0^2} > 0$, that is, as the initial uncertainty increases, the agent increases his effort provision more under centralization than under delegation. However, the rents from delegation may still be increasing with σ_0^2. Note that

[39] More explicitly, for given κ we set $\underline{\mu_A}(\kappa) = \mu'_A(\kappa) + \epsilon$ where $\epsilon > 0$ is small and μ'_A is defined by $\psi^d\left(B_\emptyset^2 - B_s^2\right) = B_\emptyset^2 - \kappa + \left[\psi^c - \psi^d\right]\Delta\sigma^2$.

$\frac{\partial \Delta^d(\sigma_0^2,\sigma_s^2)}{\partial \sigma_0^2} = \left(\frac{\partial \psi_M^d}{\partial \sigma_0^2} - \frac{\partial \psi^c}{\partial \sigma_0^2}\right)\Delta\sigma^2 + \frac{\partial \Delta\sigma^2}{\partial \sigma_0^2}\left(\psi_M^d - \psi^c\right) + \frac{\partial \psi_M^d}{\partial \sigma_0^2}\left(R+\kappa - B_s^2\right) - \frac{\partial B_s^2}{\partial \sigma_0^2}\psi_M^d$. *Except for the first term, the other terms are positive since* $\frac{\partial \psi_M^d}{\partial \sigma_0^2} > 0$, $\frac{\partial \Delta\sigma^2}{\partial \sigma_0^2} > 0$, *and* $\frac{\partial B_s^2}{\partial \sigma_0^2} < 0$. *In particular, the positive effects dominate whenever* κ *is not very small (or when* R *is sufficiently large). Therefore,* $\frac{\partial \Delta^d(\sigma_0^2,\sigma_s^2)}{\partial \sigma_0^2} > 0$. *To consider the effect of* σ_s^2 *on* $\Delta^d(\sigma_0^2,\sigma_s^2)$, *we follow the same approach. The implicit function theorem yields* $\frac{\partial \psi^c}{\partial \sigma_s^2} = \frac{1}{g''}\frac{\partial\left(\Delta\sigma^2 + B_\emptyset^2 - B_s^2\right)}{\partial \sigma_s^2}$ *and* $\frac{\partial \psi_M^d}{\partial \sigma_s^2} = \frac{1}{g''}\frac{\partial\left(\Delta\sigma^2 + B_\emptyset^2\right)}{\partial \sigma_s^2}$. *It follows from* $\frac{\partial \Delta\sigma^2}{\partial \sigma_s^2} < 0$ *and* $\frac{\partial B_s^2}{\partial \sigma_s^2} > 0$ *that* $\frac{\partial \psi^c}{\partial \sigma_s^2} < \frac{\partial \psi_M^d}{\partial \sigma_s^2} < 0$. *Differentiating* $\Delta^d(\sigma_0^2,\sigma_s^2)$ *with respect to* σ_s^2 *gives* $\frac{\partial \Delta^d(\sigma_0^2,\sigma_s^2)}{\partial \sigma_s^2} = \left(\frac{\partial \psi_M^d}{\partial \sigma_s^2} - \frac{\partial \psi^c}{\partial \sigma_s^2}\right)\Delta\sigma^2 + \frac{\partial \Delta\sigma^2}{\partial \sigma_s^2}\left(\psi_M^d - \psi^c\right) + \frac{\partial \psi_M^d}{\partial \sigma_s^2}\left(R+\kappa - B_s^2\right) - \frac{\partial B_s^2}{\partial \sigma_s^2}\psi_M^d$. *Note that* $\frac{\partial \Delta^d(\sigma_0^2,\sigma_s^2)}{\partial \sigma_s^2} < 0$ *as long as* κ *is not very small. Hence, the result follows.*

Remark 1. *Let* m *and* k *denote the organizational mode and the degree of differences of opinion between the principal and the agent, respectively, where* $m = c, d$ *and* $k = L, M, H$. *We have* $\frac{\partial \psi_k^m(t)}{\partial t} = -\frac{g_{\psi t}}{g_{\psi\psi}} > 0$ *and that* $\frac{\partial \psi_k^m(t)}{\partial t}$ *does not depend on* μ_A.

Proof of Remark 1. *Fix* m *and* k. *We write the first-order condition that characterizes the agent's optimal effort choice,* ψ_k^m, *as follows:*

$$\Lambda(.) = \frac{\partial g\left(\psi_k^m, t_k^m\right)}{\partial \psi_k}, \tag{A.2}$$

where $\Lambda(.)$ *is the marginal benefit of effort and it is a function of the model's parameters—importantly, it is not a function of* t.[40] *Using the implicit function theorem, we write the optimal effort choice as a function of* t, *that is,* $\psi_k^m = \psi_k^m(t)$. *Differentiating (A.2) with respect to* t *gives* $\frac{\partial \psi_k^m(t)}{\partial t} = -\frac{\partial^2 g\left(\psi_k^m, t\right)/\partial \psi_k \partial t}{\partial^2 g\left(\psi_k^m, t\right)/\partial \psi_k^2} = -\frac{g_{\psi t}}{g_{\psi\psi}} > 0$ *since* $g_{\psi t} < 0$ *and* $g_{\psi\psi} > 0$. *Finally, since neither of* $g_{\psi t}$ *and* $g_{\psi\psi}$ *depends on* μ_A, $\frac{\partial \psi_k^m(t)}{\partial t}$ *does not depend on agent type either.*

Proof of Lemma 4. *For notational convenience, let* $\Upsilon = -\frac{g_{\psi t}}{g_{\psi\psi}}$. *Note that* Υ *is positive and does not depend on* μ_A *(see Remark 1).*

To show (i), consider the first-order conditions that characterize the principal's training choice for each organizational mode and degree of differences of opinion. Let mb^c *denote the principal's marginal benefit of providing an additional level of training under centralization. Similarly, let* mb_k^d *denote the marginal benefit of training when the agent is initially delegated authority and the degree of disagreement is* k, *where* $k = L, M, H$. *Writing (9) more explicitly yields* $mb^c = \Upsilon\Delta\sigma^2$. *Recall that the optimal training levels chosen by the principal are those that maximize* $U_P^d\left(t_k^d; \mu_A\right)$. *From the first-order conditions characterizing the optimal levels of training, one can write* $mb_H^d = \Upsilon\Delta\sigma^2$, $mb_M^d = \Upsilon\left[\Delta\sigma^2 + \left(R + \kappa - B_s^2\right)\right]$, *and* $mb_L^d = \Upsilon\left[\Delta\sigma^2 + \left(B_\emptyset^2 - B_s^2\right)\right]$. *From these, it follows that* $mb_M^d > mb_H^d = mb^c$ *and* $mb_L^d > mb_H^d = mb^c$. *Hence, the result follows.*

[40] See the corresponding discussion in the text.

To show (ii), note that the agent's marginal benefit of effort is the same as those indicated in Lemma 3. The reason is that the introduction of training alters neither the players' preferred actions (i.e., $\alpha_P(\Omega)$ and $\alpha_A(\Omega)$ for given Ω) nor the conditions under which the principal retracts the agent's authority. However, training affects the agent's effort provision through its effect on the marginal cost of effort borne by the agent. It follows from $t_M^d > t_H^d = t^c$ and $MB_M^d > MB_H^d = MB^c$ (see Lemma 3) that $\psi_M^d\left(t_M^d\right) > \psi_M^d\left(t_H^d\right) = \psi_M^d\left(t^c\right)$. Next, note that since $t_L^d > t^c$ but $MB_L^d < MB^c$ (see Lemma 3), whether $\psi_L^d\left(t_L^d\right)$ exceeds $\psi^c\left(t^c\right)$ is not certain. In particular, if $g_{\psi t}$ is sufficiently large, in absolute value, then $\psi_L^d\left(t_L^d\right) > \psi^c\left(t^c\right)$. This follows for two reasons. First, as $g_{\psi t}$ increases (in absolute value), t_L^d increases more than t^c (note that as Υ increases the marginal benefit of providing additional level of training increases faster when $m = d$ and $k = L$ than when $m = c$). Second, since the agent receives a higher level of training under delegation than under centralization, the increase in his effort provision as $g_{\psi t}$ becomes larger (in absolute value) is higher in the former case than the latter case.

Proof of Proposition 3. *Suppose $\mu_A > \widetilde{\mu_A}(s)$. As shown in Lemma 4, both the level of training provided by the principal and the level of effort exerted by the agent are the same under centralization and under delegation (i.e., $t_H^d = t^c$ and $\psi_H^d\left(t_H^d\right) = \psi^c\left(t^c\right)$). In this case, the result shown in the Proof of Proposition 2 applies: $U_P^c\left(\psi^c;\mu_A\right) > U_P^d\left(\psi_H^d;\mu_A\right)$; thus, the principal retains authority and provides training t^c while the agent exerts effort $\psi^c\left(t^c\right)$.*

Next, suppose $\widetilde{\mu_A}(s) > \mu_A > \widetilde{\mu_A}(\emptyset)$. Let Δ_M^d denote the rents from delegating authority to the agent when the degree of differences of opinion is moderate (i.e., $k = M$). So we have $\Delta_M^d = U_P^d\left(t_M^d;\psi_M^d\left(t_M^d\right)\right) - U_P^c\left(t^c;\psi^c\left(t^c\right)\right)$, where

$$\Delta_M^d = \left[\psi_M^d\left(t_M^d\right) - \psi^c\left(t^c\right)\right]\Delta\sigma^2 + \psi_M^d\left(t_M^d\right)\left[R + \kappa - B_s^2\right] - R - \left[c\left(t_M^d\right) - c\left(t^c\right)\right].$$

To derive the effect of σ_0^2 on Δ_M^d, we first look at how choice variables change with σ_0^2. To this end, we use the implicit function theorem to obtain $\frac{\partial t^c}{\partial\sigma_0^2} = \Upsilon\left[c''\left(t^c\right)\right]^{-1}\frac{\partial\Delta\sigma^2}{\partial\sigma_0^2}$ and $\frac{\partial t_M^d}{\partial\sigma_0^2} = \Upsilon\left[c''\left(t_M^d\right)\right]^{-1}\frac{\partial\left(\Delta\sigma^2 - B_s^2\right)}{\partial\sigma_0^2}$. This implies that $\frac{\partial t_M^d}{\partial\sigma_0^2} > \frac{\partial t^c}{\partial\sigma_0^2}$ since $\frac{\partial\left(\Delta\sigma^2 - B_s^2\right)}{\partial\sigma_0^2} > \frac{\partial\Delta\sigma^2}{\partial\sigma_0^2} > 0$ and $c''' \leq 0$. Applying the implicit function theorem to the first-order conditions that characterize ψ^c and ψ_M^d gives $\frac{\partial\psi^c\left(t^c\right)}{\partial\sigma_0^2} = \left[g_{\psi\psi}\right]^{-1}\left\{\frac{\partial\left(\Delta\sigma^2 + B_\emptyset^2 - B_s^2\right)}{\partial\sigma_0^2} - g_{\psi t}\frac{\partial t^c}{\partial\sigma_0^2}\right\}$ and $\frac{\partial\psi_M^d\left(t_M^d\right)}{\partial\sigma_0^2} = \left[g_{\psi\psi}\right]^{-1}\left\{\frac{\partial\left(\Delta\sigma^2 + B_\emptyset^2\right)}{\partial\sigma_0^2} - g_{\psi t}\frac{\partial t_M^d}{\partial\sigma_0^2}\right\}$, respectively. Note that $\frac{\partial\psi_M^d\left(t_M^d\right)}{\partial\sigma_0^2} > \frac{\partial\psi^c\left(t^c\right)}{\partial\sigma_0^2} > 0$, where the first inequality holds as long as $g_{\psi t}$ is sufficiently large in absolute value.[41] *Considering the direct effect of a change in σ_0^2 on Δ_M^d (that is, holding the choice variables constant) gives $\left[\psi_M^d\left(t_M^d\right) - \psi^c\left(t^c\right)\right]\frac{\partial\Delta\sigma^2}{\partial\sigma_0^2} - \psi_M^d\left(t_M^d\right)\frac{\partial B_s^2}{\partial\sigma_0^2} > 0$, since $\frac{\partial\Delta\sigma^2}{\partial\sigma_0^2} > 0$, $\frac{\partial B_s^2}{\partial\sigma_0^2} < 0$, and $\psi_M^d\left(t_M^d\right) > \psi^c\left(t^c\right)$. That is, ignoring the partial effects of σ_0^2 on effort and training choices, the expected rents from delegation increase with σ_0^2. Next, we consider the par-*

[41] More specifically, the assumption required to have the first inequality is $\left(g_{\psi t}\right)^2 > g_{\psi\psi}c''(t)$ for any $t > 0$.

tial effects of σ_0^2*, i.e.,* $\left[\frac{\partial\psi_M^d(t_M^d)}{\partial\sigma_0^2} - \frac{\partial\psi^c(t^c)}{\partial\sigma_0^2}\right]\Delta\sigma^2 + \frac{\partial\psi_M^d(t_M^d)}{\partial\sigma_0^2}\left[R+\kappa-B_s^2\right] - \left[c'\left(t_M^d\right)\frac{\partial t_M^d}{\partial\sigma_0^2} - c'\left(t^c\right)\frac{\partial t^c}{\partial\sigma_0^2}\right]$*. Note that the first two terms are positive, whereas the last term, the change in the training cost under delegation and under centralization, is negative since* $\frac{\partial t_M^d}{\partial\sigma_0^2} > \frac{\partial t^c}{\partial\sigma_0^2} > 0$*. As a sufficient (but not a necessary condition), we assume that the training cost does not rise very quickly, i.e.,* $c'(.)$ *is not very large for given* t*. Hence,* $\frac{\partial\Delta_M^d}{\partial\sigma_0^2} > 0$ *when* $g_{\psi t}$ *is sufficiently large in absolute value.*

To consider the effect of σ_s^2 *on* Δ_M^d*, we follow the same approach. Applying the implicit function theorem to the first-order conditions for* t^c *and* t_M^d *yields* $\frac{\partial t^c}{\partial\sigma_s^2} = \Upsilon\left[c''(t^c)\right]^{-1}\frac{\partial\Delta\sigma^2}{\partial\sigma_s^2}$ *and* $\frac{\partial t_M^d}{\partial\sigma_s^2} = \Upsilon\left[c''\left(t_M^d\right)\right]^{-1}\frac{\partial\left(\Delta\sigma^2-B_s^2\right)}{\partial\sigma_s^2}$*, respectively. This implies that* $\frac{\partial t_M^d}{\partial\sigma_s^2} < \frac{\partial t^c}{\partial\sigma_s^2} < 0$*, since* $\frac{\partial\left(\Delta\sigma^2-B_s^2\right)}{\partial\sigma_s^2} < \frac{\partial\Delta\sigma^2}{\partial\sigma_s^2} < 0$ *and* $c'''(.) \leq 0$*. Next, we apply the implicit function theorem to the first-order conditions that characterize the optimal effort choices to obtain* $\frac{\partial\psi^c(t^c)}{\partial\sigma_s^2} = \left[g_{\psi\psi}\right]^{-1}\left\{\frac{\partial\left(\Delta\sigma^2+B_\emptyset^2-B_s^2\right)}{\partial\sigma_s^2} - g_{\psi t}\frac{\partial t^c}{\partial\sigma_s^2}\right\}$ *and* $\frac{\partial\psi_M^d(t_M^d)}{\partial\sigma_s^2} = \left[g_{\psi\psi}\right]^{-1}\left\{\frac{\partial\left(\Delta\sigma^2+B_\emptyset^2\right)}{\partial\sigma_s^2} - g_{\psi t}\frac{\partial t_M^d}{\partial\sigma_s^2}\right\}$*. When* $g_{\psi t}$ *is sufficiently large (in absolute value), we have* $\frac{\partial\psi_M^d(t_M^d)}{\partial\sigma_s^2} < \frac{\partial\psi^c(t^c)}{\partial\sigma_s^2} < 0$*. Considering the direct effect of* σ_s^2 *on* Δ_M^d *gives* $\left[\psi_M^d\left(t_M^d\right) - \psi^c\left(t^c\right)\right]\frac{\partial\Delta\sigma^2}{\partial\sigma_s^2} - \psi_M^d\left(t_M^d\right)\frac{\partial B_s^2}{\partial\sigma_s^2} < 0$*, since* $\frac{\partial\Delta\sigma^2}{\partial\sigma_s^2} < 0$*,* $\frac{\partial B_s^2}{\partial\sigma_s^2} > 0$*, and* $\psi_M^d\left(t_M^d\right) > \psi^c\left(t^c\right)$*. We then consider the partial effects of* σ_s^2 *and obtain* $\left[\frac{\partial\psi_M^d(t_M^d)}{\partial\sigma_s^2} - \frac{\partial\psi^c(t^c)}{\partial\sigma_s^2}\right]\Delta\sigma^2 + \frac{\partial\psi_H^d(t_M^d)}{\partial\sigma_s^2}\left[R+\kappa-B_s^2\right] - \left[c'\left(t_M^d\right)\frac{\partial t_M^d}{\partial\sigma_s^2} - c'\left(t^c\right)\frac{\partial t^c}{\partial\sigma_s^2}\right] < 0$*. Hence,* $\frac{\partial\Delta_H^d}{\partial\sigma_s^2} < 0$ *when* $g_{\psi t}$ *is sufficiently large in absolute value.*

Lastly, suppose $\mu_A < \widetilde{\mu_A}(\emptyset)$ *and let* Δ_L^d *denote the rents from delegating authority to the agent when* $k = L$*, i.e.,* $\Delta_L^d = U_P^d\left(t_L^d; \psi_L^d\left(t_L^d\right)\right) - U_P^c\left(t^c; \psi^c\left(t^c\right)\right)$*. As indicated by (iii) of Lemma 4, if* $g_{\psi t}$ *is small, in absolute value, then* $\psi_L^d\left(t_L^d\right) < \psi^c\left(t^c\right)$*. In this case,* $\Delta_L^d < 0$ *as shown by (A.1)—note that this case is equivalent to the case analyzed in the benchmark case in which the principal's delegation decision is irreversible and therefore the agent always chooses his preferred action once he is granted authority. Now assume* $g_{\psi t}$ *is sufficiently large (in absolute value) so that the effort provision is higher under delegation than under centralization, i.e.,* $\psi_L^d\left(t_L^d\right) > \psi^c\left(t^c\right)$*. Writing* Δ_L^d *explicitly gives*

$$\Delta_L^d = \left[\psi_L^d\left(t_L^d\right) - \psi^c\left(t^c\right)\right]\Delta\sigma^2 + \psi_L^d\left(t_L^d\right)\left[B_\emptyset^2 - B_s^2\right] + \left[\kappa - B_\emptyset^2\right] - \left[c\left(t_L^d\right) - c\left(t^c\right)\right].$$

As implied by Lemma 1, ψ^c *increases with* μ_A *while* ψ_L^d *does not depend on it. Note also that because* $\frac{\partial\left(B_\emptyset^2-B_s^2\right)}{\partial\mu_A} > \frac{\partial B_\emptyset^2}{\partial\mu_A} > 0$ *and* $\psi_L^d\left(t_L^d\right) < 1$*,* Δ_L^d *decreases with* μ_A*. This means that for given* κ *there exists* $\mu_A^+ < \widetilde{\mu_A}(\emptyset)$ *such that* $\Delta_L^d > 0$ *as long as* $\mu_A < \mu_A^+$*. To see why* μ_A^+ *increases with* $g_{\psi t}$*, consider what happens to* Δ_L^d *as* $g_{\psi t}$ *increases. As indicated in the Proof of Lemma 4, as* $g_{\psi t}$ *becomes larger in absolute value, the agent's effort provision increases faster under delegation than under centralization. Thus, the returns to delegation increase with* $g_{\psi t}$ *since the difference between* ψ_L^d *and* ψ^c *becomes larger. Hence, the degree of disagreement at which the principal is indifferent* *between delegation and centralization, that is, μ_A^+, also increases.*

For the effect of σ_0^2 on Δ_L^d, we first consider how choice variables change with σ_0^2. To this end, we use the implicit function theorem to obtain $\frac{\partial t_L^d}{\partial \sigma_0^2} = \Upsilon \left[c''\left(t_L^d\right)\right]^{-1} \frac{\partial\left(\Delta\sigma^2 - B_s^2\right)}{\partial \sigma_0^2}$. This implies that $\frac{\partial t_L^d}{\partial \sigma_0^2} > \frac{\partial t^c}{\partial \sigma_0^2}$, since $\frac{\partial\left(\Delta\sigma^2 - B_s^2\right)}{\partial \sigma_0^2} > \frac{\partial \Delta\sigma^2}{\partial \sigma_0^2} > 0$ and $c''' \leq 0$. Next, we apply the implicit function theorem to the first-order condition that characterizes ψ_L^d to obtain $\frac{\partial \psi_L^d\left(t_L^d\right)}{\partial \sigma_0^2} = \left[g_{\psi\psi}\right]^{-1}\left\{\frac{\partial \Delta\sigma^2}{\partial \sigma_0^2} - g_{\psi t}\frac{\partial t_L^d}{\partial \sigma_0^2}\right\}$. Note that $\frac{\partial \psi_L^d\left(t_L^d\right)}{\partial \sigma_0^2} > \frac{\partial \psi^c\left(t^c\right)}{\partial \sigma_0^2} > 0$ as long as $g_{\psi t}$ is sufficiently large in absolute value. Considering the direct effect of σ_0^2 on Δ_L^d gives $\left[\psi_L^d\left(t_L^d\right) - \psi^c\left(t^c\right)\right]\frac{\partial \Delta\sigma^2}{\partial \sigma_0^2} - \psi_L^d\left(t_L^d\right)\frac{\partial B_s^2}{\partial \sigma_0^2} > 0$, since $\frac{\partial \Delta\sigma^2}{\partial \sigma_0^2} > 0$, $\frac{\partial B_s^2}{\partial \sigma_0^2} < 0$, and $\psi_L^d\left(t_L^d\right) > \psi^c\left(t^c\right)$. In other words, ignoring the partial effects of σ_0^2 on effort and training choices, the expected rents from delegation increase with σ_0^2. Next, we consider the partial effects of σ_0^2, i.e., $\left[\frac{\partial \psi_L^d\left(t_L^d\right)}{\partial \sigma_0^2} - \frac{\partial \psi^c\left(t^c\right)}{\partial \sigma_0^2}\right]\Delta\sigma^2 + \frac{\partial \psi_L^d\left(t_L^d\right)}{\partial \sigma_0^2}\left[B_\emptyset^2 - B_s^2\right] - \left[c'\left(t_L^d\right)\frac{\partial t_L^d}{\partial \sigma_0^2} - c'\left(t^c\right)\frac{\partial t^c}{\partial \sigma_0^2}\right]$. Here the first two terms are positive, whereas the last term is negative since $\frac{\partial t_L^d}{\partial \sigma_0^2} > \frac{\partial t_H^c}{\partial \sigma_0^2} > 0$. As before, we assume that the training cost does not rise very quickly, i.e., $c'(.)$ is not very large. Hence, $\frac{\partial \Delta_L^d}{\partial \sigma_0^2} > 0$ when $g_{\psi t}$ is sufficiently large in absolute value.

Finally, we consider the effect of σ_s^2 on Δ_L^d. Applying the implicit function theorem yields $\frac{\partial t_L^d}{\partial \sigma_s^2} = \Upsilon \left[c''\left(t_L^d\right)\right]^{-1} \frac{\partial\left(\Delta\sigma^2 - B_s^2\right)}{\partial \sigma_s^2}$ and $\frac{\partial \psi_L^d\left(t_L^d\right)}{\partial \sigma_s^2} = \left[g_{\psi\psi}\right]^{-1}\left\{\frac{\partial \Delta\sigma^2}{\partial \sigma_s^2} - g_{\psi t}\frac{\partial t_L^d}{\partial \sigma_s^2}\right\}$. We have $\frac{\partial t_L^d}{\partial \sigma_s^2} < \frac{\partial t^c}{\partial \sigma_s^2} < 0$, since $\frac{\partial\left(\Delta\sigma^2 - B_s^2\right)}{\partial \sigma_s^2} < \frac{\partial \Delta\sigma^2}{\partial \sigma_s^2} < 0$ and $c''' \leq 0$. Also, note that $\frac{\partial \psi_L^d\left(t_L^d\right)}{\partial \sigma_s^2} < \frac{\partial \psi^c\left(t^c\right)}{\partial \sigma_s^2} < 0$ as long as $g_{\psi t}$ is sufficiently large in absolute value. Next, considering the direct effect of σ_s^2 on Δ_L^d gives $\left[\psi_L^d\left(t_L^d\right) - \psi^c\left(t^c\right)\right]\frac{\partial \Delta\sigma^2}{\partial \sigma_s^2} - \psi_L^d\left(t_L^d\right)\frac{\partial B_s^2}{\partial \sigma_s^2} < 0$, since $\frac{\partial \Delta\sigma^2}{\partial \sigma_s^2} < 0$, $\frac{\partial B_s^2}{\partial \sigma_s^2} > 0$, and $\psi_L^d\left(t_L^d\right) > \psi^c\left(t^c\right)$. Finally, we consider the partial effects of σ_s^2, i.e., $\left[\frac{\partial \psi_L^d\left(t_L^d\right)}{\partial \sigma_s^2} - \frac{\partial \psi^c\left(t^c\right)}{\partial \sigma_s^2}\right]\Delta\sigma^2 + \frac{\partial \psi_L^d\left(t_L^d\right)}{\partial \sigma_s^2}\left[B_\emptyset^2 - B_s^2\right] - \left[c'\left(t_L^d\right)\frac{\partial t_L^d}{\partial \sigma_s^2} - c'\left(t^c\right)\frac{\partial t^c}{\partial \sigma_s^2}\right]$. Note that the first two terms are negative, whereas the last term, which is positive, is dominated by the negative effect as long as training cost does not rise very quickly. This concludes that $\frac{\partial \Delta_L^d}{\partial \sigma_s^2} < 0$ when $g_{\psi t}$ is sufficiently large in absolute value.

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TABLE 1. Descriptive Statistics

Variable	Mean	St. dev.
Individual level variables		
Training		
1="None"	0.394	0.489
2="Less than 1 day"	0.109	0.311
3="1 to less than 2 days"	0.140	0.347
4="2 to less than 5 days"	0.200	0.400
5="5 to less than 10 days"	0.085	0.278
6="10 days or more"	0.073	0.261
Personal characteristics		
Female	0.472	0.499
Male	0.528	0.499
Age	39.054	12.444
Job characteristics		
Tenure	7.144	7.317
Permanent job	0.923	0.267
Temporary job	0.050	0.218
Fixed term job	0.027	0.163
Occupations		
Managers, senior administrators	0.102	0.303
Professional	0.092	0.289
Associate professional, technical	0.132	0.339
Clerical and secretarial	0.162	0.369
Craft and skilled service	0.084	0.277
Personal and protective service	0.059	0.235
Sales	0.111	0.315
Operative and assembly	0.108	0.310
Routine/unskilled	0.149	0.356
Academic qualifications		
GCSE, grades D-G	0.081	0.272
GCSE, grades A-C	0.173	0.378
A levels (1 A-level and above)	0.093	0.291
First degree (BSc, BA, Bed, HND, HNC)	0.125	0.331
Higher degree or equivalent (MSc, MA, MBA, PGCE, PhD)	0.040	0.195
No educational qualification or other educational qualification	0.488	0.500
Job-skill match		
Overqualified	0.543	0.498
Qualified	0.409	0.492
Underqualified	0.047	0.212
Workplace level variables		
Industry		
Manufacturing	0.156	0.363
Utilities (electricity, gas, water)	0.001	0.037
Construction	0.042	0.200
Wholesale and retail	0.229	0.420
Hotels and restaurants	0.065	0.246
Transportation and communication	0.056	0.230
Financial services	0.063	0.243
Other business services	0.171	0.376
Education	0.013	0.115
Health	0.141	0.348
Other community services	0.063	0.243
Region		

Scotland	0.088	0.284
North	0.058	0.235
North west	0.139	0.346
East Midlands	0.075	0.263
West Midlands	0.11	0.313
East Anglia	0.054	0.226
South east	0.258	0.437
South west	0.094	0.291
Wales	0.028	0.166
Yorkshire and Humberside	0.095	0.293
Workplace characteristics		
Number of employees in the workplace	55.930	136.197
Part of a larger organization	0.617	0.486
Single independent workplace not belonging	0.366	0.482
Sole UK establishment of a foreign organization	0.017	0.130
Workplace age - less than 5 years	0.091	0.287
Workplace age - 5 to 9 years	0.126	0.332
Workplace age - 10 to 14 years	0.137	0.344
Workplace age - 15 to 20 years	0.173	0.378
Workplace age - 21 to 24 years	0.061	0.239
Workplace age - 25 years plus	0.413	0.492
Occupational group percentages		
Managerial and senior administrative	0.125	0.097
Professional	0.071	0.164
Technical	0.071	0.151
Sales	0.181	0.304
Operative and assembly	0.109	0.221
Clerical and secretarial	0.146	0.207
Craft and skilled services	0.086	0.188
Protective and personal service	0.092	0.244
Routine/unskilled	0.117	0.232
Current state of the market		
Market is growing	0.508	0.500
Market is declining	0.105	0.306
Market is turbulent	0.143	0.350
Market is mature	0.244	0.429
Number of competitors		
No competitors	0.066	0.249
Few competitors (less than 5)	0.386	0.487
Many competitors	0.547	0.498
Observations	10,983	

Notes. This table displays the summary statistics for all variables used in the analysis. Individual characteristics are weighted using employment weights and establishment characteristics are weighted using establishment weights.

TABLE 2: The Effect of Training Propensity and Training Intensity on Delegation Dependent Variable: Delegation (0="no delegation", 1="delegation")

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Training	0.228***	0.157***	0.155***			
	(0.034)	(0.036)	(0.036)			
Training						
<1 day				0.053	0.060	0.063
				(0.055)	(0.055)	(0.055)
>=1 day to <2 days				0.230***	0.176***	0.171***
				(0.053)	(0.054)	(0.054)
>=2 days to <5 days				0.332***	0.235***	0.233***
				(0.048)	(0.050)	(0.050)
>=5 days to <10 days				0.292***	0.149**	0.150**
				(0.067)	(0.069)	(0.069)
>=10 days				0.219***	0.130**	0.125*
				(0.065)	(0.066)	(0.066)
Growing market	0.072	0.080*	0.061	0.071	0.079*	0.061
	(0.047)	(0.046)	(0.046)	(0.046)	(0.046)	(0.046)
Declining market	0.057	0.068	0.038	0.055	0.066	0.036
	(0.079)	(0.078)	(0.080)	(0.079)	(0.078)	(0.080)
Turbulent market	0.118**	0.126**	0.099*	0.119**	0.126**	0.100*
	(0.054)	(0.054)	(0.053)	(0.054)	(0.054)	(0.053)
GCSE grades D-G	-0.041	0.035	0.031	-0.041	0.033	0.030
	(0.061)	(0.063)	(0.063)	(0.061)	(0.063)	(0.063)
GCSE grades A-C	-0.021	-0.021	-0.022	-0.019	-0.022	-0.022
	(0.042)	(0.045)	(0.045)	(0.042)	(0.045)	(0.045)
A-levels	0.085	0.026	0.019	0.082	0.024	0.018
	(0.058)	(0.060)	(0.061)	(0.058)	(0.060)	(0.061)
First degree	0.223***	0.049	0.038	0.216***	0.047	0.036
	(0.059)	(0.062)	(0.062)	(0.060)	(0.063)	(0.062)
Higher degree	0.315***	0.094	0.085	0.309***	0.092	0.084
	(0.101)	(0.106)	(0.107)	(0.102)	(0.107)	(0.107)
Age	0.040***	0.027***	0.027***	0.039***	0.026***	0.026***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Age sq/100	-0.053***	-0.037***	-0.036***	-0.051***	-0.036***	-0.035***
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Tenure	0.042***	0.036***	0.037***	0.042***	0.036***	0.037***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Tenure sq/100	-0.101*	-0.079	-0.085	-0.101*	-0.078	-0.084
	(0.054)	(0.055)	(0.055)	(0.054)	(0.055)	(0.055)
Overqualified	0.158**	0.221***	0.225***	0.158**	0.218***	0.221***
	(0.072)	(0.073)	(0.073)	(0.072)	(0.073)	(0.073)
Qualified	0.280***	0.318***	0.324***	0.272***	0.311***	0.317***
	(0.074)	(0.076)	(0.076)	(0.074)	(0.076)	(0.076)
Female	-0.142***	-0.161***	-0.154***	-0.135***	-0.158***	-0.151***
	(0.038)	(0.041)	(0.041)	(0.039)	(0.041)	(0.041)
Permanent job	-0.036	0.023	0.027	-0.037	0.021	0.024
	(0.096)	(0.103)	(0.104)	(0.095)	(0.102)	(0.103)
Temporary job	-0.192	-0.061	-0.050	-0.175	-0.057	-0.048
	(0.118)	(0.125)	(0.127)	(0.118)	(0.124)	(0.125)
Log no. of employees	-0.044***	-0.043***	-0.040**	-0.044***	-0.042***	-0.040**
	(0.015)	(0.015)	(0.017)	(0.015)	(0.015)	(0.017)
Part of a larger workplace	-0.239**	-0.158	-0.157	-0.250**	-0.166	-0.166
	(0.102)	(0.108)	(0.115)	(0.100)	(0.106)	(0.114)
Single independent workplace	-0.151	-0.033	-0.022	-0.160	-0.041	-0.030
	(0.107)	(0.113)	(0.121)	(0.105)	(0.112)	(0.120)

Workplace age < 5 years	0.182**	0.172*	0.175**	0.182**	0.170*	0.174**
	(0.090)	(0.092)	(0.086)	(0.091)	(0.092)	(0.085)
Workplace age >=5 to <=9	0.132**	0.131**	0.135**	0.130**	0.130**	0.134**
	(0.064)	(0.062)	(0.062)	(0.063)	(0.062)	(0.062)
Workplace age >=10 to <=14	0.009	0.051	0.065	0.012	0.052	0.065
	(0.061)	(0.063)	(0.064)	(0.061)	(0.063)	(0.064)
Workplace age >=15 to <=20	0.041	0.045	0.045	0.044	0.045	0.045
	(0.056)	(0.055)	(0.054)	(0.055)	(0.055)	(0.053)
Workplace age >=21 to <=24	0.122	0.137	0.144*	0.122	0.135	0.142*
	(0.085)	(0.086)	(0.085)	(0.086)	(0.086)	(0.085)
Few competitors (<5)	-0.126	-0.118	-0.161**	-0.122	-0.115	-0.158**
	(0.085)	(0.088)	(0.078)	(0.085)	(0.088)	(0.078)
Many competitors	-0.134	-0.139	-0.177**	-0.132	-0.138	-0.175**
	(0.083)	(0.086)	(0.076)	(0.083)	(0.086)	(0.076)
Manager		1.188***	1.192***		1.170***	1.175***
		(0.110)	(0.114)		(0.110)	(0.113)
Professional		0.668***	0.676***		0.657***	0.666***
		(0.084)	(0.090)		(0.084)	(0.090)
Technical		0.587***	0.596***		0.573***	0.583***
		(0.074)	(0.077)		(0.074)	(0.076)
Clerk		0.300***	0.332***		0.291***	0.324***
		(0.068)	(0.069)		(0.068)	(0.069)
Craft		0.080	0.105		0.074	0.101
		(0.072)	(0.077)		(0.073)	(0.077)
Service		0.120	0.142		0.113	0.137
		(0.085)	(0.091)		(0.085)	(0.092)
Sales		0.138*	0.136*		0.130*	0.130
		(0.075)	(0.081)		(0.075)	(0.081)
Operative		-0.064	-0.093		-0.069	-0.097
		(0.065)	(0.071)		(0.065)	(0.071)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes	Yes	Yes
Workforce composition	No	No	Yes	No	No	Yes
Constant	0.462*	0.307	0.376	0.490*	0.337	0.408
	(0.268)	(0.277)	(0.290)	(0.265)	(0.273)	(0.286)
Observations	10,983					

Notes: Cell entries are probit coefficients with standard errors clustered at the workplace level. The omitted categories are: male, no training, no academic or other educational qualification, underqualified, routine/unskilled occupation, fixed term job, percentage of routine/unskilled staff, mature market, no competitors, sole UK workplace of a foreign organization, workplace older than 25 years of age, other community services sector, Yorkshire and Humberside". Levels of significance: *** p<0.01, ** p<0.05, * p<0.1.

TABLE 3: The Effect of Training Propensity and Training Intensity on Delegation Dependent Variable: Delegation (0="None", 1="A little", 2="Some", 3="A lot")

VARIABLES	(1)	(2)	(3)	(4)
Training	0.086***			
	(0.024)			
Training				
<1 day		-0.056	-0.047	-0.044
		(0.037)	(0.037)	(0.037)
>=1 day to <2 days		0.136***	0.083**	0.083**
		(0.034)	(0.034)	(0.034)
>=2 days to <5 days		0.237***	0.151***	0.151***
		(0.032)	(0.033)	(0.033)
>=5 days to <10 days		0.238***	0.113***	0.116***
		(0.040)	(0.041)	(0.041)
>=10 days		0.206***	0.118***	0.120***
		(0.045)	(0.045)	(0.044)
Growing market	0.059*	0.063*	0.069**	0.059*
	(0.034)	(0.034)	(0.034)	(0.034)
Declining market	0.036	0.045	0.054	0.036
	(0.056)	(0.057)	(0.055)	(0.056)
Turbulent market	0.037	0.042	0.047	0.039
	(0.038)	(0.038)	(0.037)	(0.038)
GCSE grades D-G	0.013	-0.046	0.016	0.012
	(0.043)	(0.042)	(0.043)	(0.043)
GCSE grades A-C	-0.121***	-0.116***	-0.118***	-0.119***
	(0.029)	(0.029)	(0.029)	(0.029)
A-levels	-0.020	0.027	-0.022	-0.020
	(0.039)	(0.039)	(0.039)	(0.039)
First degree	-0.027	0.090***	-0.033	-0.026
	(0.034)	(0.033)	(0.034)	(0.034)
Higher degree	0.096*	0.200***	0.084	0.099*
	(0.054)	(0.054)	(0.054)	(0.054)
Age	0.034***	0.047***	0.033***	0.034***
	(0.006)	(0.006)	(0.006)	(0.006)
Age sq/100	-0.037***	-0.053***	-0.036***	-0.037***
	(0.008)	(0.008)	(0.008)	(0.008)
Tenure	0.043***	0.046***	0.042***	0.043***
	(0.008)	(0.008)	(0.008)	(0.008)
Tenure sq/100	-0.124***	-0.133***	-0.118***	-0.125***
	(0.037)	(0.036)	(0.036)	(0.036)
Overqualified	0.286***	0.238***	0.284***	0.287***
	(0.045)	(0.046)	(0.045)	(0.045)
Qualified	0.329***	0.287***	0.319***	0.325***
	(0.047)	(0.047)	(0.047)	(0.047)
Female	-0.107***	-0.114***	-0.104***	-0.102***
	(0.027)	(0.027)	(0.027)	(0.027)
Permanent job	0.027	-0.006	0.029	0.024
	(0.069)	(0.066)	(0.068)	(0.069)
Temporary job	-0.095	-0.156*	-0.079	-0.087
	(0.083)	(0.080)	(0.083)	(0.083)
Log no. of employees	-0.040***	-0.045***	-0.045***	-0.041***
	(0.011)	(0.010)	(0.010)	(0.011)
Part of a larger workplace	0.072	0.017	0.075	0.062
	(0.057)	(0.055)	(0.056)	(0.055)
Single independent workplace	0.178***	0.096	0.182***	0.168***
	(0.062)	(0.059)	(0.061)	(0.061)
Workplace age < 5 years	0.171***	0.183***	0.167***	0.171***

	(0.057)	(0.062)	(0.059)	(0.057)
Workplace age >=5 to <=9	0.123***	0.141***	0.124***	0.123***
	(0.039)	(0.041)	(0.040)	(0.040)
Workplace age >=10 to <=14	0.091**	0.077*	0.098**	0.092**
	(0.045)	(0.046)	(0.046)	(0.046)
Workplace age >=15 to <=20	0.063	0.068*	0.069*	0.066*
	(0.039)	(0.040)	(0.038)	(0.039)
Workplace age >=21 to <=24	0.189***	0.183***	0.192***	0.189***
	(0.058)	(0.058)	(0.059)	(0.059)
Few competitors (< 5)	-0.066	-0.049	-0.039	-0.063
	(0.053)	(0.054)	(0.055)	(0.053)
Many competitors	-0.035	-0.008	-0.010	-0.032
	(0.052)	(0.053)	(0.054)	(0.052)
Manager	0.886***		0.836***	0.859***
	(0.054)		(0.053)	(0.055)
Professional	0.345***		0.288***	0.328***
	(0.053)		(0.051)	(0.053)
Technical	0.478***		0.427***	0.459***
	(0.051)		(0.049)	(0.051)
Clerk	0.182***		0.134***	0.170***
	(0.050)		(0.049)	(0.050)
Craft	0.031		0.001	0.021
	(0.057)		(0.054)	(0.057)
Service	0.104		0.087	0.089
	(0.069)		(0.064)	(0.069)
Sales	0.000		-0.025	-0.003
	(0.058)		(0.054)	(0.058)
Operative	-0.106**		-0.088*	-0.114**
	(0.053)		(0.049)	(0.053)
Industry dummies	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes
Workforce composition	Yes	No	No	Yes
Ordered probit cutoffs				
Cutoff1	0.065	0.072	0.070	0.042
	(0.190)	(0.175)	(0.179)	(0.189)
Cutoff2	0.659***	0.649***	0.663***	0.636***
	(0.190)	(0.175)	(0.179)	(0.189)
Cutoff3	1.707***	1.669***	1.711***	1.685***
	(0.191)	(0.176)	(0.179)	(0.190)
Observations	10,983			

Notes: Cell entries are ordered probit coefficients with standard errors clustered at the workplace level. The omitted categories are: male, no training, no academic or other educational qualification, underqualified, routine/unskilled occupation, fixed term job, percentage of routine/unskilled staff, mature market, no competitors, sole UK workplace of a foreign organization, workplace older than 25 years of age, other community services sector, Yorkshire and Humberside". Levels of significance: *** p<0.01, ** p<0.05, * p<0.1.