Advocates, Information Transmission, and Sequential Search

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Abstract

This paper examines whether an organization should centralize with a single agent or decentralize with two agents, to privately search for and defend two competing causes. Based on agents' unverifiable search outcomes, a decision-maker chooses among different decisions for the organization. The literature argues that decentralization is more efficient or less costly for the organization than centralization, assuming that agents' search is simultaneous and the search outcomes are publicly observed. In contrast, this paper shows that centralization may be more efficient, if search is sequential and each agent privately observes his search outcome. A single agent with renegotiation power has incentives to disclose his first search outcome to the decision maker, prior to conducting future search. Renegotiation between the decision-maker and the agent leads to efficient sequential search. The optimal contract leaves rent to the agent only when his renegotiation power is large enough. When there are two agents, the agent who searches first will strategically delay disclosure to the decision-maker and privately communicate with the other agent, to deter the latter's search. Given these effects, the optimal contracts have to leave rent to the agents and may not implement efficient search. The organization prefers centralization when agents have small renegotiation power and when the agents' search is very costly or not too effective. The results are robust in the more general scenario where the agents can endogenously choose between simultaneous and sequential search.

Introduction

Organization often hires agents to investigate and defend competing causes. Based on the agents' search outcomes which may be unverifiable, a decision-maker chooses among different causes for the organization, and the agents are rewarded based on which cause is chosen. Should the organization centralize the competing search tasks with one single agent or decentralize them with different agents? In

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practice, some firms adopt decentralized organization,[2] while many other firms centralize competing search tasks with one agent, for example, having one R&D center to search for competing innovations or having one marketing agent to investigate competing product designs.[3] The literature on agency theory mostly favors decentralization. For example, Dewatripont and Tirole (1999) showed that competition between two agents leads to efficient search while centralization may result in inefficient search, assuming that agents' search is simultaneous and the search outcomes are observed by the decision-maker.

In many scenarios, however, agents' search is sequential. Agents' search sequence may be given exogenously. A firm may receive competing innovations or product designs sequentially. Similarly, in recruiting, given limited resources, an organization may interview competing candidates sequentially and the interviews may be conduct by the same interviewer or different interviewers. More generally, agents can endogenously choose to search for competing causes simultaneously or sequentially, since the decision-maker cannot observe agents' search action.

Furthermore, the decision-maker often cannot directly observe agents' search outcomes. However, each agent can choose to disclose his search outcome publicly to the decision-maker, and/or privately to other agents, before further search is conducted. Such private communication among agents is common in organizations and may affect the agents' search effort.

Given the above observations, this paper intends to compare centralization to decentralization in the general scenarios where agents may search sequentially and

[2] For example, Samsung Electronics Co. has two independent R&D centers, which develop and advocate for competing innovations.(Harvard Business School case #705508)

[3] Innovations or product designs may compete for resource allocation or market adoption. For example, suppose that a firm has an existing product. The firm receives two competing new product designs. Customers' preferences over the two new designs are negatively correlated. If agents get evidence that some customers like one new design, then this design will be adopted by the firm. However, if there is evidence showing that some customers like the first design while other customers like the second, it may be better for the firm to keep the existing product.

choose to publicly or privately disclose their search outcomes. It will also address the interaction between agents' search effort and disclosure incentives. In particular, under centralization, a single agent is assigned to search evidence for competing causes. As long as the agent has renegotiation power, he would disclose his search outcome on the first cause to the decision-maker, prior to his search for the second cause. The corresponding renegotiation over the agent's contract leads to efficient sequential search. Under decentralization, two agents are hired. The agent who searches first and obtains evidence in favor of his cause may make a private disclosure to the other agent, in order to deter the latter's search. To overcome such deterrence effects, the optimal contracts have to provide more rent to the agents. And efficient search may not be implemented when there is contingent sequential search. Given these trade-offs, an organization may prefer centralization to decentralization.

More formally, within an organization, a decision-maker attempts to maximize the total value of the organization by choosing from three possible actions: A, B, or the status quo. If there is evidence in favor of both A and B, the efficient decision should be the status quo. The organization can hire one single agent or two agents to search evidence for causes A and B. The decision-maker offers contracts to the agents and only the final decision made by the decision-maker is contractible.[4] The agents are protected by limited liability. Searching is costly for the agents. If an agent finds evidence in favor of his cause, he can choose whether to disclose it credibly to the decision-maker, and/or privately to the other agent. The decision-maker can renegotiate with each agent over his contract.

This paper first considers the basic framework where search sequence is exogenously given: search for cause A happens before search for cause B. The search decision on cause B may or may not depend on the search outcome on cause A.

[4] This is because that it is impossible or very costly to verify the agents' search outcome or disclosure.

First, suppose that it is always efficient to search for both cause A and cause B. When there is only one agent, if the agent obtains evidence in favor of cause A, he would disclose it to the decision-maker. Then renegotiation over the agent's contract leads him to search for cause B. If the agent receives more renegotiation benefits, the optimal ex-ante contract can offer lower compensation, without destroying the agent's incentives to search for cause A. Therefore, centralization induces efficient search and may not leave rent to the agent. When there are two agents, each agent only has one task, so that there is no renegotiation. If the first agent finds evidence in favor of cause A, he may privately disclose it to the second agent. Then the second agent has less incentive to search since cause B would not be chosen by the decision-maker. To avoid such deterrence, the optimal contracts have to offer extra rent to the agents. Overall, the organization prefers centralization to decentralization, when the agents' renegotiation power is small and search is very costly or not too effective.

Second, suppose that there is "competing contingent search": it is efficient to search for cause B only when there is evidence in favor of cause A. Under centralization, the optimal contract can still induce efficient search as long as there is renegotiation. Under decentralization, however, no contract can implement efficient search because of the deterrence effects. The optimal contract may induce either insufficient search or too extensive search, and it may leave extra rent to the agents. Therefore, given competing contingent search, the organization is more likely to adopt centralization.

Third, suppose that there is "non-competing contingent search": it is efficient to search for cause B only when there is no evidence in favor of cause A. Then, even under decentralization, the deterrence effects from the agents' private disclosure implement efficient search. Centralization and decentralization achieve the same efficiency.

This paper then generalizes the analysis to the scenario where the agents endogenously choose between simultaneous and sequential search. Under both centralization and decentralization, it is a weakly dominant strategy for the agents to choose sequential search. Therefore, the results in the basic framework are robust: Centralization implements efficient search; while decentralization has to leave rent to the agent and may not induce efficient search. However, since the decision-maker cannot observe the agents' search sequence, under both organization forms, the optimal contracts have to leave more rent to the agents than in the basic framework where search sequence is exogenously given.

The paper also discusses several extensions. For one extension, if the decision-maker could implement mandatory disclosure of the agents' search outcomes, inefficient private communication under decentralization would be mitigated. Another extension discusses the role of option contract, which allows the decision-maker to choose different contracts after an agent's search for cause A but before his search for cause B. Finally, if agents' search may lead to unfavorable evidence but they can hide it, centralization may still be more efficient than decentralization.

Overall, this paper identifies some inefficiency under decentralization: private communication between agents may reduce their search incentives and delay disclosure to the decision-maker. In fact, the features of sequential search and private communication are not unique to organizational design. They are also relevant in litigation process or political lobbies.[5] Consider a lawsuit where a plaintiff and a defendant compete for the ownership of an asset. The judge may permit the asset to go to either side or split it between the two (status quo). Under the adversarial legal system, both plaintiff and defendant have their own expert witnesses to provide

[5] For the literature on political lobbies and advocates, see Morris, 2001; Caillaud and Tirole, 2002; Baron, 2004; Maskin and Tirole, 2004; Bennedsen and Feldmann, 2006.

evidence; while under the inquisitorial system, courts often have only one expert witness searching evidence for both sides.[6] Under the adversarial system, expert witnesses typically are not allowed to privately communicate with each other, which mitigates the deterrence effects.

The related literature traces back to the multi-task problem analyzed by Holmstrom and Milgrom (1991). They found that when an agent was assigned multi-tasks, he would devote more effort to the task that offered a larger reward. Dewatripont and Tirole (1999) suggested that having two agents to simultaneously search for competing causes was more efficient than having one agent to search for both causes. Their main intuition was that an agent would have excessive incentives to persuade the decision-maker to take a particular action instead of doing nothing. Beniers, Dur, and Swank (2005) extended the comparison to the scenario with sequential search by two agents: if each agent searched only in one round, there exist contracts which implement efficient search and leave no rent to the agents. Different from the previous studies, this paper argues that decentralization with two agents may be less efficient than centralization with one agent. It also discusses the interaction between agents' incentives for search and incentives to disclose search outcomes to the decision-maker and/or other agents. This paper further considers contingent sequential search decisions and the agents' endogenous choice of search sequence.

Schmitz (2005) discussed the choice between having one agent and two agents to undergo sequential hidden action, where the first action increased the effectiveness of the second action. The two actions, therefore, were not competing, and the outcome of each action was observable and verifiable. Inderst and Ottaviani (2008) analyzed mis-selling problems, when a single marketing agent conducted multi-tasks

[6] The United States, England, and many other common-law countries adopt the adversarial system. Civil-law countries often adopt the inquisitorial system. For more discussions, see Zweigert and Kotz (1987), Glaeser and Shleifer (2002), and Froeb and Kobayashi (2001).

sequentially. Ottaviani and Lewis (2008) examined whether to have one or more agents sequentially search for one new innovation. In these studies, information transmission increased efficiency in sequential search and the agents did not work on competing tasks. In this paper, however, the agents search for competing causes and decide whether and when to disclose their search outcomes.

There is also a large literature on agents' information transmission and the choice of agents. Most of the studies did not consider hidden action and focused on cheap talk by agents.[7] Crawford and Sobel (1982) showed that a single agent would withhold useful information from the decision-maker. Krishna and Morgan (2001) and Austen-Smith (1993) showed that a decision-maker could extract more information when he sequentially consulted two agents. This literature also covers agents' reputation concerns (Sobel, 1985; Morgan and Stocken, 1998; Morris, 2001; Ottaviani and Sorensen, 2001), continuum experts (Friedman, 1998; Banerjee and Somanathan, 2001), delegated expertise and decentralization (Dessein, 2002; Alonso and Matouschek, 2007; Alonso and Matouschek, 2008; Alonso, Dessein, and Matouschek, 2008; Inderst and Ottaviani, 2008). Different from this literature, this paper focuses on credible information transmission and addresses the interaction between agents' search effort and information transmission.

This paper proceeds as follows. Section 2 presents the basic model. Section 3 compares centralization and decentralization when the agents' search sequence is exogenously given. Section 4 extends the analysis to the general scenario where the agents endogenously choose their search sequence. Section 5 discusses extensions such as forging evidence, option contracts, monitoring and mandatory disclosure. Section 6 provides concluding remarks.

[7] In addition, Frexias, Guesnerie, and Tirole (1988), Hart and Tirole (1988), and Laffont and Tirole (1993) discussed how to design optimal contracts when there was information flow with dynamic adverse selection problems.

2. The basic model

The model adopts a framework similar to what in Dewatripont and Tirole (1999). A decision-maker, on behalf of an organization, chooses one of three decisions: A, B or the status quo.[8] The decision-maker has career concern and therefore tries to make the "right" decision to maximize the total value of the organization.[9] The decision may be based upon a non-verifiable parameter $\theta \in \{-1,0,1\}$, where $\theta = \theta_A + \theta_B$. Here, θ_A is equal to negative one with the probability α, and zero with the probability $1-\alpha$. Similarly, θ_B is equal to one with the probability α, and zero with the probability $1-\alpha$. The two parameters are independently distributed. When the true state is $\theta = \theta_A + \theta_B < 0$, the loss to the organization is L_M if cause B is chosen and L_I if the status quo is chosen. When the true state is $\theta = 0$, the loss is L_E if either cause A or B is chosen. When the true state is $\theta = \theta_A + \theta_B > 0$, the loss to the organization is L_M if cause A is chosen and L_I if the status quo is chosen.

The organization must hire agents to search for information about $\theta_i, i = A, B$. However, the decision-maker cannot observe whether an agent conducts search or not. Search is costly to an agent with unverifiable costs $C_i, i = A, B$.[10] If an agent does not search, he learns nothing. If the agent searches for cause i but $\theta_i = 0$, he learns nothing. If he searches and $|\theta_i| = 1$, the agent learns nothing with the probability $1-q$ and obtains evidence $|\theta_i| = 1$ with the probability $q \in (0,1)$.

This paper has two key building blocks different from the literature. First, the agents' search for the two causes may be sequential. Second, each agent privately

[8] The decision-maker may not be the principal or owner of the organization.

[9] If the decision-maker's objective is to maximize the total value for the organization minus the payment made to agents, for most parameter values, the main results in the paper still hold. However, there exist some parameter values such that the decision-maker may choose inefficient decisions after the agents' search and disclosure.

[10] The searching costs for the two causes may be different.

observes his search outcome and decides whether and when to disclose the search outcome to the decision-maker and/or other agents. The agents cannot collude with each other.[11]

The agents are protected by limited liability, so that only positive payments to the agents are possible. Since θ_A, θ_B are unverifiable, contracts can only include payments contingent on the final decision (A, B, or status quo) and upfront transfers.

The basic model assumes that agents' search sequence is given. The timing is as follows:

Stage 1: Given the organizational structure (centralization with one single agent or decentralization with two agents), the decision-maker offers contracts to the agent(s) independently.[12] Each agent's reservation value is normalized to zero. If there are two agents, define the contract for Agent 1 as (W_{1A}, W_{1B}, W_{10}) and that for Agent 2 as (W_{2A}, W_{2B}, W_{20}). If there is only one agent, define the contract as (W_A, W_B, W_0), where W_i is the payment to the agent when the decision-maker chooses cause i, $i = A, B, 0$ (i.e. the status quo)..

Stage 2: Agent 1 privately decides whether to search for cause A or not. When Agent 1 obtains evidence in favor of cause A, he decides whether to disclose the evidence immediately to the decision-maker, or to only privately communicate it to Agent 2, if Agent 2 is hired.[13] If Agent 1 discloses the evidence to the decision-maker, the decision-maker and each agent may renegotiate over their contracts. The agent has renegotiation power π and the decision maker has renegotiation power $1-\pi$: that is, the agent gets π shares of the renegotiation benefits. Without loss of generalization,

[11] The agents cannot collude since they cannot write a contract or use tit-for-tat strategies to enforce collusion. If the agents could perfectly collude and collectively bargain with the decision-maker, having two agents would be the same as having one agent.

[12] The results in the paper still hold even if the agents have some bargaining power at stage 1.

[13] When Agent 1 only privately communicates the evidence in favor of cause A to Agent 2, Agent 2 cannot credibly disclose such evidence further to the decision-maker. For example, Agent 2 may not have the supporting documents in favor of cause A in his hands.

assume $\pi > 0$.

Stage 3: When there is only one agent, the single agent decides whether to continue to search for cause B or not. When there are two agents, Agent 2 makes the decision whether to search for cause B or not.

Stage 4: The agents, if they have not done so before, decide whether to disclose their search outcomes to the decision-maker or not. The decision-maker chooses the final decision from A, B, and the status quo. Agents are paid accordingly.

In Section 4, the above model will be generalized to allow agents' endogenous choice of search sequence: Each agent can choose to search for his cause(s) either at stage 2 or at stage 3. That is, there will be three different search sequences: (1) agents may search for the causes simultaneously; (2) agents may search sequentially with cause A at stage 2 and cause B at stage 3; (3) agents may search sequentially but with cause B at stage 2. The search sequence cannot be observed by the decision-maker.

As discussed in the introduction, sequential search is common or agents often endogenously choose sequential search, especially when the search decision on one cause depends on the search outcome on the other cause.

The model also assumes that each agent's search outcome is not publicly observed and not verifiable. However, each agent can disclose his search outcome to the decision-maker or the other agent. This is realistic since it is easier for insiders of an organization than outsides such as courts to interpret the meaning of the search outcomes. Furthermore, assume that the decision-maker cannot observe the exact timing of the sequential search: that is, when search for A has finished while search for B has not started. Therefore, the decision-maker cannot offer a contract to force agents to disclose the search outcome on cause A before further search for cause B.[14]

Without loss of generalization, assume that each agent's disclosure costs are

[14] Section 5.1 provides more related discussions.

arbitrarily close to zero.[15] Therefore, disclosure costs will be ignored in the analysis. However, when an agent is indifferent between making a disclosure and not making a disclosure, it will be assumed that the agent will not make the disclosure. Such an assumption is more robust with small increases of disclosure costs.

For simplicity, assume that C_A is not too large so that it is always efficient to search for cause A. However, the decision-maker may not always want to motivate the search for cause B, as will be discussed later.

If an agent searches for cause *i*, but does not find any evidence in favor of cause *i*, the posterior belief that $|\theta_i| = 1$ conditional on no evidence found is defined as α_S:

$$\alpha_S = \frac{\alpha(1-q)}{\alpha(1-q)+(1-\alpha)} < \alpha$$

First, suppose that there is evidence found in favor of cause A ($\theta_A = -1$), and there is no search for cause B. Then, the expected loss from choosing cause A is αL_E and the expected loss from choosing the status quo is $(1-\alpha)L_I$. The following assumption implies that it is efficient to choose cause A:

Assumption 1: $\alpha L_E < (1-\alpha)L_I$

Assumption 1 also implies $\alpha_S L_E < (1-\alpha_S)L_I$ given $\alpha_S < \alpha$. That is, if there is evidence in favor of cause A and if search for cause B has been taken but no evidence has been obtained, the optimal decision should be cause A.

Second, suppose that agents have searched for both causes, but no evidence was found. The expected loss from choosing the status quo is $2\alpha_S(1-\alpha_S)L_I$. The expected loss from choosing either A or B is $[1-2\alpha_S(1-\alpha_S)]L_E + \alpha_S(1-\alpha_S)L_M$. The following assumption says that it is optimal to choose the status quo.

Assumption 2: $[1-2\alpha_S(1-\alpha_S)]L_E + \alpha_S(1-\alpha_S)(L_M - 2L_I) > 0$

Finally, suppose that the agents have searched for cause A but not for cause B,

[15] The main intuition in the paper holds as long as such disclosure costs are not too large.

and no evidence has been found. The expected loss from choosing the status quo is $[\alpha(1-\alpha_S)+\alpha_S(1-\alpha)]L_I$. The expected loss from choosing B is $[1-\alpha(1-\alpha_S)-\alpha_S(1-\alpha)]L_E+\alpha_S(1-\alpha)L_M$. The following assumption implies that it is optimal to choose the status quo.

Assumption 3: $L_E+\alpha_S(1-\alpha)(L_M-L_I-L_E)-\alpha(1-\alpha_S)(L_E+L_I)>0$

Assumptions 1 through 3 will be maintained throughout the paper.

3. Information transmission and exogenous sequential search

When the search process is sequential, the search decision on cause B may depend on the search outcome on cause A. The following lemma characterizes the conditions for efficient search decisions.

Lemma 1: Suppose that Agent 1 has searched for cause A. If and only if $C_B<\alpha qL_E$, it is efficient to continue to search for cause B when there is evidence found in favor of cause A. If and only if $C_B<\alpha q[(1-\alpha_S)L_I-\alpha_S L_E]$, it is efficient to continue to search for cause B when there is no evidence found in favor of cause A.

Proof: in the appendix.

This section will first examine non-contingent sequential search and then extend the analysis to contingent sequential search. In all these scenarios, under both centralization and decentralization, if an agent has only searched for one cause and found evidence, since he had incentives to undergo costly search, he would disclose the evidence to the decision-maker at either stage 2 or stage 4. Under centralization, the single agent may search for both causes. However, it can be verified that, if the agent has obtained evidence in favor of cause A but does not disclose it at stage 2, he would not continue to search for cause B. Therefore, if the agent has searched for two

causes, he must have disclosed the evidence in favor of cause A at stage 2. These results are summarized in the following lemma.

Lemma 2: In any equilibrium, at Stage 4, the agents would disclose evidence that they have found to the decision-maker, if they have not done so at an earlier stage.

3.1 Non-contingent search

Assume that $C_B < \alpha q L_E$ and $C_B < \alpha q[(1-\alpha_S)L_I - \alpha_S L_E]$, so that it is always efficient to search for cause B no matter what the search outcome on cause A is.

Centralization with one agent

Suppose that only one agent is hired and offered a contract (W_A, W_B, W_0). First, as a benchmark, suppose that renegotiation is not feasible. To induce the agent to search for cause B even after he has found evidence in favor of cause A, the ex-ante contract should satisfy:

$$\alpha q W_0 + (1-\alpha q)W_A - C_B \geq W_A$$

This condition implies that $W_0 \geq W_A$. However, if $W_0 \geq W_A$, the agent would never search for cause A. Therefore, there is no contract which can induce the agent to search for cause B if the agent has found evidence in favor of cause A. To motivate the agent to search for cause A and search for cause B when there is no evidence in favor of cause A, the contract should satisfy:

$$\alpha q W_B + (1-\alpha q)W_0 - C_B \geq W_0 \quad \text{and}$$

$$\alpha q W_A + (1-\alpha q)W_0 - C_A \geq W_0 .$$

To minimize payments, the optimal contract is $(W_A, W_B, W_0) = (\frac{C_A}{\alpha q}, \frac{C_B}{\alpha q}, 0)$.

Now suppose that renegotiation is possible. The agent would disclose the

evidence in favor of cause A, if any, to the decision-maker before deciding whether to search for cause B. The decision-maker and the agent can renegotiate for a new contract (W_A', W_B', W_0') and a fixed transfer *T* to the agent. The following condition guarantees that the agent will search for cause B after renegotiation:

$$\alpha q W_0' + (1-\alpha q) W_A' - C_B \geq W_A'$$

Therefore, the contract renegotiated is $(W_A', W_B', W_0') = (0,0,\frac{C_B}{\alpha q})$. Renegotiation leads the agent to search for cause B and increases the total value for the organization by $\alpha q L_E - C_B$. Given the agent's renegotiation power, $T = W_A + \pi(\alpha q L_E - C_B)$.

Given the potential renegotiation, the optimal ex-ante contract should satisfy:

$$Min_{(W_A, W_B, W_0)} \alpha q[W_A + \pi(\alpha q L_E - C_B)] + (1-\alpha q)\alpha q W_B + (1-\alpha q)^2 W_0$$

$$\text{Subject to} \quad \alpha q W_B + (1-\alpha q) W_0 - C_B \geq W_0 \qquad \text{(ICB)}$$

$$\alpha q T - C_A = \alpha q[W_A + \pi(\alpha q L_E - C_B)] - C_A \geq 0 \qquad \text{(ICA)}$$

$$W_A, W_B, W_0 \geq 0 \qquad \text{(LL)}$$

Condition (ICB) says that the agent will search for cause B if there is no evidence in favor of cause A. Condition (ICA) implies that the agent will search for cause A. Note that the agent is protected by limited liability. The following proposition characterizes the optimal contract.

Proposition 1: Suppose that there is no contingent search and only one agent is hired. (1) When renegotiation is not feasible, the optimal contract is $(W_A, W_B, W_0) = (\frac{C_A}{\alpha q}, \frac{C_B}{\alpha q}, 0)$. The agent does not search for cause B if there is evidence in favor of cause A. (2) When renegotiation is feasible and the agent has small

renegotiation power $\pi \le \frac{C_A}{\alpha q(\alpha q L_E - C_B)}$, the optimal contract is $(W_A, W_B, W_0) = (\frac{C_A}{\alpha q} - \pi(\alpha q L_E - C_B), \frac{C_B}{\alpha q}, 0)$. The agent searches for both causes and does not get rent. (3) When $\pi > \frac{C_A}{\alpha q(\alpha q L_E - C_B)}$, the optimal contract is $(W_A, W_B, W_0) = (0, \frac{C_B}{\alpha q}, 0)$. The agent searches for both causes and earns positive rent $\alpha q \pi(\alpha q L_E - C_B) - C_A$.

Intuitively, when there is only one agent, as long as there is renegotiation, the agent would disclose his search outcome to the decision-maker before deciding whether to continue to search for cause B or not. Such a disclosure leads to efficient search decisions. Furthermore, the optimal contract may not leave rent to the agent: the agent anticipates renegotiation benefits, so the decision-maker can offer a small payment in the ex-ante contract without destroying the agent's incentives of searching for cause A. Note that the payments specified in the ex-ante contracts cannot be reduced below zero given limited liability. Therefore, the agent gets positive rent when he has large renegotiation power.

Decentralization with two agents

Under decentralization, two agents are hired. Since Agent 1 is only assigned to the task of searching for cause A, there is no renegotiation opportunity for Agent 1 and the decision-maker. Furthermore, as will be shown in this section, Agent 1 may privately disclose his search outcome to Agent 2 to deter the latter's search. Therefore, Agent 1 would not disclose his search outcome to the decision-maker before Agent 2 takes action. Define the contract for Agent 1 as (W_{1A}, W_{1B}, W_{10}) and that for Agent 2

as (W_{2A}, W_{2B}, W_{20}).[16]

First, suppose that $W_{1A} > W_{10}$. Then Agent 1 may have incentives to privately disclose his search outcome to Agent 2 to deter the latter's search. To avoid such deterrence effects, the contract offered to Agent 2 should satisfy:

$$\alpha q W_{20} + (1-\alpha q) W_{2A} - C_B \geq W_{2A}, \text{ or equivalently, } W_{20} \geq W_{2A} + \frac{C_B}{\alpha q}$$

To motivate Agent 2 to search even if Agent 1 does not make private disclosure, the contract should satisfy

$$\alpha q W_{2B} + (1-\alpha q) W_{20} - C_B \geq W_{20} \text{ , or equivalently, } W_{2B} \geq W_{20} + \frac{C_B}{\alpha q}$$

Given $W_{20} \geq W_{2A} + \frac{C_B}{\alpha q}$ and $W_{2B} \geq W_{20} + \frac{C_B}{\alpha q}$, the contract that minimizes payments to Agent 2 is $(W_{2A}, W_{2B}, W_{20}) = (0, \frac{2C_B}{\alpha q}, \frac{C_B}{\alpha q})$.

Finally, to induce Agent 1 to search for cause A, the contract should satisfy:

$$\alpha q(1-\alpha q) W_{1A} + \alpha q(1-\alpha q) W_{1B} + [1 - 2\alpha q(1-\alpha q)] W_{10} - C_A \geq \alpha q W_{1B} + (1-\alpha q) W_{10}.$$

Thus, the contract that minimizes payments to Agent 1 is $(W_{1A}, W_{1B}, W_{10}) = (\frac{C_A}{\alpha q(1-\alpha q)}, 0, 0)$. Note that, given these contracts, Agent 1 will not make a private disclosure to Agent 2 in equilibrium. However, given the disclosure threat in the off-equilibrium path, Agent 2 earns positive rent of $(1-\alpha q)[\alpha q W_{2B} + (1-\alpha q) W_{20} - C_B] = (1-\alpha q)\frac{C_B}{\alpha q} > 0$.

Second, suppose that $W_{1A} \leq W_{10}$. Then Agent 1 has no incentive to disclose his search outcome to Agent 2. However, if $W_{1A} \leq W_{10}$, W_{10} should be strictly positive to induce Agent 1 to search:

$$\alpha q(1-\alpha q) W_{1A} + \alpha q(1-\alpha q) W_{1B} + [1 - 2\alpha q(1-\alpha q)] W_{10} - C_A \geq \alpha q W_{1B} + (1-\alpha q) W_{10}$$

Given the above condition and $W_{1A} \leq W_{10}$, the optimal contract that minimizes

[16] It can be shown that the decision-maker and Agent 2 will prefer signing the contract at stage 1 before Agent 1 searches. If the decision-maker offers the contract after Agent 2 privately learns Agent 1's search outcome, the contract may be rejected.

the payment to Agent 1 is $(W_{1A}, W_{1B}, W_{10}) = (\frac{C_A}{\alpha^2 q^2}, 0, \frac{C_A}{\alpha^2 q^2})$. This contract provides Agent 1 with positive expected rent of $(1-\alpha q)\frac{C_A}{\alpha^2 q^2}$. Since Agent 1 has no incentive to communicate with Agent 2, the optimal contract offered to Agent 2 should satisfy

$$\alpha q(1-\alpha q)W_{2A} + \alpha q(1-\alpha q)W_{2B} + [1-2\alpha q(1-\alpha q)]W_{20} - C_A \geq \alpha q W_{2A} + (1-\alpha q)W_{20}$$

Thus, the optimal contract for Agent 2 is $(W_{2A}, W_{2B}, W_{20}) = (0, \frac{C_B}{\alpha q(1-\alpha q)}, 0)$.

The following proposition summarizes the above results.[17]

Proposition 2: Suppose that there is no contingent search and two agents are hired. The optimal contracts lead to efficient search:

(1) If $C_B \geq \frac{C_A}{\alpha q}$, the optimal contracts are $(W_{1A}, W_{1B}, W_{10}) = (\frac{C_A}{\alpha^2 q^2}, 0, \frac{C_A}{\alpha^2 q^2})$ and $(W_{2A}, W_{2B}, W_{20}) = (0, \frac{C_B}{\alpha q(1-\alpha q)}, 0)$. Agent 1 earns positive rent of $(1-\alpha q)\frac{C_A}{\alpha^2 q^2}$.

(2) If $C_B < \frac{C_A}{\alpha q}$, the optimal contracts are $(W_{1A}, W_{1B}, W_{10}) = (\frac{C_A}{\alpha q(1-\alpha q)}, 0, 0)$ and $(W_{2A}, W_{2B}, W_{20}) = (0, \frac{2C_B}{\alpha q}, \frac{C_B}{\alpha q})$. Agent 2 earns positive rent of $(1-\alpha q)\frac{C_B}{\alpha q}$.

Intuitively, Agent 1's private disclosure to Agent 2 may deter the latter's search. Therefore, the optimal contracts have to offer rent to one of the two agents. If Agent 1's search costs are relatively small, the optimal contracts should leave rent to Agent 1 so that he would have no incentives for private disclosure to Agent 2. If Agent 2's search costs are relatively small, the optimal contracts should leave rent to Agent 2 so that he would always search for cause B, no matter whether Agent 1 makes a private

[17] Note that the decision-maker potentially has another choice. Instead of motivating the agents to conduct efficient search and offering rent to the agents, he may induce Agent 2 search only when there is no evidence in favor of cause A. However, given the assumptions $C_B < \alpha q L_E$ and $C_B < \alpha q[(1-\alpha_S)L_I - \alpha_S L_E]$, it is efficient for the organization to always search for cause B.

disclosure or not.

Proposition 1 implies that, under centralization, the single agent obtains rent of $\max(0, \alpha q \pi(\alpha q L_E - C_B) - C_A)$ when he has positive renegotiation power. Proposition 2 implies that, under decentralization with two agents, the rent paid to the agents is $\min((1-\alpha q)\frac{C_A}{\alpha^2 q^2}, (1-\alpha q)\frac{C_B}{\alpha q})$.

Corollary 1: There exist cut-offs $\hat{\pi}, \hat{q}, \hat{\alpha}, \hat{C}_A, \hat{C}_B$: (1) When the agents have small renegotiation power $\pi < \hat{\pi}$, search costs are high $C_A > \hat{C}_A$ (or $C_B > \hat{C}_B$), or search is not too effective $q < \hat{q}$ (or $\alpha < \hat{\alpha}$), the organization will adopt centralization, which leaves less rent to the agents than decentralization. (2) When the agents have large renegotiation power $\pi \geq \hat{\pi}$, search costs are low $C_A \leq \hat{C}_A$ (or $C_B \leq \hat{C}_B$), or search is very effective $q \geq \hat{q}$ (or $\alpha \geq \hat{\alpha}$), the organization will adopt decentralization, which leaves less rent to the agents.

Proof: in the appendix.

Intuitively, under centralization, the agent may and may not get rent given renegotiation and limited liability. When the search effort becomes more costly or less effective, under centralization, the renegotiation benefits get smaller and, correspondingly, the single agent's rent is smaller. Under decentralization, the agents get rent because of the deterrence effects from the agents' private communication. When the search effort becomes more costly or less effective, it is easier for Agent 1 to deter Agent 2's search through private communication, and therefore, the contracts have to offer the agents larger rent to avoid such deterrence. Therefore, the firm is more likely to adopt centralization.

3.2. Competing contingent search

One potential value of information transmission in sequential search is that the search decision on cause B may depend upon the search outcome on cause A. This section assumes that $\alpha q[(1-\alpha_S)L_I - \alpha_S L_E] \leq C_B < \alpha q L_E$, so that it is efficient to search for cause B only when there is evidence found in favor of cause A. Note that this is only possible if $L_E > \frac{1-\alpha_S}{1+\alpha_S} L_I$. That is, the expected loss for the organization from choosing cause A or B is large, relative to the loss of choosing the status quo.

This above scenario is common in sequential search. For example, suppose that a firm has a current product in the market to different types of customers.[18] If the earlier market investigation reveals that some customers prefer to change some features of the product, then further investigation will be important since other customers may not like such changes and prefer opposite modifications. Taking the extreme action to change features without further investigation of other customers' preferences may be very harmful to the firm. In contrast, if the earlier market investigation does not find evidence that some customers prefer to change the product features and if further investigation is very costly, then there is no need to conduct further investigation.

Centralization with one agent

Suppose that only one agent is hired. The analysis is similar to that in Section 3.1. As long as renegotiation is feasible, the agent would disclosure the evidence in favor of cause A to the decision-maker, prior to further search. Renegotiation leads to efficient sequential search. The only difference from what analyzed in Section 3.1 is

[18] Suppose that the firm cannot offer two versions of the product, given limited resources or economy of scale.

that the optimal contract does not motivate the agent to search for cause B if there is no evidence in favor of cause A.

Proposition 3: Suppose that there is competing contingent search and only one agent is hired. (1) When the agent has small renegotiation power $\pi \le \frac{C_A}{\alpha q(\alpha q L_E - C_B)}$, the optimal contract is $(W_A, W_B, W_0) = (\frac{C_A}{\alpha q} - \pi(\alpha q L_E - C_B), 0, 0)$. The agent conducts efficient sequential search and does not get rent. (2) When $\pi > \frac{C_A}{\alpha q(\alpha q L_E - C_B)}$, the optimal contract is $(W_A, W_B, W_0) = (0,0,0)$. The agent conducts efficient sequential search and earns positive rent of $\alpha q \pi(\alpha q L_E - C_B) - C_A$.

Decentralization with two agents

Now, suppose that two agents are hired. Suppose that there exists a contract to induce Agent 2 to search for cause B only when there is evidence disclosed in favor of cause A. However, for Agent 1 to make a disclosure when he obtains evidence in favor of cause A, his contract must satisfy:

$\alpha q W_{10} + (1 - \alpha q) W_{1A} > W_{1A}$, or equivalently, $W_{10} > W_{1A}$.

However, if $W_{10} > W_{1A}$, Agent 1 would not search for cause A at all and, correspondingly, Agent 2 would not search for cause B either. Therefore, efficient search cannot be implemented. This leaves the decision-maker with two possible choices to be discussed in details.

First, suppose that, given the contract, Agent 2 would never search for cause B. This can be implemented simply by offering Agent 2 zero payment. In addition, to motivate Agent 1 to search for cause A, the contract offered to Agent 1 should satisfy:

$\alpha q W_{1A} + (1 - \alpha q) W_{10} - C_A > W_{10}$

Therefore, the contract that minimizes payments to Agent 1 is

$(W_{1A}, W_{1B}, W_{10}) = (\frac{C_A}{\alpha q}, 0, 0)$. There is insufficient search for cause B.

Second, suppose that, given the contract, Agent 2 would always search for cause B. Then the optimal contracts should be the same as specified in Proposition 2. There is too much search on cause B, compared to what is efficient for the organization. Furthermore, to avoid deterrence effects, the optimal contracts offer rent to the agents.

Comparing the two above choices leads to the following proposition:

Proposition 4: Suppose that there is competing contingent search and two agents are hired. Efficient search cannot be implemented. There exists a cut-off $\overline{C}_B$. (1) If $C_B > \overline{C}_B$, the optimal contract is $(W_{1A}, W_{1B}, W_{10}) = (\frac{C_A}{\alpha q}, 0, 0)$. Agent 2 gets no payment and never searches. (2) If $C_B \le \overline{C}_B$ and $C_B \ge \frac{C_A}{\alpha q}$, the optimal contracts are $(W_{1A}, W_{1B}, W_{10}) = (\frac{C_A}{\alpha^2 q^2}, 0, \frac{C_A}{\alpha^2 q^2})$ and $(W_{2A}, W_{2B}, W_{20}) = (0, \frac{C_B}{\alpha q(1-\alpha q)}, 0)$. Agent 1 earns positive rent and Agent 2 always searches for cause B. (3) If $C_B \le \overline{C}_B$ and $C_B < \frac{C_A}{\alpha q}$, the optimal contracts are $(W_{1A}, W_{1B}, W_{10}) = (\frac{C_A}{\alpha q(1-\alpha q)}, 0, 0)$ and $(W_{2A}, W_{2B}, W_{20}) = (0, \frac{2C_B}{\alpha q}, \frac{C_B}{\alpha q})$. Agent 2 earns positive rent and always searches for cause B.

Proof: in the appendix.

Intuitively, if search costs are large enough, the decision-maker would rather implement insufficient search than provide extra rent to the agents. If search costs are small, then the decision-maker would have to implement too much search and provide rent to the agents.

Propositions 3 and 4 lead to the following comparisons between centralization and decentralization:

Corollary 2: Suppose that the organizational structure is chosen to maximize the total value of the organization excluding the rent paid to the agents. There exist cut-offs $\pi' > \hat{\pi}, C_A' < \hat{C}_A, C_B' < \hat{C}_B$: (1) When the agents have small renegotiation power $\pi < \pi'$, or large search costs $C_A > C_A'$, or $C_B > C_B'$, the organization adopts centralization. (2) When $\pi \geq \pi'$, or $C_A \leq C_A'$, or $C_B \leq C_B'$, the organization adopts decentralization. *Proof*: in the appendix.

Corollary 3: Suppose that the organizational structure is to maximize the total value of the organization without excluding the rent paid to the agents.[19] When renegotiation is feasible, centralization results in efficient search, while decentralization leads to either insufficient or too much search. The organization should adopt centralization.

In summary, under the scenario of "competing contingent search", there is more inefficiency with decentralization than under the scenario of non-contingent search. Decentralization leads to either too much or too little search for cause B. Therefore, the organization is more likely to prefer centralization.

3.3. Non-competing contingent search

This section assumes that $\alpha q L_E < C_B \leq \alpha q[(1-\alpha_S)L_I - \alpha_S L_E]$, so that it is efficient to search for cause B only when there is no evidence found in favor of cause A. Note that this scenario is possible only when $L_E \leq \frac{1-\alpha_S}{1+\alpha_S} L_I$. That is, the potential loss of choosing A or B is small, relative to the potential loss of choosing the status

[19] This is true for non-profit organizations or institutions.

quo.

Centralization with one agent

Suppose that only one agent is hired. Consider the following contract $(W_A, W_B, W_0) = (\frac{C_A}{\alpha q}, \frac{C_B}{\alpha q}, 0)$. First, suppose that the agent has found evidence in favor of cause A. Given $W_0 = 0$, the agent would not search for cause B. This is efficient for the organization. Second, suppose that the agent has not found evidence in favor of cause A. He would search for cause B, given $\alpha q W_B - C_B \geq 0$. Note that the agent would search for cause A, given $\alpha q W_A + (1-\alpha q)(\alpha q W_B - C_B) - C_A \geq 0$. Centralization implements efficient search and the agent does not earn any rent.

Decentralization with two agents

Under decentralization, consider the following contracts: $(W_{1A}, W_{1B}, W_{10}) = (\frac{C_A}{\alpha q}, 0, 0)$ and $(W_{2A}, W_{2B}, W_{20}) = (0, \frac{C_B}{\alpha q}, 0)$.

Suppose that Agent 1 has found evidence in favor of cause A. Given $W_{1A} > W_{10}$ and $W_{20} = 0$, Agent 1 has incentives to disclose the evidence to Agent 2, which deters the latter's search. This outcome is efficient for the organization. This result is not surprising since Agent 1's private incentives to deter Agent 2's search is in align with what the organization desires. Therefore, decentralization also implement efficient search and does not offer rent to the agents.

Proposition 5 summarizes these results.

Proposition 5: Suppose that there is non-competing contingent search. Both centralization and decentralization lead to efficient search and the optimal contracts do not leave rent to the agents.

In summary, this section has shown that, under decentralization, the agent who searches first may delay his disclosure to the decision-maker and privately communicate with the other agent, in order to deter the latter's search. To avoid these effects, the optimal contracts have to offer extra rent to the agents or may not implement efficient search. Given non-contingent search or competing contingent search, the organization may prefer centralization to decentralization, when the agents have small renegotiation power and when agents' search is very costly or not too effective.

4. Information transmission and endogenous choice of search sequence

The previous section has assumed that the search opportunity for cause A exogenously arrives before that for cause B. This assumption is valid, for example, when the firm receives two innovations sequentially or when the firm has too limited resource to support simultaneous searching. In many other situations, however, agents may choose to search for two causes either simultaneously or sequentially, and the decision-maker cannot observe the timing of the agents' search sequence. This section will generalize the basic model by allowing agents' endogenous choice between simultaneous and sequential search. Without loss of generalization, assume that $C_A \leq C_B$.

For illustration, this section will focus on the scenario with non-contingent search. The analysis for the scenarios with contingent search leads to similar results as in Section 3.2 and 3.3.

Assume that $C_B < \alpha q L_E$ and $C_B < \alpha q[(1-\alpha_S)L_I - \alpha_S L_E]$, so that it is always efficient to search for cause B no matter what the search outcome on cause A is. Since

$C_A \le C_B$, it is also always efficient to search for cause A.

Centralization with one agent

Suppose that only one agent is hired. Since the decision-maker cannot observe the agent's search sequence, it is a weakly dominant strategy for the agent to search sequentially. No matter with the agent's search sequence, if the agent obtains evidence after the first search, as long as he has positive renegotiation power, he will make a disclosure before further search. Then renegotiation guarantees efficient sequential search.

If the agent searches for cause A first but does not find evidence, then to induce search for cause B, the contract should satisfy

$\alpha q W_B + (1-\alpha q)W_0 - C_B \ge W_0$, or equivalently, $W_B \ge W_0 + \frac{C_B}{\alpha q}$.

Similarly, if the agent searches for cause B first but does not find evidence, to induce search for cause A, the contract should satisfy

$\alpha q W_A + (1-\alpha q)W_0 - C_A \ge W_0$, or equivalently, $W_A \ge W_0 + \frac{C_A}{\alpha q}$.

The decision-maker does not have to offer a contract with both $W_A \ge W_0 + \frac{C_A}{\alpha q}$ and $W_B \ge W_0 + \frac{C_B}{\alpha q}$, even though he cannot observe the agent's search sequence. Instead, as long as $C_B > C_A$, it is possible to design a specific contract with $W_A \ge W_0 + \frac{C_A}{\alpha q}$ and $W_B < W_0 + \frac{C_B}{\alpha q}$, which motivates the agent to search for cause B first. Intuitively, this is because that the agent anticipates receiving more renegotiation benefits when renegotiation is over the less costly search for cause A. As shown in the following proposition, it is optimal to offer the agent a contract with $W_A = \frac{C_A}{\alpha q}$ and $W_B \le \frac{C_B}{\alpha q}$.

Proposition 6: Suppose that there is no contingent search and only one agent is hired. The optimal contract is $(W_A, W_B, W_0) = (\frac{C_A}{\alpha q}, \frac{C_B}{\alpha q} - \pi(C_B - C_A), 0)$, which leads to efficient search. The agent takes the more costly search for cause B first. The agent earns positive rent $\alpha q \pi(\alpha q L_E - C_B)$.

Proof: in the appendix.

Intuitively, under centralization, efficient search can still be implemented, as long as the agent can choose sequential search and renegotiation is feasible. Different from the analysis in Section 3, the agent would almost always get positive rent, since the decision-maker does not know the agent's search sequence: If the decision-maker offers a very low payment W_B, the agent would choose to search for cause A first, and would not continue to search for cause B if he does not obtain evidence in favor of cause A.

Decentralization with two agents

Now suppose Agent 1 is assigned to search for cause A while Agent 2 is assigned to search for cause B. Each agent can choose to search at an early stage or at a late stage. There may exist multiple equilibria: one equilibrium with simultaneous search and another equilibrium with sequential search. However, given that one agent searches at the early stage, it is always a weakly dominated strategy for the other agent to search at the same stage. Therefore, we can focus on the equilibrium with sequential search.

Given sequential search, the agent who searches first and obtains evidence may make a private disclosure to the other agent, to deter the latter's search. Therefore, the

optimal contracts may have to offer extra rents to the agents. The following proposition characterizes the optimal contracts.

Proposition 7: Suppose that there is no contingent search and two agents are hired. The optimal contracts lead to efficient search. The agents are indifferent between simultaneous search and sequential search.

(1) If $C_B \geq \frac{1-\alpha q}{\alpha q} C_A$, the optimal contracts are $(W_{1A}, W_{1B}, W_{10}) = (\frac{C_A}{\alpha^2 q^2}, 0, \frac{C_A}{\alpha^2 q^2})$ and $(W_{2A}, W_{2B}, W_{20}) = (0, \frac{C_B}{\alpha q(1-\alpha q)}, 0)$. Agent 1 earns rent of $(1-\alpha q)\frac{C_A}{\alpha^2 q^2}$.

(2) If $C_B < \frac{1-\alpha q}{\alpha q} C_A$, the optimal contracts are $(W_{1A}, W_{1B}, W_{10}) = (\frac{2C_A}{\alpha q}, 0, \frac{C_A}{\alpha q})$ and $(W_{2A}, W_{2B}, W_{20}) = (0, \frac{2C_B}{\alpha q}, \frac{C_B}{\alpha q})$. Agent 1 earns rent of $(1-\alpha q)\frac{C_A}{\alpha q}$ while Agent 2 earns rent of $(1-\alpha q)\frac{C_B}{\alpha q}$.

Proof: in the appendix.

The comparison between Proposition 7 and Proposition 2 shows that, when the decision maker cannot observe the agents' search sequence, the total rent offered to the agents is higher than when the agents' search sequence is exogenously given.

As shown in Proposition 6, under centralization, the agent's rent is $\alpha q \pi(\alpha q L_E - C_B)$, which increases in α, q, π and decreases in C_B . Under decentralization, as shown in Proposition 7, the agents' rent is $\min((1-\alpha q)\frac{C_A}{\alpha^2 q^2}, (1-\alpha q)\frac{C_A + C_B}{\alpha q})$, which decreases in α, q, π and increases in C_A, C_B. This comparison leads to the following corollary.

Corollary 4: There exist cut-offs $\tilde{\pi}, \tilde{q}, \tilde{\alpha}, \tilde{C}_A, \tilde{C}_B$: (1) When the agents have small

renegotiation power $\pi \le \tilde{\pi}$, search costs are large $C_A > \tilde{C}_A$ (or $C_B > \tilde{C}_B$), or search is not effective $q \le \tilde{q}$ (or $\alpha \le \tilde{\alpha}$), the organization will adopt centralization. (2) When the agents have large renegotiation power $\pi > \tilde{\pi}$, search costs are small $C_A \le \tilde{C}_A$ (or $C_B \le \tilde{C}_B$), or search is effective $q > \tilde{q}$ (or $\alpha > \tilde{\alpha}$), the organization will adopt decentralization.

In sum, even when the agents endogenously choose their searching time, the firm may still prefer centralization, when the search effort is too costly or not too effective and when the agent's negotiation power is small.

5. Discussions

5.1 Mandatory disclosure

A key building block in the basic model is that the decision-maker cannot force Agent 1 to publicly disclose the search outcome on cause A before Agent 2 searches for cause B. There are two underlying reasons.

First, although agents can disclose their search outcomes to the decision-maker, such disclosure or the disclosed evidence cannot be verified by courts. Outsiders such as courts may lack enough knowledge or information to interpret the disclosed evidence. Or it is very costly for courts to verify the disclosed evidence, even though such evidence is hard information. Given these restrictions, the contract offered to agents cannot be based on the disclosed evidence.

Second, in practice, the decision-maker often cannot observe the exact timing of the sequential search: that is, when search for A has finished while search for B has not started. This is particularly valid when agents can endogenously choose their search sequence. In these scenarios, the contract offered to agents cannot be based on

the time of the agents' disclosure.

Note that, if the decision-maker knows the exact timing of the sequential search and the agents' disclosure can be verified by courts, then the decision-maker can give Agent 1 positive payment only when he makes a disclosure before the search for cause B. Alternatively, the decision-maker can set a deadline for the agents' disclosure. Then both centralization and decentralization can implement efficient search and does not leave rent to the agents.

5.2 Option contracts

The previous sections have only considered deterministic ex-ante contracts with payments contingent on the final decision/action of the firm. One underlying assumption is that the decision-maker does not have the option to choose different contracts between sequential search. In many organizations, the decision-maker cannot observe whether and when the agents have conduct effort. Correspondingly, it is difficult for the decision-maker to decide when to exercise the option.

If the timing of the agents' sequential search is certain, the decision-maker knows when the agents have searched for cause A but not searched for caused B yet. In such scenarios, under centralization with one agent, there exist option contracts which implement efficient search and do not leave rent to the agent.

Suppose that it is always efficient to search for both causes A and B. Consider an ex-ante agreement which gives the decision-maker the option to choose between two contracts for the agent: $(W_A, W_B, W_0) = (\frac{C_A}{\alpha q}, \frac{C_B}{\alpha q}, 0)$ or $(W_A, W_B, W_0) = (\frac{C_A}{\alpha q}, \frac{C_B}{\alpha q}, \frac{C_A + C_B}{\alpha q})$. If the single agent discloses evidence in favor of cause A, the decision-maker would choose $(W_A, W_B, W_0) = (\frac{C_A}{\alpha q}, \frac{C_B}{\alpha q}, \frac{C_A + C_B}{\alpha q})$, so that the agent will continue to search for cause B. If the agent does not disclose

evidence in favor of cause A, the decision-maker would choose $(W_A, W_B, W_0) = (\frac{C_A}{\alpha q}, \frac{C_B}{\alpha q}, 0)$. Anticipating the decision-maker's choice of contracts, the agent would make a disclosure when he obtains evidence in favor of cause A. The agent does not earn any rent.

Note that the above option contract is not feasible when the firm hires two agents, since each agent is assigned with only one task.

5.3 Forging evidence

In practice, agents may be able to forge evidence in favor of their own causes. [20] Consider the following modifications of the basic model analyzed in Section 3: When an agent has no evidence in favor of one cause, he can forge evidence with a certain probability, which is assumed not too large. For illustration, suppose that it is always efficient to search for both causes A and B, even if the agents forge evidence.

Under centralization with one agent, as long as the agent has searched for cause A, he would have incentives to forge evidence on cause A. In both scenarios where the agent has found evidence in favor of cause A, and where he forges evidence, renegotiation leads the agent to search further for cause B. Correspondingly, the agent will have incentives to forge evidence on cause B as well. In summary, the agent always tries to forge evidence. Under decentralization with two agents, similarly, as long as each agent has taken search, he would have incentives to forge evidence.

Since agents have the same incentives to forge evidence on both causes, the comparison between centralization and decentralization will depend more on whether efficient search can be implemented and whether the agents get extra rent. The analysis is similar to that in Sections 3. The organization still may prefer having one

[20] Dewatripont and Tirole (1999) discussed forging evidence with simultaneous search. They showed that a single agent had different incentives to forge evidence, compared to the scenario with two agents.

agent.[21]

6. Conclusions

This paper has examined the interaction between agents' incentives to search evidence for competing causes and their incentives to disclose the search outcomes to a decision-maker and/or other agents in the organization. The organization can choose to centralize the search tasks with one single agent, or decentralize them with two agents. The agents' search may be sequential as exogenously given, or the agents can choose between simultaneous and sequential search.

Under decentralization, the agent who searches first may strategically delay his disclosure to the decision-maker but make a private disclosure to the other agent, in order to deter the latter's search. To avoid such deterrence effects, the optimal contracts have to offer extra rents to the agents. Furthermore, if there is passive contingent search, decentralization cannot implement efficient search.

Under centralization, if the agent obtains evidence in favor of one cause, he would disclose the evidence and renegotiate with the decision-maker, prior to further search for another cause. Therefore, efficient search can be implemented. If the agent gets more renegotiation benefits, the optimal ex-ante contract can offer lower payments, without affecting the agent's search incentives. The agent earns positive rent only when his renegotiation power is large enough.

As long as sequential search is possible and agents privately observe their search outcome, centralization with one agent may be more efficient or less costly than decentralization with two agents. The organization is more likely to adopt centralization, when the agent has smaller renegotiation power, search costs are larger,

[21] If there is competing contingent search, the agents always forge evidence on both causes. Then under centralization, there may be too much search than what is efficient for the organization. Under decentralization, there may be insufficient or too much search.

or the search effort is less effective.

There are several extensions for future research. First of all, this paper assumes that the search outcomes for the two causes are independent. More generally, the choice between centralization and decentralization may depend upon whether the search outcomes are positively or negatively correlated.[22] Second, this paper does not consider direct collusion between the agents. It remains an interesting question how the agents' collusion would affect the choice between centralization and decentralization. Finally, this paper shows that, given private communication among agents, decentralization may not provide better incentives for agents to take effort than centralization. Therefore it is worthwhile to explore other potential justifications for decentralization or examine mechanisms which affect agents' private communication.

Appendix

Proof of Lemma 1: First, suppose that there is evidence that $\theta_A = -1$. If there is search for cause B, the search costs are C_B and the expected loss from making the wrong decision is:

$$a[q*0+(1-q)L_E]+(1-\alpha)*0=\alpha(1-q)L_E$$

If there is no search for cause B, the expected loss is:

$$aL_E+(1-\alpha)*0=\alpha L_E$$

Thus, if and only if $C_B < \alpha q L_E$, it is efficient to continue to search for cause B.

Second, suppose that there is no evidence found in favor of cause A, the posterior belief that $\theta_A = -1$ is α_S. If there is search for cause B, the search costs are C_B and the expected loss from making the wrong decision is:

[22] For positively (or negatively) correlated search outcomes, if there is evidence found in favor of the first cause, it is more (or less) likely to find evidence in favor of the second cause.

$$\alpha_S\{\alpha[qL_E+(1-q)*0]+(1-\alpha)L_I\}+(1-\alpha_S)\{a[q*0+(1-q)L_I]+(1-\alpha)*0\}$$
$$=\alpha_S\alpha qL_E+\alpha_S(1-\alpha)L_I+(1-\alpha_S)\alpha(1-q)L_I$$

If there is no search for cause B, the expected loss is:

$$\alpha_S\{\alpha*0+(1-\alpha)L_I\}+(1-\alpha_S)\{aL_I+(1-\alpha)*0\}$$
$$=\alpha_S(1-\alpha)L_I+(1-\alpha_S)\alpha L_I$$

Therefore, if and only if $C_B<\alpha q[(1-\alpha_S)L_I-\alpha_S L_E]$, it is efficient to continue to search for cause B when there is no evidence found in favor of cause A. Q.E.D

Proof of Corollary 1: Under centralization, the rent paid to the agent is $\max(0,\alpha q\pi(\alpha qL_E-C_B)-C_A)$ which increases in α,q,π and decreases in C_A,C_B. Under decentralization, the rent paid to the agents is $\min((1-\alpha q)\frac{C_A}{\alpha^2q^2},(1-\alpha q)\frac{C_B}{\alpha q})$, which decreases in α,q,π and increases in C_A,C_B. Therefore, the cut-offs are unique. Q.E.D.

Proof of Proposition 4: If the decision-maker offers $(W_{1A},W_{1B},W_{10})=(\frac{C_A}{\alpha q},0,0)$ to Agent 1 and zero payment to Agent 2, there is no search for cause B and the agents do not get any rent. The expected loss for the whole organization, compared to that from the efficient search effort, is $\alpha q(\alpha qL_E-C_B)$, which decreases in C_B.

If the decision-maker offers contracts such that Agent 2 always searches for cause B, the optimal contracts should be the same as specified in Proposition 2. There is too much search for cause B comparing to what is most efficient for the organization. The expected loss for the organization plus rent paid to the agents is:

$$(1-\alpha q)\{C_B-\alpha q[(1-\alpha_S)L_I-\alpha_S L_E]\}+\min((1-\alpha q)\frac{C_A}{\alpha^2q^2},(1-\alpha q)\frac{C_B}{\alpha q}),$$

which increases in C_B.

Therefore, the difference in the expected loss between the above scenarios is monotone in C_B. Q.E.D.

Proof of Corollary 2:

First of all, consider the effect from changing the agent's renegotiation power. If $C_B > \overline{C}_B$, when there are two agents, the expected loss for the whole organization, compared to that from the efficient search effort, is $\alpha q(\alpha q L_E - C_B)$; when there is only one agent, the expected rent paid to the agent is $\alpha q \pi(\alpha q L_E - C_B) - C_A$, which is strictly smaller than $\alpha q(\alpha q L_E - C_B)$ for any π. It is strictly better to hire one agent. In this case, define $\pi' = 1$.

Now suppose that $C_B \le \overline{C}_B$. Note that if $\pi = \hat{\pi}$, having only one agent leads to efficient search, while having two agents cannot implement efficient search. And if $\pi = \hat{\pi}$, having only one agent and having two agents leave the same rent to the agents. Therefore, if $\pi = \hat{\pi}$, the expected loss for the organization including the rent paid to the agents from having two agents is strictly higher than that from having one agent. If $\pi > \hat{\pi}$, when there is only one agent, the agent would get rent $\alpha q \pi(\alpha q L_E - C_B) - C_A$, which is strictly increasing in π. In contrast, when there are two agents, the expected loss for the organization does not depend on π. Therefore, there exists a cut-off $\pi' > \hat{\pi}$, such that the organization would hire two agents if and only if $\pi > \pi'$.

Second, consider the effect from changing search costs C_B. If $C_B > \overline{C}_B$, as shown above, it is strictly better to hire one agent. Now suppose $C_B \le \overline{C}_B$. Note that if $C_B = \hat{C}_B$, having only one agent and having two agents leave the same rent to the agents. Having only one agent leads to efficient search, while having two agents cannot implement efficient search. Therefore, if $C_B = \hat{C}_B$, it is strictly better to hire only one agent.

When there is only one agent, the organization has to pay the agent extra rent

$\max(0, \alpha q \pi(\alpha q L_E - C_B) - C_A)$, which is strictly decreasing in C_B.

When there are two agents, according to Proposition 4, if $C_B \le \overline{C}_B$, Agent 2 conducts too extensive search and gets rent of $\min((1-\alpha q)\frac{C_A}{\alpha^2 q^2}, (1-\alpha q)\frac{C_B}{\alpha q})$. Therefore, the expected loss to the organization and the rent paid to Agent 2 are increasing in C_B.

Given the above comparisons, there exists one cut-off $C_B' < \hat{C}_B$, such that it is optimal to hire two agents, if and only if $C_B < C_B'$.

Finally, consider the effect from changing search costs C_A. Note that if $C_A = \hat{C}_A$, it is strictly better for the organization to hire only one agent. .

When there is only one agent, the organization has to pay the agent extra rent $\max(0, \alpha q \pi(\alpha q L_E - C_B) - C_A)$, which is strictly decreasing in C_A.

When there are two agents, according to Proposition 5, the change in C_A does not affect Agent 2's search decisions. If $C_B > \overline{C}_B$, the agents get no rent. If $C_B \le \overline{C}_B$, the rent paid to the agents is $\min((1-\alpha q)\frac{C_A}{\alpha^2 q^2}, (1-\alpha q)\frac{C_B}{\alpha q})$. Therefore, the expected loss to the organization and the rent paid to Agent 2 is weakly increasing in C_A.

Given the above comparisons, there exists one cut-off $C_A' < \hat{C}_A$, such that it is optimal to hire two agents if and only if $C_A < C_A'$. Q.E.D.

Proof of Proposition 6: The optimal contract offers $W_0 = 0$. If the contract induces efficient search but $W_0 > 0$, the decision-maker can always decrease W_0 and W_A (or W_B) to reduce the agent's rent, without affecting the agent's search incentives.

First, consider a contract with $W_A = \frac{C_A}{\alpha q}$ and $W_B \le \frac{C_B}{\alpha q}$. If the agent searches for cause B first and does not obtain evidence in favor of cause B, he would search for cause A. If he obtains evidence in favor of B, he would make a disclosure and

renegotiate with the decision maker. The contract renegotiated would be $(W_A', W_B', W_0') = (0,0,\frac{C_A}{\alpha q})$, together with a fixed payment to the agent: $T = W_B + \pi(\alpha q L_E - C_A)$. The agent earns expected rent $\alpha q[W_B + \pi(\alpha q L_E - C_A] - C_B$.

If the agent searches for cause A first but does not find evidence, he would not search for cause B if $W_B < \frac{C_B}{\alpha q}$. If he obtains evidence in favor of cause A, the agent gets renegotiation benefits $W_A + \pi(\alpha q L_E - C_B)$. There is inefficient search and the agent earns expected rent $\alpha q[W_A + \pi(\alpha q L_E - C_B] - C_A = \alpha q \pi(\alpha q L_E - C_B)$.

To motivate the agent to search for cause B first, the contract should satisfy

$\alpha q[W_B + \pi(\alpha q L_E - C_A] - C_B \geq \alpha q \pi(\alpha q L_E - C_B)$.

The lowest payment satisfying the above condition is $W_B = \frac{C_B}{\alpha q} - \pi(C_B - C_A)$. Correspondingly, the agent earns expected rent $\alpha q \pi(\alpha q L_E - C_B)$.

Second, consider a contract with $W_A < \frac{C_A}{\alpha q}$ and $W_B = \frac{C_B}{\alpha q}$. Similar to the above analysis, there is inefficient search and the agent earns expected rent $\alpha q \pi(\alpha q L_E - C_A)$, which is higher than $\alpha q \pi(\alpha q L_E - C_B)$.

Therefore, the optimal contract is $(W_A, W_B, W_0) = (\frac{C_A}{\alpha q}, \frac{C_B}{\alpha q} - \pi(C_B - C_A), 0)$.

Q.E.D.

Proof of Proposition 7: First, suppose that $W_{1A} > W_{10}$. Then if Agent 1 searches first, he may have incentives to privately disclose his search outcome to Agent 2 to deter the latter's search. Similar to the analysis in Section 3.1, to minimize payments, the optimal contract is $(W_{2A}, W_{2B}, W_{20}) = (0, \frac{2C_B}{\alpha q}, \frac{C_B}{\alpha q})$. Since $W_{2B} > W_{20}$, if Agent 2 searches first, he may privately disclose his search outcome to Agent 1 to deter the latter's search. Similarly, the optimal contract offered to Agent 1 is $(W_{1A}, W_{1B}, W_{10}) = (\frac{2C_A}{\alpha q}, 0, \frac{C_A}{\alpha q})$. It can also be verified that, given these contracts, each

agent will take search effort if he does not know the other agent's search outcome:

$$\alpha q(1-\alpha q)W_{1A} + \alpha q(1-\alpha q)W_{1B} + [1-2\alpha q(1-\alpha q)]W_{10} - C_A \geq \alpha q W_{1B} + (1-\alpha q)W_{10}$$

$$\alpha q(1-\alpha q)W_{2A} + \alpha q(1-\alpha q)W_{2B} + [1-2\alpha q(1-\alpha q)]W_{20} - C_B \geq \alpha q W_{2A} + (1-\alpha q)W_{20}$$

Agent 1's expected rent is $(1-\alpha q)W_{10} = (1-\alpha q)\frac{C_A}{\alpha q}$ and Agent 2's rent is $(1-\alpha q)W_{20} = (1-\alpha q)\frac{C_B}{\alpha q}$.

Second, if $W_{1A} \leq W_{10}$, consider the contracts $(W_{1A}, W_{1B}, W_{10}) = (\frac{C_A}{\alpha^2 q^2}, 0, \frac{C_A}{\alpha^2 q^2})$, and $(W_{2A}, W_{2B}, W_{20}) = (0, \frac{C_B}{\alpha q(1-\alpha q)}, 0)$. As shown in Proposition 2, if Agent 1 searches first, the above contracts implement efficient search and minimizes the agents' rent. Now, if Agent 2 searches first and obtains evidence, he would not have incentives to disclose it to Agent 1, since there is no deterrence effect given

$$\alpha q W_{10} + (1-\alpha q)W_{1B} - C_A = \frac{C_A}{\alpha q} - C_A > 0.$$

Therefore, Agent 1 would always take search effort. Given these contracts, only Agent 1 gets positive rent $(1-\alpha q)W_{10} = (1-\alpha q)\frac{C_A}{\alpha^2 q^2}$.

Finally, note that $(1-\alpha q)\frac{C_A}{\alpha^2 q^2} \leq (1-\alpha q)\frac{C_A + C_B}{\alpha q}$ if and only if $C_B \geq \frac{1-\alpha q}{\alpha q} C_A$. Q.E.D.

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