The Organization of Delegated Expertise *

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May 18, 2004

Abstract

This paper proposes a theory of the optimal organization of delegated expertise. For incentive purposes, a principal should reward an expert when his recommendation is confirmed either by the facts or by other experts' recommendations. With a single expert, we show that the agency costs of delegated expertise exhibit diseconomies of scale. Possible organizational responses to this problem include basing decisions on a less than optimal amount of information, and relying on multiple experts. We analyze the source of gains from having multiple experts in different contracting environments corresponding to different nexi of collusion between the principal and/or the experts.

*We thank Mark Armstrong, Juan Carillo, Hendrik Hakenes, Li Hui, Rongkang Kang, Godfrey Keller, Jean-Jacques Laffont, Christian Laux, Jonathan Levin, Gyöngyi Lóránth, George Mailath, Eric Maskin, Lisa Oliver, Marco Ottaviani, Jean Tirole, and Dimitri Vayanos as well as seminar participants at CERNA Paris, ETAPE Paris, Frankfurt, HEC Paris, Institut Henri Poincaré Paris, London Business School, the LAMES in Sao Paulo, Munich, Oxford, Wuhan University and the Econometric Society European Meeting 2003 in Stockholm for discussions and comments. We also thank Marie-Pierre Boé and Cathy Wilson for their help in preparing the manuscript. All errors are ours.

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1 Introduction

With scientific and technological boundaries moving constantly, decision-making has come to rely increasingly on expertise. Decision-makers do not always have the time and skills to gather and process information on complex issues. Instead, this task is often delegated to experts. In this paper, we analyze the problem of motivating experts to gather and report information through monetary compensations and organization design.

Examples of delegated expertise abound and span both the private and public spheres. Firms routinely seek the advice of consultants to evaluate strategies. Investors follow the recommendations of financial analysts. Public policies aimed at managing risks rely on scientific experts as illustrated during the debates in several European countries over nuclear programmes, transgenic plants and global warming. The architecture of governments, and most specifically of legislatures, requires that groups of legislators gather and publicize information before legislative decision-making takes place.

How do experts really get informed? How can one ensure that the information they provide is accurate and can indeed improve decision-making? How accountable should experts be for their recommendations? How should one organize the delegation of expertise? Should one rely on one or several experts? To address these questions, one must realize that delegated expertise involves an incentive problem between the principal and the expert(s), with quite specific and intriguing features. Indeed, unlike other activities involving moral hazard, experts produce a non-verifiable output, namely information. Therefore, experts must be given incentives not only to acquire information, but also not to manipulate it. An efficient design of incentives for experts must therefore solve an intricate problem mixing both moral hazard and adverse selection.

This paper studies the optimal design of incentive contracts for experts and explores implications for the organization of delegated expertise. We consider the relationship between a decision-maker (principal) and one or several agents (experts) whose task is to gather information (signals) on the likelihood of success of a project. The project is *a priori* unprofitable. However, based on the information reported by the expert(s), the principal decides whether to undertake the project. Because information gathering is costly for the experts, they must be motivated by incentive contracts. While the principal and the experts are risk-neutral, the experts are assumed to be protected by limited liability, which limits the set of feasible contracts.

Starting with a single expert gathering a single signal, the one-expert/one-signal case, we characterize the optimal incentive contract. If the expert recommends undertaking the project and it fails, the expert should be punished. Under limited liability, the maximum punishment is to receive no transfer from the principal. Instead, incentives to acquire and report a positive signal are provided by rewards if the project succeeds. Similarly incentives to gather and report a negative signal are provided by rewarding the status quo. Therefore delegated expertise involves agency costs, i.e., the expert derives a rent.

We then turn to the paper's central issue, i.e., the organization of delegated expertise. For this, we consider that two signals can be gathered, that are independent conditional on the project's outcome and otherwise identical in cost and precision. This implies constant technological returns to scale. To simplify, we first assume that both signals have to be gathered simultaneously. The paper studies and compares the performance and optimality of different organization forms under different contracting environments. Specifically, we compare the agency costs arising when the principal relies on one expert to gather both signals (the one-expert/two-signals case) and when he relies on two experts each of which gathers one signal (the two-experts/two-signals case).

First we study the one-expert/two-signals case, and identify a key property of delegated expertise: *diseconomies of scale* in agency costs. That is, agency costs are more than twice as large in the two-signals as in the one-signal case. The intuition is simple. Consider an expert having already gathered one positive signal. A second signal may turn out to conflict with the first one, in which case the project should be rejected and the status quo implemented. To induce the expert to gather the second signal, the contract must bias him towards the status quo if signals are conflicting. However, this bias is costly for the principal since the expert is now tempted to recommend the status quo while remaining uninformed. This is the source of the diseconomies of scale. Because an expert is rewarded when his assessment of a project is confirmed, he is reluctant to acquire information that may conflict with his initial assessment of the project. The transfers needed to motivate the expert to gather more information are increasingly costly for the principal. To reduce agency costs, the principal may forego the benefit of more information and make less than optimally informed decisions. In other words, a possible response to agency costs is to distort the decision rule.

We then analyze the two-experts/two-signals case and show that whether resorting to two experts dominates a single expert depends on the contracting environment.

First, we consider an environment in which the principal can contract with each expert on his report and that of the other expert, as well as on the project's outcome. Such *report-based contracts* are not possible with a single expert because reports are fully manipulable, i.e., an adverse selection constraint is binding. With two experts, however, this constraint is no longer binding and *report-based contracts* are *a priori* possible. This added degree of freedom in contracting is useful for two distinct reasons. First, it allows to put all the weight of an expert's reward for a positive report on the state that is most informative (i.e., the project succeeding) and none on a less informative state (i.e., the project being rejected following a negative report by the other expert). Second, because the signals gathered by the two experts are correlated, *report-based contracts* allow to use one expert's report to cross-check the other's. For both reasons, motivating each expert becomes cheaper. In fact, the agency costs exhibit now *increasing returns to scale.* The optimal arrangement is for each expert to be rewarded only if his report is confirmed by the facts and by the other expert's report. Interestingly, this optimal arrangement rewarding consensus has the obvious drawback of being exposed to the possibility of horizontal collusion between experts. If this type of collusion cannot be avoided, the principal might have to resort to relying on a single signal at the cost of distorting the decision rule.

Second, we analyze the case of *own-report-based contracts*, i.e., in which the principal can contract with each expert on the project's outcome as well as on their report but not on the other expert's report. These contracts are in fact robust to the threat of vertical collusion between the principal and the experts. In that case, two experts still dominate a single expert, but less than under report-based contracts as there are only *constant returns to scale* in agency costs.

Finally, we analyze the case in which contracts can only be signed on the project's outcome, but not on the reports themselves. For such *outcome-based contracts*, which arise when both horizontal and vertical collusions are possible, we show that using a single expert is optimal. This result derives from the decreasing returns to scale property: with outcome-based contracts, each expert behaves as if he is gathering the second, more expensive, signal.

Summarizing, the structure of agency costs for delegated expertise calls for using multiple experts. However, the value improvement brought about by such a management depends critically on the scope for vertical and horizontal collusion. Without public and transparent report procedures, it can even be counterproductive.

While the design of expertise is well studied in Administrative Law and Accounting, economists have devoted less attention to it.[2] Lambert (1985), Demski and Sappington (1987) and Malcomson (2001) emphasize the cost of delegated expertise arising from information gathering being non-verifiable. They characterize the optimal contract for one expert under fairly general information structures. Instead our model is simpler but we compare several organizations of expertise. Another difference is our focus on the experts' limited liability rather than risk aversion as the source of agency costs. This makes our model more tractable, allowing extensions such as multiple signals and experts. Osband (1989) analyzes incentives for experts who report estimates of the unknown mean of a random signal. Unlike in our model, the principal is passive and does not take decisions based on the estimate. Nevertheless, the reports are useful as they reduce the principal's loss function. Finally, experts are assumed to have private information about their degree of expertise, an adverse selection dimension that is absent in our model.

Dewatripont and Tirole (1999) study the design of expertise in an incomplete contracts framework. Within our model, this incompleteness requires that contracts be outcome-based, i.e., based on whether the project is undertaken but not on reports. Two hard information independent signals need to be gathered and can be either positive or negative. Having each of two experts collect one kind of signal is the only way to induce information gathering since outcome-based contracts cannot reward a single expert for gathering conflicting signals. Instead of incomplete contracts, we follow a mechanism design approach. Contracts are contingent on the experts' reports and experts acquire signals that are *a priori* identical, i.e., identically distributed and soft information. Screening remains possible because of the stochastic nature of the project. We show that conflicting evidence is nevertheless easier to obtain with two experts. The optimal collusion-free contract is necessarily report-based. With decision-based contracts, a single expert is optimal.[3] Laffont and Martimort (1999) also show that splitting information between several experts (reg-

[2]See Hermitte (1997) and Harrison (2001) for Administrative Law. See, among others, Baiman and Demski (1980) for Accounting.

[3]It is important to stress two other differences. First, in Dewatripont and Tirole (1999), decisions yield non-random outcomes. Second, the signals are hard information, i.e., they can be concealed but not manipulated. In their model, if information were fully manipulable as in ours, incentives could not be provided to the expert.

ulators) reduces agency costs. However, the agency costs arise from the experts colluding with private interests, and not from information gathering. Another important difference is that we consider endogenous information structures.

Our result on the benefit of having multiple experts bears also some resemblance with the literature on the interaction between planning and implementation in organizations.[4] There, it is argued that splitting information gathering and production can relax incentive problems. Our model differs by his focus on two information gathering tasks.

A literature following Crawford and Sobel (1983) and mainly motivated by applications to Political Science, assumes that already informed experts move first and report to the decision-maker who is not committed to a decision rule and that monetary transfers are not feasible. This timing may be relevant to model committee organization in legislatures or informational lobbying but less so in environments where the decision-maker has a leading role in organizing information gathering. Recent papers in that line have also argued that multiple experts can generate more information, reducing the scope for pooling and allowing fully separating equilibria.[5] We depart from this literature in several ways. We let the decision-maker move first and allow monetary incentives. We endogenize information structures and analyze how the problems of gathering and eliciting information interact.

The one-expert/one-signal model is presented in Section 2 and analyzed in Section 3. Section 4 studies the one-expert/two-signals case and identifies diseconomies of scale due to agency costs. The two-experts/two-signals case is studied for *report-based* contracts in Section 5, and for *own-report-based* and *decision-based* contracts in Section 6. Section 7 studies sequential information gathering. Section 8 concludes. Proofs are in the Appendix.

2 A Model of Delegated Expertise

We consider the relationship between a decision-maker (principal) and a single agent (expert) whose task is to gather information on the profitability of a risky project. Based on this information, the principal decides whether to undertake the project. Both the principal and the expert are risk-neutral. The expert is unbiased, in the sense that he is

[4]See Hirao (1994), Lewis and Sappington (1997), Laux (2001a), Khalil, Kim and Shin (2002) and Jeon (2003).

[5]See Baron and Meirowitz (2001), Krishna and Morgan (1998), and Wolinsky (2000) for recent papers.

a priori indifferent about whether the project is undertaken and about its outcome.[6]

The project's payoff is $\bar{S} > 0$ if it succeeds, and $\underline{S} < 0$ otherwise. Denote by ν the *a priori* probability of success. Absent further information, undertaking the project is assumed to be inefficient which introduces a bias towards the status quo in our model:[7]

$$\nu\bar{S} + (1-\nu)\underline{S} < 0.$$

For instance, one can think of the principal as being a CEO having to decide whether to enter a new market, and using the expertise of consultants. Whether entry will prove profitable is *a priori* unknown. The principal could also be a Health Agency having to decide whether to authorize a new drug, and relying on scientists' recommendations.

Information Structure: By incurring a personal cost ψ, the expert observes a signal $\sigma \in \{\underline{\sigma}, \bar{\sigma}\}$.[8] Denote by $\theta \in (1/2, 1]$ the signal's precision defined as $\text{Proba}(\bar{\sigma}|\bar{S}) = \text{Proba}(\underline{\sigma}|\underline{S}) = \theta$. Hence, $\bar{\sigma}$ is "good news" and $\underline{\sigma}$ "bad news" about the project.[9] If the project is undertaken, its outcome is observed. Otherwise, no further information arrives.

Notation: Denote $p(\sigma)$ the likelihood of $\sigma \in \{\underline{\sigma}, \bar{\sigma}\}$ and $\nu(\sigma)$ the probability of success conditional on σ. For example, $p(\bar{\sigma}) = \nu\theta + (1-\nu)(1-\theta)$ and $\nu(\bar{\sigma}) = \frac{\theta\nu}{\nu\theta+(1-\nu)(1-\theta)}$.

First-Best Decision Rule: As a benchmark, consider the first-best decision rule.[10] Once ψ is sunk, the optimal decision rule is to undertake the project if and only if $\sigma = \bar{\sigma}$. Hence gathering information is valuable if this is cheap enough (ψ small enough), and the signal precise enough (θ close enough to 1). The project's expected surplus is:

$$p(\bar{\sigma})\left(\nu(\bar{\sigma})\bar{S} + (1-\nu(\bar{\sigma}))\,\underline{S}\right) - \psi = \theta\nu\bar{S} + (1-\theta)(1-\nu)\underline{S} - \psi \geq 0.$$

3 Expertise and Incentives

This section describes the incentive issues arising in the principal-expert relationship. Departing from the first-best, three contracting frictions are assumed.

[6]Biased experts in political contexts have been analyzed by Dur and Swank (2004) and Laux (2001a).

[7]The opposite case in analyzed in the Appendix. The results are similar.

[8]The outcome of information gathering could be random, with the expert observing a signal or nothing with some probability. This would increase the number of possible reports by the expert (he could report being uninformed) but would not alter the paper's main insights.

[9]Indeed, for $\theta \in (1/2, 1]$, we have $\frac{\text{Proba}(\bar{\sigma}|\bar{S})}{\text{Proba}(\underline{\sigma}|\bar{S})} = \frac{\theta}{1-\theta} > \frac{1-\theta}{\theta} = \frac{\text{Proba}(\bar{\sigma}|\underline{S})}{\text{Proba}(\underline{\sigma}|\underline{S})}$.

[10]This case corresponds to the principal being able to gather information himself or, equivalently, to the expert's cost of information gathering being contractible.

Assumptions 1

- *Moral hazard: Whether the expert acquires information or not is not observable.*
- *Limited liability: Transfers from the principal to the expert are non-negative.*
- *Soft information: The signal σ is not observable by other parties.*

The first point implies that the expert must be given incentives to gather information. The second implies that incentive provision is costly for the principal. Indeed, with unlimited liability, the expert could be made residual claimant for the project. In particular, if the expert's report were positive but the project failed, he would have to make a transfer to the principal. This is not feasible under limited liability. Instead, incentive provision requires leaving an information rent to the expert.[11] The third point implies that the expert has private information. The expert produces information which is a non-verifiable and fully manipulable output. In particular, he can report having observed a signal even if he did not.[12]

A contract for the expert consists of transfers from the principal, and decisions whether to undertake the project based on his report $\hat{\sigma}$ on the signal. The project being risky, the transfers can be lotteries conditional on its outcome. Of course, such lotteries are helpful only if the project is undertaken. Otherwise, a constant transfer suffices. Formally, a contract is a menu of lotteries on transfers and a vector of decisions depending on the expert's report $\hat{\sigma} \in \{\underline{\sigma}, \bar{\sigma}\}$.

We begin by characterizing the optimal contract implementing the first-best decision rule. This is the first step in the optimization of the decision rule itself, which we complete later in the section. A contract implementing the first-best decision rule is summarized by the expert's transfers t_0 if the project is rejected, $\bar{t}$ if it is undertaken and succeeds, and $\underline{t}$ if it fails. To streamline the presentation, we assume that $\underline{t} = 0$, which is clearly optimal (see the Appendix for a formal proof).

Note that, absent the incentive problem, the ex post information asymmetry between the principal and the expert could be solved at no cost with a flat contract since the

[11] As usual under moral hazard and risk-neutrality, the incentive problem could be solved if the expert could post an ex-ante bond equal to the rent. This would require that the expert be wealthy enough. This solution clearly is not feasible in many cases of relevance for this paper.

[12] This feature distinguishes expertise from most other productive activities since output is generally observable.

expert is *a priori* unbiased. Such a flat contract would not work, however, when the expert must be induced to gather information. Indeed, the expert may be tempted not to gather information and report the signal implying the highest expected transfer. Therefore the expert must be given incentives to gather information, but also to report the signal accurately. In other words, the principal-expert relationship involves both moral hazard ex ante and adverse selection ex post.

Summarizing, the expert should not prefer reporting $\underline{\sigma}$ after having observed $\bar{\sigma}$, i.e.,

$$\nu(\bar{\sigma})\bar{t} \geq t_0. \tag{1}$$

not should he prefer reporting $\bar{\sigma}$ after having observed $\underline{\sigma}$, i.e.,

$$t_0 \geq \nu(\underline{\sigma})\bar{t}. \tag{2}$$

The contract must also satisfy a moral hazard incentive constraint for the expert to gather information. The expert must not prefer to remain uninformed and reporting $\underline{\sigma}$, i.e.,

$$p(\bar{\sigma})\nu(\bar{\sigma})\bar{t} + p(\underline{\sigma})t_0 - \psi \geq t_0, \tag{3}$$

or a positive report (in which case his belief remains ν), i.e.,

$$p(\bar{\sigma})\nu(\bar{\sigma})\bar{t} + p(\underline{\sigma})t_0 - \psi \geq \nu\bar{t}. \tag{4}$$

These two constraints imply the adverse selection constraints (1) and (2).[13] Intuitively, for the expert to acquire information, a positive wedge must exist in each state of nature between his expected transfer when being truthful and when lying. If, when informed, the expert were indifferent between recommending to undertake or reject the project, he would prefer not to incur the cost ψ and make an uninformed recommendation.[14] The ex post manipulability of the report is irrelevant once the expert is informed. However the fact that information is soft allows the expert to pretend he has observed a signal, $\underline{\sigma}$ or $\bar{\sigma}$, even when he has not observed any. Therefore the signal's manipulability affects the moral hazard incentive constraint.

[13]Indeed, we can rewrite these constraints as: $\nu(\bar{\sigma})\bar{t} \geq t_0 + \frac{\psi}{p(\bar{\sigma})}$ and $t_0 \geq \nu(\underline{\sigma})\bar{t} + \frac{\psi}{p(\underline{\sigma})}$.

[14]Demski and Sappington (1987) discuss a model with information gathering (ex ante moral hazard) and production (ex post moral hazard) where productive effort is costless. They show that the latter incentive problem does not add any incentive cost in the case of two outcomes of the productive activity. Our result that adverse selection ex post is not a binding constraint is similar.

Finally, the expert's participation and limited liability constraints

$$p(\bar{\sigma})\nu(\bar{\sigma})\bar{t} + p(\underline{\sigma})t_0 - \psi \geq 0, \quad \text{and } \bar{t}, t_0 \geq 0 \tag{5}$$

being always satisfied in the environments below, they are omitted henceforth.

To implement the first-best decisions at minimum cost, the principal solves:

$$\min_{\{\bar{t}, t_0\}} \; p(\bar{\sigma})\nu(\bar{\sigma})\bar{t} + p(\underline{\sigma})t_0$$
$$\text{subject to (3) and (4).}$$

Important properties of the optimal contract can be derived from the simple observation that it is defined by constraints (3) and (4) being binding. First, the expert must be indifferent between acquiring information or not. Second, both constraints' RHS must be equal, i.e., $t_0 = \nu\bar{t}$, meaning that if uninformed, the expert is indifferent between recommending to undertake the project or not. Finally, the expert's expected payoff ((3)'s LHS) must equal t_0 ((3)'s RHS), his payoff if he remains uninformed and rejects the project.[15]

Proposition 1 *The expert's optimal incentive contract implementing the first-best decision rule rewards (resp. punishes) the expert when he recommends undertaking the project and the project succeeds (resp. fails). The optimal transfers are as follows:*

$$\underline{t}^{1,1} = 0, \qquad \bar{t}^{1,1} = \frac{\psi}{\nu(1-\nu)(2\theta-1)}, \qquad \textit{and} \qquad t_0^{1,1} = \nu\bar{t}^{1,1} = \frac{\psi}{(1-\nu)(2\theta-1)}. \tag{6}$$

If his report is positive, the expert is rewarded if the project succeeds and punished otherwise, which makes him willing to learn a positive signal. The expert is also rewarded for a negative report, which makes him willing to learn a negative signal. This simply reflects the usual relationship in moral hazard environments, i.e., an agent's rewards should be positively linked with the outcomes that are most informative about his having exerted effort, here about his having gathered information.[16]

[15] To better understand the optimal contract, a graphical representation of the principal's problem may be useful. See Figure 1. The set of incentive feasible contract $\{t_0, \bar{t}\}$ satisfying (3) and (4) defines a cone in the positive quadrant. Indeed, any contract can be written as $\bar{t} = \bar{t}^{1,1} + \lambda$ and $t_0 = t_0^{1,1} + \mu$ where $\nu(\bar{\sigma})\lambda \geq \mu \geq \nu(\underline{\sigma})\lambda$. The extreme point of this cone corresponds to $\{t_0^{1,1}, \bar{t}^{1,1}\}$. Since the principal's payoff increases when his indifference curve moves south-west, this transfer pair minimizes the principal's expected transfer to the expert.

[16] In practice, it is often the case that experts receive payments (explicit or implicit) conditionally on whether their recommendations are confirmed by facts. For example, financial experts receive rewards linked to the performance of the portfolio they manage on behalf of investors. Consultants and economic experts will be hired again if their recommendations are confirmed.

Note that an asymmetry exists between the two decisions. Undertaking the project reveals ex post information which might contradict the expert's favorable recommendation, whereas no further information arrives after the project is rejected.[17]

Corollary 1 *The expert's rent is given by:*

$$U^{1,1} = \frac{\psi}{(1-\nu)(2\theta-1)}.$$

Comparative Statics: It will prove important to note that motivating the expert is more costly when the project is *a priori* more likely to succeed. Indeed, when ν increases, the expert is more tempted to remain uninformed and recommend adopting the project because the *a priori* probability that he will be rewarded is high. Moreover, the project's outcome is unlikely to reflect that the expert has remained uninformed. A more informative event occurs when the expert recommends the status quo. It is indeed likely that he has gathered information. Avoiding this excessive bias towards adoption requires to increase the status quo payoff t_0 so that the expert is more willing to incur the cost of gathering a signal that might contradict his initial assessment of the project.

The rent decreases with the signal's precision, i.e., more precise experts are easier to incentivize. To see this, recall that moral hazard is less of an issue when the agent's performance is less noisy. Here, with greater precision, a positive report is more closely linked to the project's success. Therefore, the project's outcome tracks the expert's effort more closely and the agency cost is lower.[18]

Decision Rule: Having characterized the optimal contract implementing the first-best decision rule, we now optimize the decision rule itself. Here, the only relevant alternative to implementing the first-best is never to undertake the project, which yields a zero payoff. Indeed, by assumption, always undertaking the project yields a negative expected payoff and is therefore dominated by never undertaking it. Moreover, it is easily shown that the principal cannot gain by committing to sometimes reject the project despite a

[17]In the Conclusion, we comment on this feature and discuss how our results can be extended when the principal can also use some ex post information even if the status quo is chosen.

[18]Of course, this effects holds other things equal. If the effort cost were higher for more precise experts, the rent could increase with the signal's precision. Denote $\psi(\theta)$ the effort cost for an expert of precision θ. It is natural to assume $\psi(1/2) = 0$, i.e., uninformative signals are costless. For more precise experts to command greater rents, it must be that $\psi(\theta)/(\theta - 1/2)$ increases with θ, i.e., that the average effort cost of a signal increases with its precision.

positive report. The intuition is that such a policy would reduce the information available to confirm the expert's positive report, i.e., would imply a less precise outcome-reward mapping. In contrast, the principal might be able to reduce agency costs by committing to undertake the project sometimes despite a negative report. Indeed, this policy would imply a more precise outcome-reward mapping. However, this policy has two shortcomings. First, undertaking the project despite a negative signal may be too costly when $\nu(\underline{\sigma})\bar{S} + (1 - \nu(\underline{\sigma}))\underline{S} \ll 0$. This cost may outweigh the benefit in terms of incentive provision. Second, such a random policy is not *renegotiation-proof* since it relies on the principal taking ex post inefficient decisions.[19,20]

Given agency costs, information gathering is less often optimal than in the first-best. The principal will not hire an expert and will always reject the project unless the value of the signal exceeds the sum of the cost ψ and the agency cost, i.e., unless

$$\theta\nu\bar{S} + (1-\theta)(1-\nu)\underline{S} - \psi - U^{1,1} > 0 \tag{7}$$

Remark 1: For future reference, consider the asymmetric case where $\text{Proba}(\bar{\sigma}|\bar{S}) \neq \text{Proba}(\underline{\sigma}|\underline{S})$. It is easily shown that both moral hazard constraints (3) and (4) remain binding. The more general expressions for the optimal transfers and rent are:[21]

$$U^{1,1} = t_0^{1,1} = \nu\bar{t}^{1,1} = \frac{\psi}{\text{Proba}(\bar{\sigma}|\bar{S})p(\underline{\sigma}) - \text{Proba}(\underline{\sigma}|\bar{S})p(\bar{\sigma})}. \tag{8}$$

Remark 2: While we focus on monetary incentives, in many cases of practical importance, experts' incentives partly stem from career concerns. Our model can be easily reinterpreted to account for such concerns. Take for instance $t = pB$ with p the probability of the expert's reputation improving, and B his private benefit from good reputation.[22]

[19]Obviously, renegotiation is not an issue following a positive report.

[20]Note however that in more complex models such as those we investigate in Section 4, the optimal set of states of nature in which the project is undertaken under asymmetric information may be different from that under complete information. In this section, we consider a one-dimensional signal, reducing this set means never undertaking the project and increasing this set means always undertaking the project. Section 4 shows than when the expert gathers a multidimensional signal, the decision rule can be distorted in a less trivial way. See also Malcomson (2001).

[21]The RHS of (8) can be written as $\frac{\nu\psi}{p(\bar{\sigma})p(\underline{\sigma})(\nu(\bar{\sigma})-\nu(\underline{\sigma}))}$ which is positive since $\nu(\bar{\sigma}) > \nu(\underline{\sigma})$.

[22]See Gromb and Martimort (2003) for a model with endogenous career concerns for experts.

4 One Expert with Two Signals

4.1 Model

Assume now that the expert can gather simultaneously two signals, $(\sigma_1, \sigma_2) \in \{\underline{\sigma}, \bar{\sigma}\}^2$, that are independently distributed, and have the same precision θ and cost ψ.[23,24] Hence the cost of gathering two signals of equal precision θ is twice that of gathering one signal, i.e., we assume constant returns to scale for the information gathering technology.

Denote $p(\sigma_1, \sigma_2)$ the probability of observing (σ_1, σ_2) and $\nu(\sigma_1, \sigma_2)$ the conditional probability of success, e.g., $p(\bar{\sigma}, \bar{\sigma}) = \theta^2\nu + (1-\theta)^2(1-\nu)$ and $\nu(\bar{\sigma}, \bar{\sigma}) = \frac{\theta^2\nu}{\theta^2\nu+(1-\theta)^2(1-\nu)}$.

Under our assumptions, undertaking the project is efficient only if both signals are positive. Instead, with conflicting signals, Bayesian updating leads to maintaining the prior belief, under which the status quo is efficient.[25]

First-Best Decision Rule: Gathering two signals is efficient if:

$$-\theta(1-\theta)(\nu\bar{S} + (1-\nu)\underline{S}) \geq \psi. \tag{9}$$

The LHS is the benefit of a second signal: rejecting the project when the second signal contradicts a first positive one, i.e., with probability $p(\bar{\sigma}, \underline{\sigma}) = \theta(1-\theta)$. The RHS is the cost of gathering the second signal. Under condition (9), the principal's strategy can be interpreted as a precautionary behavior. The project is undertaken only if all evidence that can be gathered is favorable.

4.2 Diseconomies of Scale

Assume now that information gathering is delegated to an expert. An incentive scheme must specify a decision rule and the expert's payment depending on his two reports $\hat{\sigma}_1$ and $\hat{\sigma}_2$. Indeed, optimal contracts should use all the information available, i.e., the project's outcome as well as the expert's two reports. However, not all such contracts are feasible.

[23] For instance, the expert may be a consultant who can conduct two market studies to assess whether entry in a new market will be profitable.

[24] The simultaneous timing corresponds to cases where the principal cannot control the timing of reports or, alternatively, where time constraints make it impossible to learn information sequentially. Our initial focus on simultaneous information gathering makes also the interaction between the expert's two tasks easier to present. Section 7 studies sequential information gathering and the robustness of our results.

[25] Indeed, $\nu(\bar{\sigma}, \underline{\sigma}) = \frac{\theta(1-\theta)\nu}{\theta(1-\theta)\nu+(1-\theta)\theta(1-\nu)} = \nu$.

Indeed, when at least one report is negative, the status quo is efficient. Therefore, all transfers when $\hat{\sigma}_1 = \underline{\sigma}$ or $\hat{\sigma}_2 = \underline{\sigma}$ must be equal. Otherwise, the expert would always make the report yielding the highest transfer. Therefore, signal manipulability limits the set of feasible contracts. The expert's reward can be based on the decision to undertake the project or not, and the project's outcome, but not on the way this decision is taken.

Lemma 1 *With a single expert gathering two signals, contracts must be outcome-based, i.e., transfers are contingent only on the project's outcome (success, failure or rejection), not on the reports* $(\hat{\sigma}_1, \hat{\sigma}_2)$*.*

Denote by t_0 the transfer for all reports yielding the status quo, and by $\bar{t}$ that if the project is undertaken and succeeds.

Three other adverse selection incentive constraints must be considered. First, the expert should prefer reporting $(\bar{\sigma}, \bar{\sigma})$ when this is what he observed,

$$\nu(\bar{\sigma}, \bar{\sigma})\bar{t} \geq t_0. \tag{10}$$

Conversely, the expert should not prefer reporting $(\bar{\sigma}, \bar{\sigma})$ after observing conflicting signals,

$$t_0 \geq \nu(\bar{\sigma}, \underline{\sigma})\bar{t}, \tag{11}$$

or two negative signals,

$$t_0 \geq \nu(\underline{\sigma}, \underline{\sigma})\bar{t}. \tag{12}$$

Clearly, constraint (11) implies constraint (12): if the expert prefers the status quo given conflicting signals, he also does given two negative ones.

Moral hazard incentive constraints are slightly more complex than in the one-signal case. Indeed, the expert has a third alternative to gathering both signals: he can gather only one signal. If he observes a single signal, his recommendation takes it into account. Therefore, the moral hazard incentive constraint can be written as:

$$p(\bar{\sigma}, \bar{\sigma})\nu(\bar{\sigma}, \bar{\sigma})\bar{t} + (1 - p(\bar{\sigma}, \bar{\sigma}))t_0 - 2\psi \geq \max\{t_0, \nu\bar{t}, p(\bar{\sigma})\nu(\bar{\sigma})\bar{t} + p(\underline{\sigma})t_0 - \psi\}. \tag{13}$$

The new term on the RHS captures the expert's expected payoff when he bases his recommendation on only one signal.[26]

[26]This new term should be $p(\bar{\sigma})\max\{t_0, \nu(\bar{\sigma})\bar{t}\} + p(\underline{\sigma})\max\{t_0, \nu(\underline{\sigma})\bar{t}\} - \psi$. However, if $\max\{t_0, \nu(\bar{\sigma})\bar{t}\} = \max\{t_0, \nu(\underline{\sigma})\bar{t}\}$ the constraint is not binding as it is superseded by one of the other two. Note also that, as before, the expert must also accept the contract, $p(\bar{\sigma}, \bar{\sigma})\nu(\bar{\sigma}, \bar{\sigma})\bar{t} + (1 - p(\bar{\sigma}, \bar{\sigma}))t_0 - 2\psi \geq 0$, and again this constraint holds as a result of the moral hazard and limited liability constraints.

Diseconomies of Scale: To build intuition, assume that the principal simply scales up the optimal contract $\{\bar{t}^{1,1}, t_0^{1,1}\}$ of the one-signal case, i.e., offers $\{\bar{t}, t_0\} = \{2\bar{t}^{1,1}, 2t_0^{1,1}\}$. With constant returns to scale in agency costs, this scheme would certainly be optimal in the two-signal case. This scheme is easily shown to satisfy the adverse selection incentive constraints since $t_0^{1,1} = \nu\bar{t}^{1,1}$. Consider now the moral hazard constraints. The expert is easily shown to be indifferent between gathering two signals and none (and making any report) as his expected payoff is $2t_0^{1,1}$ in both cases. Instead, if the expert gathers only one signal, he gets $2(p(\bar{\sigma})\nu(\bar{\sigma})\bar{t}^{1,1} + p(\underline{\sigma})t_0^{1,1}) - \psi = 2t_0^{1,1} + \psi$. Therefore the expert will acquire and base his recommendation on only one signal. To induce him to gather a second signal, the transfers $t_0^{1,1}$ and $\bar{t}^{1,1}$ must be modified.

The direction in which the contract has to change is easily seen. Indeed, the project is undertaken too often as the expert recommends undertaking the project based on one positive signal. To avoid this problem, the expert must be induced to learn information that may contradict his initial positive assessment. This is done by raising t_0.

To formalize this argument, we now solve the principal's problem below:

$$\min_{\{\bar{t}, t_0\}} \; p(\bar{\sigma}, \bar{\sigma})\nu(\bar{\sigma}, \bar{\sigma})\bar{t} + (1 - p(\bar{\sigma}, \bar{\sigma}))t_0$$
$$\text{subject to (10) to (13).}$$

Proposition 2 *If one expert is to gather two signals, the optimal incentive contract is:*

$$\underline{t}^{1,2} = 0, \qquad \frac{\nu\theta(2-\theta)}{1 - p(\underline{\sigma}, \underline{\sigma})}\bar{t}^{1,2} = t_0^{1,2} = \frac{(2-\theta)\psi}{(1-\nu)(2\theta-1)(1-\theta)}.$$

The contract is biased towards the status quo, i.e., $t_0^{1,2} > \nu\bar{t}^{1,2}$.

The logic is as in the one-signal case. To gather information, the expert must be rewarded for reporting good news that is confirmed by the project's success. Instead, he is not rewarded if the project fails. The status quo is also rewarded to elicit bad news. As suggested above, the optimal contract should be biased towards the status quo.

Corollary 2 *If the expert gathers two signals, his rent can be written as:*

$$U^{1,2} = \underbrace{\frac{\psi}{(1-\nu)(2\theta-1)}}_{\textit{Infra-marginal rent}} + \underbrace{\frac{\psi/p(\bar{\sigma})}{(1-\nu(\bar{\sigma}))(2\theta-1)}}_{\textit{Marginal rent}}. \tag{14}$$

This expression has a simple intuition. The problem of gathering two signals can be decomposed into that of gathering a first (infra-marginal) signal, and that of gathering a second (marginal) one. To get the expert to gather the first signal, he needs to be given the infra-marginal rent $U^{1,1}$ as in the one-signal case. This is the first term of the expression. To understand the second term, consider now the expert having gathered (but not yet observed because the decisions to gather each signal are simultaneous) the first signal and deciding whether to acquire the second. If the first signal turns out to be negative, the project is rejected irrespective of the second signal. Hence the second signal is pivotal only if the first signal turns out to be positive. In that case, the expert's updated belief is $\nu(\bar{\sigma})$. Moreover, the second signal mattering only with probability $p(\bar{\sigma})$ amounts to the cost of acquiring it being $\psi/p(\bar{\sigma})$. The marginal rent is thus the rent derived in the one-signal case if the prior is $\nu(\bar{\sigma})$ and the cost is $\psi/p(\bar{\sigma})$.

The rent corresponding to the marginal signal exceeds that for the infra-marginal signal. There are two reasons for this. First, the prior is more optimistic, i.e., $\nu(\bar{\sigma}) > \nu$, which implies a higher rent than in the one-signal case. Second, the effective information gathering cost is greater, i.e., $\psi/p(\bar{\sigma}) > \psi$, as the expert is more reluctant to acquire a signal less likely to matter.

The agency cost of inducing an expert to gather two signals is strictly more than twice that of inducing him to gather only one signal. Hence, even though the information gathering technology exhibits constant returns, agency costs exhibit diseconomies of scale. This is an important result that is central to the rest of our analysis.

Proposition 3 *Delegated expertise to a single expert exhibits diseconomies of scale due to agency costs:* $U^{1,2} > 2U^{1,1}$.

There are two main difficulties in designing the contract, related to the adverse selection and moral hazard aspects of the problem.

First, unlike in the one-signal case, some adverse selection constraints are binding. Reports being manipulable, the principal cannot discriminate between the expert having observed conflicting signals and his having observed two negative signals. The transfers for all reports yielding the status quo must be equal. Contracts must be outcome-based.

Second, consider the moral hazard problem. Note first that the expert can deviate by gathering either only one or no signal. Because two conflicting signals leave the expert's beliefs unchanged ($\nu(\bar{\sigma}, \underline{\sigma}) = \nu$), the adverse selection incentive constraint (11) implies that, if uninformed, the expert is weakly biased towards the status quo. Suppose instead that the contract is such that, if uninformed, the expert is indifferent between accepting and rejecting the project, i.e., $t_0 = \nu\bar{t}$ as in the one-signal case. On the one hand, after observing a positive first signal, the expert is biased against the status quo. It is therefore more costly to motivate him to acquire a second signal that may turn out to be negative and reverse the decision. To avoid this, the contract must increase the attractiveness of acquiring a second signal when the first one is positive. This can only be achieved by increasing t_0, the transfer for the status quo. This implies that if he chose to remain uninformed, the expert would be strictly biased towards the status quo, i.e., $t_0 > \nu\bar{t}$. On the other hand, if the expert has observed a first negative signal, a second signal will not affect the decision. This second signal is not pivotal and, in a sense, it is not rewarded by the principal as is clear from the RHS of expression (14).

Importantly, creating such a bias towards the status quo also increases the cost of gathering the first signal. Indeed now that the status quo is more attractive, the expert may prefer remaining uninformed and rejecting the project. This is the externality of one task onto the other: learning the second signal requires creating a bias towards the status quo, which increases the agency cost of gathering the first signal.

Decision Rule: The principal induces the expert to gather a signal when its value exceeds the sum of the cost ψ and the agency cost. Therefore, he induces the expert to gather (at least) one signal if condition (7) holds, and also a second one only if

$$-\theta(1-\theta)(\nu\bar{S} + (1-\nu)\underline{S}) \geq \psi + \frac{\psi/p(\bar{\sigma})}{(1-\nu(\bar{\sigma}))(2\theta-1)}. \quad (15)$$

Corollary 3 *The principal can find it optimal to distort the decision rule by having the expert gather only one signal even if two signals are first-best optimal.*

When this holds, the project is undertaken too often. This shows that an optimal way of reducing agency costs can involve distorting the decision rule, here through excessive adoption of the project and decision-making based on partial information.

Remark 1: Our diseconomies of scale result resembles those of the multi-task agency literature showing that incentives for one task can swamp incentives for another if both are insufficiently rewarded.[27] In our model, inducing the gathering of one signal can reduce the incentives to gather another one. An important difference with the multitask literature remains: the information gathering technology is assumed to have constant returns to scale and the substitutability between tasks is thus endogenous to the agency problem and not imposed by the technology. Nevertheless, the main lesson of this literature still holds: correct incentives can only be obtained by making the expert more residual claimant for the full array of his recommendations. Under limited liability, having the expert better internalize the contractual externality between the tasks requires raising the power of incentives for both tasks, which leaves the expert with a large rent.

Remark 2: The two-dimensional signal $\Sigma = (\sigma_1, \sigma_2)$ takes only two relevant values: either $\Sigma = \bar{\Sigma} = (\bar{\sigma}, \bar{\sigma})$ and the project is undertaken, or $\Sigma = \underline{\Sigma} \in \{(\bar{\sigma}, \underline{\sigma}), (\underline{\sigma}, \bar{\sigma}), (\underline{\sigma}, \underline{\sigma})\}$ and it is rejected. For decision purposes, it is as if the expert gathered a one-dimensional signal, with $\text{Proba}(\bar{\Sigma}|\bar{S}) = \theta^2$ and $\text{Proba}(\underline{\Sigma}|\underline{S}) = \theta(2-\theta)$. So, is the two-signal model only a special case of the one-signal model? If yes, the agency cost would be as in expression (8), the signal-gathering cost being 2ψ instead of ψ. It is easily shown that

$$\text{Proba}(\bar{\Sigma}|\bar{S})p(\underline{\Sigma}) - \text{Proba}(\underline{\Sigma}|\bar{S})p(\bar{\Sigma}) = (1-\nu)(2\theta - 1).$$

Therefore, the rent would be $\frac{2\psi}{(1-\nu)(2\theta-1)}$ and the scaled-up contract $\{2\bar{t}^{1,1}, 2t_0^{1,1}\}$ would induce the expert to gather this signal. This, however, is strictly less than the actual rent $U^{1,2}$, the difference arising from the expert being also able to deviate by gathering only one signal. The two-signal model is no special case of the one-signal model.

5 Two Experts: Report-Based Contracts

We now investigate the effects of having each of two experts, A and B, privately observe only one signal. For instance, a firm may call upon two consulting firms to undertake market studies before deciding to enter a new market. For a public decision whether to allow a new drug, the Health agency aggregates the recommendations of several experts.

We focus on the case where the experts make simultaneous reports, not knowing the other expert's effort, signal, or report. Again we first study contracts implementing the

[27] See Holmström and Milgrom (1991) for a model with a risk averse agent and Laux (2001b) for a model with limited liability.

first-best decision rule, i.e., the project is undertaken only if both reports are positive, and optimize the decision rule later.

5.1 Optimal Contracts

Without loss of generality, we assume that both experts receive the same contract. The experts' common transfer is $\bar{t}$ if the project succeeds, and t_0 for the status quo. Note that, contrary to the single expert case, the status quo can be rewarded differently depending on how it is reached: in case of conflicting reports, the expert reporting good (resp. bad) news receives t_1 (resp. t_2), and each expert receives t_0 when both news are bad.

When an expert observes $\bar{\sigma}$, the Bayesian adverse selection incentive compatibility constraint can be written as:

$$p(\bar{\sigma}|\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})\bar{t} + p(\underline{\sigma}|\bar{\sigma})t_1 \geq p(\bar{\sigma}|\bar{\sigma})t_2 + p(\underline{\sigma}|\bar{\sigma})t_0. \tag{16}$$

When the expert observes $\underline{\sigma}$, the constraint can be written as:

$$p(\bar{\sigma}|\underline{\sigma})t_2 + p(\underline{\sigma}|\underline{\sigma})t_0 \geq p(\bar{\sigma}|\underline{\sigma})\nu(\underline{\sigma},\bar{\sigma})\bar{t} + p(\underline{\sigma}|\underline{\sigma})t_1. \tag{17}$$

An expert's moral hazard incentive constraint is now:

$$\begin{aligned} &p(\bar{\sigma},\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})\bar{t} + p(\bar{\sigma},\underline{\sigma})(t_1+t_2) + p(\underline{\sigma},\underline{\sigma})t_0 - \psi \\ &\quad \geq \max\{p(\bar{\sigma})\nu(\bar{\sigma})\bar{t} + p(\underline{\sigma})t_1, p(\bar{\sigma})t_2 + p(\underline{\sigma})t_0\}. \end{aligned} \tag{18}$$

For the same reason as in the one-signal/one-expert case, the moral hazard incentive constraints imply those of adverse selection which we omit in what follows.

Finally, the relevant limited liability constraints are:

$$t_1, t_2 \geq 0. \tag{19}$$

The principal's program is now:[28]

$$\min_{\{\bar{t},t_1,t_2,t_0\}} \; p(\bar{\sigma},\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})\bar{t} + p(\bar{\sigma},\underline{\sigma})(t_1+t_2) + p(\underline{\sigma},\underline{\sigma})t_0$$
$$\text{subject to (16) to (19).}$$

[28]Each expert's participation constraint can be written as: $p(\bar{\sigma},\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})\bar{t}+p(\bar{\sigma},\underline{\sigma})(t_1+t_2)+p(\underline{\sigma},\underline{\sigma})t_0-\psi \geq 0$. It is implied by the moral hazard constraints and is thus omitted in what follows.

Proposition 4 *With report-based contracts, if each of two experts is to gather one signal, the optimal symmetric incentive contract does not reward experts for conflicting reports. The optimal transfers are given by:*

$$\underline{t}^{2,2} = t_1^{2,2} = t_2^{2,2} = 0, \qquad \bar{t}^{2,2} = \frac{\psi p(\underline{\sigma})}{\nu(1-\nu)(2\theta-1)\theta^2}, \qquad \textit{and} \qquad t_0^{2,2} = \frac{\psi}{(1-\nu)(2\theta-1)\theta}.$$

The optimal contract is similar to that of the one-expert/one-signal case. Now, however, an expert is rewarded for reports confirmed not only by the project's outcome but also by the other expert's report.

With multiple experts, adverse selection no longer requires that contracts be outcome-based. This added degree of freedom in contracting is useful for two reasons. First, it allows to put all the weight of an expert's reward for a positive report on the state that is most informative (i.e., the project succeeding) and none on a less informative state (i.e., the project being rejected following a negative report by the other expert). That is, this allows to set $t_1 = 0$.[29] Second, by rewarding consensus, the principal can also increase each expert's incentives to become informed. This result can be best understood by appealing to the *Informativeness Principle* of the moral hazard literature.[30] This Principle establishes that, within a general principal-agent model with pure moral hazard, an additional signal helps the principal to provide incentives to the agent if it helps to detect the latter's effort.[31] In our model, if expert B is obedient and truthful, his report constitutes an endogenous signal that the principal can use to better design expert A's incentives. The principal infers from B's report that A is more likely to have gathered information when their reports coincide. For both reasons, motivating each expert becomes cheaper.

Corollary 4 *With report-based contracts, if each of two experts is to gather one signal, each expert's rent is equal to:*

$$U^{2,2} = \frac{\psi}{(1-\nu(\underline{\sigma}))(2\theta-1)}. \tag{20}$$

The rent is analogous to that obtained in the one-expert/one-signal case, but with the expert's belief being $\nu(\underline{\sigma})$ instead of ν. Note that since the rent decreases with the

[29]Note that this advantage would also arise if both signals were uncorrelated.

[30]See Holmström (1979) for a model with a risk averse agent.

[31]See Mookherjee (1984) for such a model in a multiagent framework with moral hazard.

prior probability of success, the status quo is now relatively cheap to obtain. To better understand expression (20), we rewrite constraint (18). Note first that an expert remaining uninformed is rewarded for a negative report only if the other expert does so too. Hence, his rent should be weighted by the probability of that event, $p(\underline{\sigma})$. Formally, taking into account that conflicting reports are not rewarded and dividing by $p(\underline{\sigma})$, condition (18) becomes:

$$\frac{p(\bar{\sigma},\bar{\sigma})}{p(\underline{\sigma})}\nu(\bar{\sigma},\bar{\sigma})\bar{t}+p(\underline{\sigma}|\underline{\sigma})t_0-\frac{\psi}{p(\underline{\sigma})}\geq \max\left\{\frac{p(\bar{\sigma})}{p(\underline{\sigma})}\nu(\bar{\sigma})\bar{t},t_0\right\}. \tag{21}$$

To analyze the incentives to avoid excessive adoption, suppose that the expected payment received by the expert when both reports are positive is now received following conflicting reports, i.e., consider a new payment $\bar{t}'$ such that:

$$p(\bar{\sigma},\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})\bar{t}=p(\bar{\sigma},\underline{\sigma})\nu(\bar{\sigma},\underline{\sigma})\bar{t}'.$$

With this change of variable, condition (21) becomes:

$$p(\bar{\sigma}|\underline{\sigma})\nu(\bar{\sigma},\underline{\sigma})\bar{t}'+p(\underline{\sigma}|\underline{\sigma})t_0-\frac{\psi}{p(\underline{\sigma})}\geq \max\{t_0,\nu(\underline{\sigma})\bar{t}'\}. \tag{22}$$

Note that this condition is analogous to constraints (3) and (4) in the one-expert/one-signal case, modified as follows: the expert has already observed a negative signal (i.e., his prior is $\nu(\underline{\sigma})$, not ν) and the information-gathering cost is $\psi/p(\underline{\sigma})$ not ψ. This analogy implies that the rent is $\frac{\psi/p(\underline{\sigma})}{(1-\nu(\underline{\sigma}))(2\theta-1)}$ which, multiplied by $p(\underline{\sigma})$, yields expression (20).

5.2 The Benefits of Separation

Corollary 5 *With report-based contracts, the principal is strictly better off with each of two experts gathering one signal than with one expert gathering both signals:* $2U^{2,2}<U^{1,2}$*. Moreover, excessive adoption of the project is less frequent than with a single expert.*

By separating information gathering between two experts, the principal can better control incentives for learning each signal. This cross-checking makes the status quo less costly for the principal than if he was dealing with a single expert.

To understand why with report-based contracts two experts are better than one, note that the rent left to each expert is now *strictly* below the rent $U^{1,1}$ for the infra-marginal signal in the one-expert case. Indeed, if expert A remains uninformed his expected payoff is less than if he was alone because with some positive probability expert B will make a conflicting report.

Corollary 6 *With report-based contracts, separation implies economies of scale due to agency costs:* $2U^{2,2} < 2U^{1,1}$.

Decision Rule: Finally, the principal prefers having two signals gathered by two experts when:

$$W^{2,2} = \theta^2 \nu \bar{S} + (1-\theta)^2 (1-\nu)\underline{S} - 2\psi - 2U^{2,2} > W^{1,1}.$$

Agency costs being reduced under separation, the principal relies more often on a second signal when deciding whether to undertake the project.

Remark: The parallel with multitask incentive problems is again useful. Separating tasks between two experts and comparing their performances avoids having to give a single expert high-powered incentives for each task. A corollary is that experts must be given objectives in information gathering that are as focused as possible.

Increasing Technological Returns: So far the information gathering technology was assumed to exhibit constant returns to scale. In certain contexts, it is natural to assume increasing returns to scale instead.[32] This is a rationale for relying on a single expert. We now analyze these countervailing effects. We model increasing returns by assuming that the principal incurs a deadweight cost k per expert hired.[33] Now, relying on two experts rather than one is optimal if the savings in agency costs exceed the cost of hiring a second expert, i.e., $U^{1,2} - 2U^{2,2} \geq k$. The following is easily obtained.

Proposition 5 *With a cost k per expert, the principal finds it optimal to rely on two experts rather than one when the increasing technological returns to scale in information gathering are limited (k small enough), and the project is a priori likely to succeed (ν large enough).*

[32]As an example, one leading argument in favor of an Antitrust general agency rather than sectoral regulators is that the former's experience in one field may be useful in others.

[33]An alternative would be to assume that the signal gathering cost is concave in the number of signals. The model considered here is simpler in that it avoids any interaction between the increasing returns to scale and the incentive problem.

5.3 Horizontal Collusion Between Experts

5.3.1 Implicit Horizontal Collusion and Multiple Equilibria

A problem with the optimal report-based contract is that it admits other less desirable equilibria of the overall game of information gathering and reporting.

Proposition 6 *The optimal symmetric report-based contract with two experts has two other equilibria in which the experts remain uninformed and both make either positive or negative reports.*

If B remains uninformed and reports bad news, A's best response is to do the same. Indeed, even if he observed a good signal A would never report it since conflicting reports are not rewarded. As a result, A is better off remaining uninformed and reporting bad news. Hence an equilibrium exists in which both experts always report bad news, and get a payoff $t_0^{2,2}$ that strictly exceeds $U^{2,2}$. Similarly, another equilibrium exists in which experts always report good news. In this equilibrium, each expert's payoff, $\nu\bar{t}^{2,2}$, exceeds $U^{2,2}$ but is less than $t_0^{2,2}$.[34] Note that in both collusive equilibria the principal's payoff is negative. In the first one, although the project is never undertaken, the principal bears the cost of paying the experts. In the second one, he also bears that of undertaking a negative-value project.

A possible solution to this multiple equilibria problem is to move to an asymmetric mechanism and use only one expert, i.e., to rely on a discriminatory mechanism where the otherwise identical experts receive different schemes. We are then back to the one-expert/one-signal case with the induced bias towards excessive project adoption.

5.3.2 Explicit Horizontal Collusion

Even if the experts adopt obedient strategies and gather information non-cooperatively, they may still have incentives to collude explicitly ex post by manipulating their reports.[35] This requires of course that communication between the experts cannot be perfectly controlled and forbidden by the principal. Consider the possibility that having gathered

[34] Note also that these collusive equilibria do not require agents to observe each other's effort. If this were the case, the principal could use that shared information to build revelation mechanisms à la Maskin (1999) and create incentives immune to implicit collusion.

[35] We take the standard short-cut assumption that collusive side-contracts are enforceable.

signals, the experts can credibly share them and coordinate on a common report.[36] Their optimal reporting strategy must maximize their joint payoff, implying the following *horizontal coalition-incentive constraints*:

$$2\nu(\bar{\sigma}, \bar{\sigma})\bar{t} \geq t_1 + t_2, \tag{23}$$

and

$$2t_0 = t_1 + t_2. \tag{24}$$

Clearly, constraint (24) is not satisfied by the optimal report-based contract.

Here, we do not solve for the optimal report-based contract that is robust to horizontal collusion between experts. Instead, these constraints are useful in that they will motivate our study of outcome-based contracts in Section 6.2.

6 Two Experts: Collusion-Proof Contracts

In this section, we study the organization of delegated expertise in more restrictive contracting environments. Section 6.1 studies the case of *own-report-based contracts*, i.e., in which the principal and an expert cannot contract on the other expert's report. These schemes arise when vertical collusion between the principal and an expert is possible. Section 6.2 studies the more restrictive case of purely *outcome-based contracts*, i.e., in which the principal and an expert cannot contract on either expert's report. This restriction arises when both vertical and horizontal collusion are possible. We show how the performance of different organization forms and the optimal organization depend on how robust the organization is to the threat of collusion.[37]

The various nexi of collusion studied in this section arise from limitations in the control of the communication channels between experts or between each expert and the principal. Those limits imply a departure the complete contract environment of Section 5.1.

[36] Note also that experts have no incentives to lie to each other in a report-based mechanism using cross-checking. This validates our focus on credible disclosure to analyze collusion in more general mechanism. Another motivation may be that information is *internally verifiable* between experts although not *externally verifiable* to use the expressions coined by Baron and Besanko (1999) in another context.

[37] Note that since all contracts are outcome-based in the one-expert case, we only need to analyze the two-expert case.

6.1 Own-Report-Based Contracts

In this section, we assume that the principal and each expert can contract on the project's outcome and the expert's report, but not on the other expert's report. Such own-report-based mechanisms are robust to the threat of vertical collusion between the principal and an expert is possible. Indeed, the optimal report-based contract is not robust to the possibility of vertical collusion. Suppose that the reports are initially secretly made to the principal and publicized by him only once a decision has been taken. If both initial reports are negative, the principal should make a transfer t_0 to each expert. Instead, he can bribe one of the experts into switching to a positive report, and thus avoid making the transfer to the other expert.Therefore, the possibility of vertical collusion implies that an expert's transfer following a negative report be independent of the other expert's report.

Note that this type of collusion can only occur when the project must be rejected. Indeed publicizing conflicting reports when both signals are positive changes the decision. Instead, reporting conflicting signals when the status quo must be chosen is a feasible alternative which does not change the decision rule.[38]

Lemma 2 *A contract is robust to vertical collusion between the principal and one expert if and only if it is own-report-based, i.e., if and only if*

$$t_2 = t_0. \tag{25}$$

If vertical collusion is possible, the principal's problem can be written as:

$$\min_{\{\bar{t},t_1,t_2,t_0\}} p(\bar{\sigma},\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})\bar{t} + p(\bar{\sigma},\underline{\sigma})t_1 + p(\underline{\sigma})t_0,$$
$$\text{subject to (16) to (19) and (25).}$$

Of course, constraint (25) is binding. Intuitively, it is still optimal to punish an expert who reports recommending a project when the other does the reverse and $t_1 = 0$. The principal's problem can then be simplified by replacing the only positive payment $\bar{t}$ by an

[38]One may wonder whether collusion between the principal and either agent could also be used to change the decision whether to undertake or not the project. Clearly, it may be suboptimal to reject a project if both signals are positive if the expected return from it is sufficiently large. When this is the case, collusion between the principal and either expert consists for the principal in minimizing the payments made to the other expert *for* a given decision.

expected reward $\bar{t}'$ condition on having reported a positive signal:

$$p(\bar{\sigma})\nu(\bar{\sigma})\bar{t}' = p(\bar{\sigma},\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})\bar{t} \quad \text{or} \quad \bar{t}' = \theta\bar{t}.$$

Therefore the principal's problem is formally the same as with a single expert.

Proposition 7 *The optimal own-report-based contract implementing the first-best decision rule is such that*

$$\bar{t}^{2,2*} = \frac{\psi}{\nu(1-\nu)(2\theta-1)\theta}, \quad t_1^{2,2*} = 0, \quad t_0^{2,2*} = t_2^{2,2*} = \frac{\psi}{(1-\nu)(2\theta-1)}.$$

Each expert's rent is:

$$U^{2,2*} = \frac{\psi}{(1-\nu)(2\theta-1)}.$$

In other words, the *increasing returns* due to agency costs with two experts are destroyed by the possibility of vertical collusion. Those increasing return rely on the principal's ability to commit to making public and non-manipulable reports.

Corollary 7 *Under the possibility of vertical collusion between the principal and each expert, agency costs imply constant returns to scale, i.e.,* $U^{2,2*} = U^{1,1}$.

6.2 Outcome-Based Contracts

We now focus on outcome-based contracts, i.e., we assume that reports are not contractible. This set of contracts is defined by $t_1 = t_2 = t_0$. This restriction arises naturally when both vertical and horizontal collusion are possible. Indeed, remark that constraints (24) and (25) define outcome-based contracts. With $t_1 = t_2 = t_0$, each expert's moral hazard incentive constraint can be written as:

$$p(\bar{\sigma},\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})\bar{t} + (1 - p(\bar{\sigma},\bar{\sigma}))t_0 - \psi \geq \max\{t_0, p(\bar{\sigma})\nu(\bar{\sigma})\bar{t} + p(\underline{\sigma})t_0\}, \tag{26}$$

which is easily shown to imply constraint (23), and the adverse selection constraints.[39]

[39] When an expert observes $\bar{\sigma}$, the Bayesian adverse selection incentive constraint can be written as: $p(\bar{\sigma}|\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})\bar{t} + p(\underline{\sigma}|\bar{\sigma})t_0 \geq t_0$. When the expert observes $\underline{\sigma}$, the constraint is: $t_0 \geq p(\bar{\sigma}|\underline{\sigma})\nu(\underline{\sigma},\bar{\sigma})\bar{t} + p(\underline{\sigma}|\underline{\sigma})t_0$. Note that these constraints use conditional expectations since each expert evaluates the probability that the other expert observes either signal conditionally on his own signal. It is easy to check that these constraints are the same as constraints (10) and (11) with a single expert.

Lemma 3 *The optimal contract implementing the first-best decision rule and robust to both vertical and horizontal collusion is the optimal outcome-based contract (i.e., such that* $t_1 = t_2 = t_0$*) satisfying the moral hazard incentive constraint (26).*

This result implies that any departure from constant returns to scale due to agency cost can be seen as arising from the possibility of horizontal collusion. They are thus due to the impossibility for the principal to control horizontal communication between experts.

The problem is similar to that of the one-expert/one-signal case.

Proposition 8 *The optimal outcome-based contract implementing the first-best decision rule is such that:*

$$\bar{t}^{2,2**} = \frac{\psi/p(\bar{\sigma})}{\nu(\bar{\sigma})(1-\nu(\bar{\sigma}))(2\theta-1)} \quad \textit{and} \quad t_0^{2,2**} = \frac{\psi/p(\bar{\sigma})}{(1-\nu(\bar{\sigma}))(2\theta-1)}.$$

Each expert's rent is:

$$U^{2,2**} = \frac{\psi/p(\bar{\sigma})}{(1-\nu(\bar{\sigma}))(2\theta-1)}.$$

The intuition is simple. Each expert's rent corresponds to the second term in expression (14)'s RHS, i.e., the rent left to a single expert for the marginal signal. Indeed, in equilibrium, each expert expects the other to gather information and report it truthfully. Therefore each expert behaves as if he were gathering the marginal signal.

Corollary 8 *With outcome-based contracts, the principal is strictly better off with one expert gathering both signals than with each of two experts gathering only one signal:* $2U^{2,2**} > U^{1,2}$.

Outcome-based contracts although *a priori* attractive because they are immune collusion increase too much the agency cost. Using a centralized expertise procedure is a means of avoiding hidden gaming between the players that a decentralized procedure would allow. Designing a playing field for multiple experts that is robust to any kind of collusion is thus excessively costly.

7 Sequential Information Gathering

So far, the experts were assumed to make simultaneous reports. In fact, since one negative signal suffices to reject the project, simultaneity involves an inefficient duplication of the information gathering cost. To avoid that problem, the decision-maker may rely on sequential information gathering. In that setting, the decision to gather a second signal can be conditioned on the first report. As we will check below (see Section 7.1), this timing is optimal in a first-best environment.

Of course, this sequential timing is less valuable under time constraints or when delays frustrate the principal's enjoyment of the project's flow return. To abstract from these issues, the principal and the experts are assumed not to discount the future and the project returns are realized after information gathering.

7.1 First-Best

The value of a second signal is that (expected) losses are avoided if the second signal conflicts with the first one, which occurs with probability $p(\underline{\sigma}|\bar{\sigma})$. Therefore, gathering a second signal is efficient if and only if:

$$-p(\underline{\sigma}|\bar{\sigma})(\nu\bar{S} + (1-\nu)\underline{S}) \geq \psi. \tag{27}$$

Note that $p(\underline{\sigma}|\bar{\sigma}) = \frac{\theta(1-\theta)}{\theta\nu+(1-\theta)(1-\nu)} > \theta(1-\theta)$ so that condition (27) is easier to satisfy than the corresponding condition (9) for simultaneous reports. Therefore sequential information gathering strictly dominates simultaneous information gathering.

7.2 One Expert

We first study the one-expert case. The expert receives $\bar{t}$ if the project is undertaken and succeeds, and t_1 (resp. t_2) if his first (resp. second) report $\hat{\sigma}_1$ (resp. $\hat{\sigma}_2$) is negative. Note that unlike in the simultaneous case, t_1 and t_2 can differ. Finally, we assume that the principal can fully commit to this contract.[40]

First, consider the expert's incentives to gather a second signal when he has observed and reported (truthfully in equilibrium) $\sigma_1 = \bar{\sigma}$. This ex post moral hazard constraint is

[40]It is easily shown that the optimal contract found below is sequentially optimal.

similar to constraints (3) and (4) with updated probabilities for both states:

$$p(\bar{\sigma}|\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})\bar{t} + p(\underline{\sigma}|\bar{\sigma})t_2 - \psi \geq \max\{t_2, \nu(\bar{\sigma})\bar{t}\}. \tag{28}$$

As before, these constraints imply the adverse selection incentive constraints on σ_2.

Consider now the expert's incentives to report σ_1 truthfully. Suppose first that $\sigma_1 = \bar{\sigma}$. The expert must prefer reporting a good signal, in which case the principal will ask for a second signal, rather than reporting a bad one, in which case the project is rejected, i.e.,

$$p(\bar{\sigma}|\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})\bar{t} + p(\underline{\sigma}|\bar{\sigma})t_2 - \psi \geq t_1. \tag{29}$$

Suppose now that $\sigma_1 = \underline{\sigma}$. If the expert reports a good signal, under condition (28), he will find it optimal to always report $\sigma_2 = \underline{\sigma}$. Intuitively, condition (28) implying the adverse selection constraints, if the expert prefers the status quo when $(\sigma_1, \sigma_2) = (\bar{\sigma}, \underline{\sigma})$, he also does when $(\sigma_1, \sigma_2) = (\underline{\sigma}, \underline{\sigma})$. Hence if the expert lies in the first stage, he will not gather a second signal and will always report $\sigma_2 = \underline{\sigma}$.[41] By doing so, the expert receives t_2. Therefore truthful reporting of $\sigma_1 = \underline{\sigma}$ requires:

$$t_1 \geq t_2. \tag{30}$$

Finally, the ex ante moral hazard incentive constraint for σ_1 can be written as:

$$p(\bar{\sigma})(p(\bar{\sigma}|\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})\bar{t} + p(\underline{\sigma}|\bar{\sigma})t_2 - \psi) + p(\underline{\sigma})t_1 - \psi \geq \max\{t_1, t_2, p(\bar{\sigma})\nu(\bar{\sigma})\bar{t} + p(\underline{\sigma})t_2 - \psi\}. \tag{31}$$

The RHS reflects that the relevant alternatives are to recommend the status quo either in the first or in the second stage or base the recommendation on only one signal.[42]

The optimal contract is now the solution to the problem:[43]

$$\min_{\{\bar{t},t_1,t_2\}} \; p(\bar{\sigma},\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})\bar{t} + p(\bar{\sigma},\underline{\sigma})t_2 + p(\underline{\sigma})t_1$$
$$\text{subject to (28) and (31).}$$

Proposition 9 *With sequential information gathering and a single expert, the optimal incentive contract implementing the first-best decision rule is such that the expert's payoff*

[41] Formally, condition (28) implies that $t_2 > \nu(\bar{\sigma},\underline{\sigma})\bar{t} = \nu\bar{t} > \nu(\underline{\sigma},\underline{\sigma})\bar{t}$.

[42] Gathering one signal and lying in at least one state of nature is a dominated strategy since it yields $\max\{t_2, \nu\bar{t}\} - \psi$ and the agent could get more by recommending the status quo at the second stage and not gathering the signal.

[43] As before the ex ante participation constraint of the expert and limited liability constraints on the remaining transfers will be satisfied and are thus omitted.

for recommending the status quo is independent of whether this recommendation is made at the first or at the second stage. The optimal non-zero transfers are:

$$\bar{t}^{1,2S} = \frac{\psi}{\nu(1-\nu)(2\theta-1)}\left(1+\frac{p^2(\bar{\sigma})}{\theta(1-\theta)}\right),$$
$$t_1^{1,2S} = t_2^{1,2S} = \frac{\psi}{(1-\nu)(2\theta-1)}\left(1+\frac{p(\bar{\sigma})}{1-\theta}\right).$$

The key difficulty in inducing a single expert to gather information sequentially is related to that of the simultaneous signals case. Once the expert has learned and reported a positive signal, he updates his beliefs in favor of the project. To induce him to gather a second signal that might contradict the first one, the status quo transfer t_2 must be increased. However, by condition (30), the first stage status quo transfer t_1 must also be raised accordingly. Otherwise, the expert may be tempted to make a first positive report, inducing the principal to request further investigation, only to make a negative report in the second stage. Therefore, the second stage incentive problem exerts an externality on that in the first stage, making it harder to elicit a rejection on the basis of a single negative signal. The adverse selection constraint (30) implies that the transfer for the status quo is independent of how it is reached. The optimal contract is again outcome-based, as in the case of simultaneous reports.

Decision Rule: Inducing search for the second signal is optimal if:

$$-p(\underline{\sigma}|\bar{\sigma})(\nu\bar{S}+(1-\nu)\underline{S}) \geq \psi + \frac{\psi}{(1-\nu(\bar{\sigma}))(2\theta-1)},$$

which is harder to satisfy than condition (27) under the first-best. Therefore, the principal can find it optimal to settle for a decision based on partial information.

Comparison with Simultaneous Information Gathering: With sequential information gathering, the expert's rent is:

$$U^{1,2S} = \underbrace{\frac{\psi}{(1-\nu)(2\theta-1)}}_{\text{Infra-marginal rent}} + p(\bar{\sigma})\underbrace{\frac{\psi/p(\bar{\sigma})}{(1-\nu(\bar{\sigma}))(2\theta-1)}}_{\text{Marginal rent}}. \quad (32)$$

The expression of the rent given by expression (32) is intuitive. To gather two signals sequentially, the expert must first receive the rent corresponding to the infra-marginal signal and then, only if this first signal is positive, the rent corresponding to the marginal signal. The status quo is less costly than under simultaneous information gathering because the marginal rent is left less often.

Corollary 9 *If a single expert is used, agency costs are lower under sequential than under simultaneous information gathering:* $U^{1,2S} < U^{1,2}$.

7.3 Two Experts

The principal could instead rely on a different expert for each stage of information gathering. In that case, the status quo can be rewarded differently depending on whether it is reached on the basis of the first report by A or on the basis of the second report by B. In fact, the adverse selection constraint (30) is no longer binding. Expert A can no longer hide bad news in the first stage so as to secure a rent in the second.

First, consider expert B. He is called upon only following a positive report by expert A. Therefore his rent is as in the one-signal/one-expert case (with the updated belief $\nu(\bar{\sigma})$), i.e., $U_B^S = \frac{\psi}{(1-\nu(\bar{\sigma}))(2\theta-1)}$. This rent is only paid when A reports $\sigma_1 = \bar{\sigma}$, i.e., with probability $p(\bar{\sigma})$.

Consider now expert A. There is no reason to reward him when the decision to reject the project is based on B's negative report ($\hat{\sigma}_2 = \underline{\sigma}$). Therefore, the ex ante moral hazard incentive constraint for A is:

$$p(\bar{\sigma}, \bar{\sigma})\nu(\bar{\sigma}, \bar{\sigma})\bar{t} + p(\underline{\sigma})t_1 - \psi \geq \max\{t_1, p(\bar{\sigma})\nu(\bar{\sigma})\bar{t}\}.$$

This defines two constraints that are binding at the optimum. The transfers to A are thus $\bar{t}_A = \frac{\psi}{(1-\nu)\nu\theta(2\theta-1)}$ and $t_{1A} = \frac{\psi}{(1-\nu)(2\theta-1)}$, and A's rent is given by $U_A^S = \frac{\psi}{(1-\nu)(2\theta-1)}$. This rent is the same as in the one-expert/one-signal case, i.e., the principal is able to control A at the same cost as if this expert was alone. The incentive problems in both stages are disentangled and the principal is facing a sequence of independent incentive problems. Of course, the two experts' rents differ because the beliefs differ in both stages. It is easy to check that $U_B^S > U_A^S$ because $\nu(\bar{\sigma}) > \nu$. Expert B must be given higher-powered incentives because he is more optimistic about the project as a result of the first report and it becomes harder to induce him to gather information that may favor the status quo.

7.4 The Benefits of Separation

Adding the experts' rents and comparing with the one-expert case, we get the following.

Proposition 10 *Under sequential information gathering, the principal is strictly better off implementing the first-best decision rule with two experts rather than one expert:* $U_A^S + p(\bar{\sigma})U_B^S < U^{1,2S}$*. Moreover, an early acceptance of the project is less frequent than with a single expert.*

Since agency costs are reduced using two experts rather than one, relying on such an organization allows a better implementation of the precautionary objectives of the principal. More precisely, with two experts acting sequentially, the principal faces the same agency cost as with a single expert gathering the two signals simultaneously without having to duplicate the fixed cost of information gathering since the second signal is only gathered to confirm an initial positive assessment.

Because the gain of gathering a second signal with a second expert in this sequential environment is weighted by the probability that the first signal is positive, decreasing returns in agency costs are weaker than with simultaneous reports.

It is interesting to note that the sequential timing is also robust to the threat of collusion. By design, the second expert is only called upon after a first favorable (public) report and the scope for both vertical and horizontal collusion disappears.

8 Conclusion

For incentive purposes, an expert should be rewarded only if his recommendation is confirmed by facts or by other experts' recommendations. This principle is at the source of diseconomies of scale due to agency cost of delegated expertise and justifies using multiple experts. We analyzed these agency costs and stressed that, under both vertical and horizontal collusion, a multi-expert procedure may be counterproductive.

The general insights developed here could be applied to several settings such as Political Science, Administrative Law or Corporate Governance. In Political Science for instance, lobbyists are often viewed as experts eager to convey information to influence a decision-maker because they have a stake in that decision. This assumption departs from that used in the above model where experts are unbiased. Such biased preferences could be easily modeled by introducing a non-transferable private benefit for the expert of doing (or not) the project. Those benefits of course provide part of the expert's incentives to gather information. If the expert is a priori biased in favor of the project, inducing him to gather information against (resp. favorable to) the project is easier (resp. harder). These biases affect the incentive problems but not our qualitative results.[44]

Several other extensions could be analyzed at a general level. First, one may be interested in externalities across principal-expert pairs. In our framework, if the status quo is chosen by the decision-maker, no further information arrives to confirm or not this choice. In some environments, the principal can observe the outcome of similar projects, e.g., undertaken by other principal-expert pairs even when he decides not to undertake the project. Think for instance of the expert as an analyst who brings information to a first investor who decides to invest or not in a risky asset. Other investors may have received information from their own analysts who pushed them to invest and the price of this asset brings information to the first investor. In this setting, the optimal incentive scheme should specify transfers for the status quo which depend on that asset price. The expert should be punished if he recommends not to undertake an investment which turns out to be valuable for other investors.

Second, in our model the expert's degree of expertise is common knowledge. This may be a good representation of the relationship between a decision-maker and experts with well-established reputations but more questionable for short-term relationships. When adverse selection on the degree of expertise is an issue, the incentive contract has a new objective which is to elicit that information from the expert.[45] As experts are of a better quality, one may expect their predictions to be more often confirmed by facts. Therefore, screening requires to use less often than what would be first-best optimal the prediction of bad experts and to rely on partial information. In this environment, using multiple experts may reduce agency costs and induce less costly revelation of types by threatening each expert to rely on the recommendations of others.

Third, in a more dynamic setting, part of the current incentives of an expert may be affected by his desire to influence the principal's perception of his ability. Whether the monetary incentives, on which this paper focuses, are complements or substitutes to these implicit incentives is an open question.[46] One could also study how competition between

[44]See e.g. Laux (2001a).

[45]See Osband (1989) for a related model.

[46]For some investigation of those issues, see Gromb and Martimort (2003).

experts affects their reputation building incentives.[47] Indeed, experts may not only care about their reputation vis-a-vis the principal but also vis-a-vis other experts and may compete to be opinion leaders.

It may also be interesting to study more complex environments where experts incentives are not designed by a single principal but by experts with stakes in the decision. For example, in the judicial system, advocates are hired to gather and report information by biased parties, not by the impartial court. How these biased incentives for information gathering interact is an avenue of research that we plan to investigate in the future.

Finally, it may be interesting to study how delegated expertise interacts with other tasks. For instance, should the same agent decide whether to undertake a project and implement that project? Should an agent implementing a project also decide on its orientation (e.g., termination)? These questions are relevant in a broad range of areas such as Corporate Governance, Public Policy, etc.[48] We leave them for future research.

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[47]On this, see Ottaviani and Sorensen (2002).

[48]See Boot (1991), Laux (2001a) and Dow and Raposo (2002) for instance.

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10 Appendix

Proof of Proposition 1: In this Appendix, we consider any scheme $\{\bar{t}, \underline{t}, t_0\}$, i.e., we do not impose $\underline{t} = 0$. The principal's problem is then:

$$\min_{\{\bar{t},\underline{t},t_0\}} \; p(\bar{\sigma})(\nu(\bar{\sigma})\bar{t} + (1-\nu(\bar{\sigma}))\underline{t}) + p(\underline{\sigma})t_0$$

subject to

$$\nu(\bar{\sigma})\bar{t} + (1-\nu(\bar{\sigma}))\underline{t} \geq t_0 + \frac{\psi}{p(\bar{\sigma})}, \tag{A.1}$$

$$t_0 \geq \nu(\underline{\sigma})\bar{t} + (1-\nu(\underline{\sigma}))\underline{t} + \frac{\psi}{p(\underline{\sigma})}, \tag{A.2}$$

$$\underline{t} \geq 0. \tag{A.3}$$

(5) are easily shown to be satisfied, and omitted in what follows. Because $\nu(\bar{\sigma}) > \nu(\underline{\sigma})$, one can keep the expected transfer constant and (A.1) unchanged, and relax constraint (A.2) by reducing $\underline{t}$. Hence, (A.3) is binding. The remaining constraints, (A.1) and (A.2), define a cone in the positive quadrant of the $(t_0, \bar{t})$ space, and the optimum is reached at its origin, i.e., when both constraints are binding. ■

Proof of Proposition 2: (13) can be written as a two constraints:

$$\nu(\bar{\sigma},\bar{\sigma})\bar{t} \geq t_0 + 2\frac{\psi}{p(\bar{\sigma},\bar{\sigma})}, \tag{A.4}$$

$$t_0 \geq \nu\bar{t} + \frac{\psi}{p(\bar{\sigma},\underline{\sigma})}. \tag{A.5}$$

(A.4) implies (10) and (A.5) implies both (11) and (12). Hence (A.4) and (A.5) define then a cone in the positive quadrant of the $(t_0, \bar{t})$ space, and the optimum is reached at its extreme point. ■

Proof of Proposition 4: The moral hazard incentive constraint can be rewritten as::

$$p(\bar{\sigma}|\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})\bar{t} + p(\underline{\sigma}|\bar{\sigma})t_1 \geq p(\bar{\sigma}|\bar{\sigma})t_2 + p(\underline{\sigma}|\bar{\sigma})t_0 + \frac{\psi}{p(\bar{\sigma})}, \tag{A.6}$$

and

$$p(\bar{\sigma}|\underline{\sigma})t_2 + p(\underline{\sigma}|\underline{\sigma})t_0 \geq p(\bar{\sigma}|\underline{\sigma})\nu(\bar{\sigma},\underline{\sigma})\bar{t} + p(\underline{\sigma}|\underline{\sigma})t_1 + \frac{\psi}{p(\underline{\sigma})}. \tag{A.7}$$

Consider first the following problem: for a given value T_1 of $p(\bar{\sigma}|\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})\bar{t} + p(\underline{\sigma}|\bar{\sigma})t_1$, keeping both the LHS of (A.6) and the expected transfer unchanged, what is the value of

t_1 minimizing the RHS of (A.7)? We solve:

$$\min_{\{\bar{t},t_1\}} \; p(\bar{\sigma}|\underline{\sigma})\nu(\bar{\sigma},\underline{\sigma})\bar{t} + p(\underline{\sigma}|\underline{\sigma})t_1$$
$$\text{subject to}$$
$$T_1 = p(\bar{\sigma}|\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})\bar{t} + p(\underline{\sigma}|\bar{\sigma})t_1 \tag{A.8}$$
$$t_1 \geq 0. \tag{A.9}$$

This problem can be rewritten as:

$$\min_{\{t_1\}} \; \frac{p(\bar{\sigma}|\underline{\sigma})\nu(\bar{\sigma},\underline{\sigma})}{p(\bar{\sigma}|\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})}(T_1 - p(\underline{\sigma}|\bar{\sigma})t_1) + p(\underline{\sigma}|\underline{\sigma})t_1$$
$$\text{subject to (A.9).}$$

The coefficient of t_1 in this problem is $p(\underline{\sigma}|\underline{\sigma}) - \frac{p(\bar{\sigma}|\underline{\sigma})\nu(\bar{\sigma},\underline{\sigma})}{p(\bar{\sigma}|\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})}p(\underline{\sigma}|\bar{\sigma}) = \frac{(2\theta-1)\nu}{p(\underline{\sigma})} > 0$ and thus the minimum is obtained when (A.9) is binding.[49]

Similarly, consider the following problem: for a given value T_2 of $p(\bar{\sigma}|\underline{\sigma})t_2 + p(\underline{\sigma}|\underline{\sigma})t_0$ keeping both the LHS of (A.7) and the expected transfer unchanged, what is the value of t_2 minimizing the RHS of (A.6)? We solve:

$$\min_{\{t_2,t_0\}} \; p(\bar{\sigma}|\bar{\sigma})t_2 + p(\underline{\sigma}|\bar{\sigma})t_0$$
$$\text{subject to}$$
$$T_2 = p(\bar{\sigma}|\underline{\sigma})t_2 + p(\underline{\sigma}|\underline{\sigma})t_0 \tag{A.10}$$
$$t_2 \geq 0. \tag{A.11}$$

This problem can be rewritten as:

$$\min_{\{t_2\}} \; p(\bar{\sigma}|\bar{\sigma})t_2 + \frac{p(\underline{\sigma}|\bar{\sigma})}{p(\underline{\sigma}|\underline{\sigma})}(T_2 - p(\bar{\sigma}|\underline{\sigma})t_2)$$
$$\text{subject to (A.11).}$$

The coefficient of t_2 in this problem is $p(\bar{\sigma}|\bar{\sigma}) - \frac{p(\underline{\sigma}|\bar{\sigma})}{p(\underline{\sigma}|\underline{\sigma})}p(\bar{\sigma}|\underline{\sigma}) = \frac{(2\theta-1)^2\nu(1-\nu)}{p(\bar{\sigma})p(\underline{\sigma},\underline{\sigma})} > 0$ and thus the minimum is obtained when (A.11) is binding.[50]

[49]Note that the coefficient's positivity does not depend on the signals being correlated. Therefore, $t_1 = 0$ would be optimal even in a model with uncorrelated signals.

[50]Note that the coefficient's positivity does rely on the signals being correlated.

With this in mind, the principal's problem can be rewritten as:

$$\min_{\{\bar{t},t_0\}} \; p(\bar{\sigma},\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})\bar{t} + p(\underline{\sigma},\underline{\sigma})t_0$$

subject to

$$p(\bar{\sigma}|\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})\bar{t} \geq p(\underline{\sigma}|\bar{\sigma})t_0 + \frac{\psi}{p(\bar{\sigma})}, \tag{A.12}$$

$$p(\underline{\sigma}|\underline{\sigma})t_0 \geq p(\bar{\sigma}|\underline{\sigma})\nu(\bar{\sigma},\underline{\sigma})\bar{t} + \frac{\psi}{p(\underline{\sigma})}. \tag{A.13}$$

These two constraints define a cone in the positive quadrant of the $(t_0, \bar{t})$ space and the optimum is reached at its extreme point. Simple manipulations complete the proof. ■

Proof of Proposition 5: It is easily checked that $U^{1,2} = \frac{(2-\theta)\psi}{(1-\nu)(2\theta-1)(1-\theta)}$ increases with ν and $\frac{U^{2,2}}{U^{1,2}} = \frac{2(\nu(1-\theta)+(1-\nu)\theta)(1-\theta)}{\theta(2-\theta)}$ decreases with ν. Hence, $U^{1,2} - 2U^{2,2}$ increases with ν.■

Proof of Proposition 7: First, we show that $t_1 = 0$ at the optimum. Given $t_2 = t_0$, the moral hazard incentive constraints can be written as:

$$p(\bar{\sigma}|\bar{\sigma})\nu(\bar{\sigma}|\bar{\sigma})\bar{t} + p(\underline{\sigma}|\bar{\sigma})t_1 \geq t_0 + \frac{\psi}{p(\bar{\sigma})}, \tag{A.14}$$

and

$$t_0 \geq p(\underline{\sigma}|\bar{\sigma})\nu(\bar{\sigma},\underline{\sigma})\bar{t} + p(\bar{\sigma}|\bar{\sigma})t_2 + \frac{\psi}{p(\bar{\sigma})}. \tag{A.15}$$

Adverse selection incentive constraints are obtained by suppressing the terms in ψ.

Clearly, for a given expected value of $p(\bar{\sigma}|\bar{\sigma})\nu(\bar{\sigma}|\bar{\sigma})\bar{t} + p(\underline{\sigma}|\bar{\sigma})t_1$, setting $t_1 = 0$ relaxes (A.15). The last part of the proof is explained in the text. ■

Proof of Proposition 8: (26) can be written as two constraints defining a cone in the positive quadrant of the $(t_0, \bar{t})$ space:

$$\nu(\bar{\sigma},\bar{\sigma})\bar{t} \geq t_0 + \frac{\psi}{p(\bar{\sigma},\bar{\sigma})}, \tag{A.16}$$

$$(1 - p(\bar{\sigma},\bar{\sigma}) - p(\underline{\sigma}))t_0 \geq (p(\bar{\sigma})\nu(\bar{\sigma}) - p(\bar{\sigma},\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma}))\bar{t} + \psi. \tag{A.17}$$

The optimum is reached at the cone's origin. ■

Proof of Proposition 9: Decreasing t_1 relaxes both (29) and (31) and increases the principal's payoff. Hence, (30) is binding and $t_1 = t_2$. Therefore (31) can be rewritten as:

$$\begin{aligned} &\theta^2\nu\bar{t} + [\theta(1-\theta) + \theta(1-\nu) + (1-\theta)\nu]t_2 - (1 + p(\bar{\sigma}))\psi \\ &\geq \max\{t_2, \theta\nu\bar{t} + [\theta(1-\nu) + (1-\theta)\nu]t_2 - \psi\}. \end{aligned} \tag{A.18}$$

This can in turn be rewritten as two constraints:

$$\theta(1-\theta)t_2 \geq \theta(1-\theta)\nu\bar{t} + p(\bar{\sigma})\psi \tag{A.19}$$

$$\theta^2\nu\bar{t} \geq [\theta\nu + (1-\theta)(1-\nu) - \theta(1-\theta)]t_2 + (1+p(\bar{\sigma}))\psi \tag{A.20}$$

Note that (A.19) is the same as (28) which is thus redundant. Thus, optimizing w.r.t. $\bar{t}$ and t_2, (A.19) and (A.20) must be binding. Solving this system completes the proof. ■

An Alternative Decision Rule

We now study the robustness of our results to changing the decision rule. Assume now that the project is undertaken unless the expert reports bad news, i.e.,

$$\nu\bar{S} + (1-\nu)\underline{S} > 0 > \nu(\underline{\sigma})\bar{S} + (1-\nu(\underline{\sigma}))\underline{S}.$$

In the one-expert/one-signal case, the rent is as before, i.e., $U_{1,1}$. Indeed, the moral hazard incentive constraint remains:

$$p(\overline{\sigma})\nu(\overline{\sigma})\bar{t} + p(\underline{\sigma})t_0 - \psi \geq \max\left\{t_0, \nu\bar{t}\right\},$$

implying the adverse selection constraints. Therefore $\bar{t}$ and t_0 are as in Proposition 1.

Proposition 11 *Suppose that the principal wants to undertake the project unless both signals are negative, then the following holds under the optimal contracts.*

- *If one expert gathers both signals, his rent is:*

$$U^{1,2} = \frac{(1-p(\bar{\sigma},\bar{\sigma}))\psi}{\theta(1-\theta)(2\theta-1)(1-\nu)} > 2U^{1,1}. \tag{A.21}$$

- *If each of two experts gathers one signal, his rent is:*

$$U^{2,2} = \frac{p(\underline{\sigma})\psi}{\theta(2\theta-1)(1-\nu)} < \frac{U^{1,2}}{2}. \tag{A.22}$$

Consider first the one-expert/two-signals case. Since the project should be adopted unless $\sigma_1 = \sigma_2 = \underline{\sigma}$, adverse selection incentive compatibility implies the same transfer $\bar{t}$ for all other reports. Other adverse selection constraints are:

$$\nu(\bar{\sigma},\bar{\sigma})\bar{t} \;\geq\; t_0, \tag{A.23}$$

$$\nu(\bar{\sigma},\underline{\sigma})\bar{t} \;\geq\; t_0, \tag{A.24}$$

and

$$t_0 \geq \nu(\underline{\sigma}, \underline{\sigma})\bar{t}, \tag{A.25}$$

where we have assumed that $\underline{t} = 0$ which can be shown to be optimal.

Given the option to gather one or no signal, the moral hazard incentive constraint is:

$$\begin{aligned}(p(\bar{\sigma}, \bar{\sigma})\nu(\bar{\sigma}, \bar{\sigma}) + 2p(\bar{\sigma}, \underline{\sigma})\nu(\bar{\sigma}, \underline{\sigma}))\bar{t} + p(\underline{\sigma}, \underline{\sigma})t_0 - 2\psi \geq \\ \max\{t_0, \nu\bar{t}, p(\bar{\sigma})\max\{t_0, \nu(\bar{\sigma})\bar{t}\} + p(\underline{\sigma})\max\{t_0, \nu(\underline{\sigma})\bar{t}\} - \psi\}.\end{aligned} \tag{A.26}$$

Under (A.24), the RHS above can be simplified as

$$\max\{\nu\bar{t}, p(\bar{\sigma})\nu(\bar{\sigma})\bar{t} + p(\underline{\sigma})t_0 - \psi\}.$$

As before, these constraints can be written as:

$$(\theta^2(1-\nu) + (1-\theta)^2(1-\nu))t_0 \geq \nu(1-\theta)^2\bar{t} + 2\psi, \tag{A.27}$$

and

$$\theta(1-\theta)\nu\bar{t} \geq \theta(1-\theta)t_0 + \psi. \tag{A.28}$$

It is easily checked that (A.28) implies (A.23) and (A.24). Similarly, (A.27) implies (A.25). The principal's problem can thus be written as:

$$\begin{aligned}\min_{\{\bar{t}, t_0\}} \quad & (p(\bar{\sigma}, \bar{\sigma})\nu(\bar{\sigma}, \bar{\sigma}) + 2p(\bar{\sigma}, \underline{\sigma})\nu(\bar{\sigma}, \underline{\sigma}))\bar{t} + p(\underline{\sigma}, \underline{\sigma})t_0 \\ & \text{subject to (A.27), (A.28) and } \bar{t}, t_0 \geq 0.\end{aligned}$$

The first two constraints above are binding at the optimum and the optimal transfers are $\nu\bar{t}^{1,2} = \frac{(1-p(\bar{\sigma},\bar{\sigma}))\psi}{\theta(1-\theta)(2\theta-1)(1-\nu)}$ and $t_0^{1,2} = \frac{(1+\theta)\psi}{\theta(2\theta-1)(1-\nu)}$. The expert's rent is:

$$U^{1,2} = \nu\bar{t} = \frac{(1-p(\bar{\sigma}, \bar{\sigma}))\psi}{\theta(1-\theta)(2\theta-1)(1-\nu)}. \tag{A.29}$$

Now consider the two-experts/two-signals case. Given the decision rule to be implemented, denote by $\bar{t}$ the transfer offered to one expert when $\hat{\sigma}_1 = \hat{\sigma}_2 = \bar{\sigma}$, t_1 (resp. t_2) denotes the transfer to a favorable (resp. unfavorable) expert when the other is unfavorable (resp. favorable) and the project succeeds.[51] Lastly, t_0 denotes the transfer to an expert when $\hat{\sigma}_1 = \hat{\sigma}_2 = \underline{\sigma}$.

[51] It can be easily shown that the expert's wage is zero if he recommends doing the project and it fails.

The following adverse selection constraints must be satisfied:

$$p(\bar{\sigma}|\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})\bar{t} + p(\underline{\sigma}|\bar{\sigma})\nu(\bar{\sigma},\underline{\sigma})t_1 \geq p(\bar{\sigma}|\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})t_2 + p(\underline{\sigma}|\bar{\sigma})t_0, \tag{A.30}$$

$$p(\bar{\sigma}|\underline{\sigma})\nu(\bar{\sigma},\underline{\sigma})t_2 + p(\underline{\sigma}|\underline{\sigma})t_0 \geq p(\bar{\sigma}|\underline{\sigma})\nu(\bar{\sigma},\underline{\sigma})\bar{t} + p(\underline{\sigma}|\underline{\sigma})t_1. \tag{A.31}$$

Each expert's moral hazard incentive constraint is:

$$p(\bar{\sigma},\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})\bar{t} + 2p(\bar{\sigma},\underline{\sigma})\nu(\bar{\sigma},\underline{\sigma})(t_1+t_2) + p(\underline{\sigma},\underline{\sigma})t_0 - \psi \tag{A.32}$$
$$\geq \max\{\nu\bar{t}, p(\bar{\sigma})\nu(\bar{\sigma})t_1 + p(\underline{\sigma})t_0\}.$$

As before, (A.32) as rewritten two constraints:

$$p(\bar{\sigma}|\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})\bar{t} + p(\underline{\sigma}|\bar{\sigma})\nu(\bar{\sigma},\underline{\sigma})t_1 \geq p(\bar{\sigma}|\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})t_2 + p(\underline{\sigma}|\bar{\sigma})t_0 + \frac{\psi}{p(\bar{\sigma})}, \tag{A.33}$$

$$p(\bar{\sigma}|\underline{\sigma})\nu(\bar{\sigma},\underline{\sigma})t_2 + p(\underline{\sigma}|\underline{\sigma})t_0 \geq p(\bar{\sigma}|\underline{\sigma})\nu(\bar{\sigma},\underline{\sigma})\bar{t} + p(\underline{\sigma}|\underline{\sigma})t_1 + \frac{\psi}{p(\underline{\sigma})}. \tag{A.34}$$

Of course, (A.33) implies (A.30) and (A.34) implies (A.31).

The principal's problem becomes:

$$\min_{\{\bar{t},t_1,t_2,t_0\}} \; p(\bar{\sigma},\bar{\sigma})\nu(\bar{\sigma},\bar{\sigma})\bar{t} + p(\bar{\sigma},\underline{\sigma})\nu(\bar{\sigma},\underline{\sigma})(t_1+t_2) + p(\underline{\sigma},\underline{\sigma})t_0$$
$$\text{subject to (A.33), (A.34), and } \bar{t}, t_1, t_2, t_0 \geq 0.$$

To find which limited liability constraint is binding, consider first the set of positive transfers $(\bar{t}, t_1)$ keeping constant the LHS of (A.33), i.e., $\theta^2\nu\bar{t} + \theta(1-\theta)\nu t_1$, so that the principal's expected payoff is constant. All those transfer pairs also keep the RHS of (A.34) unchanged and thus one can take $\bar{t} = t_1$ without loss of generality.

Consider now the set of positive transfers (t_1, t_0) keeping constant the LHS of (A.34), i.e., $\theta(1-\theta)\nu t_2 + (\theta^2(1-\nu)+(1-\theta)^2\nu)t_0$, so that the principal's expected payoff is constant. Among those transfer pairs, the one minimizing the RHS of (A.33), i.e., $\theta^2\nu t_2 + \theta(1-\theta)t_0$, is obtained for $t_2 = 0$.

With $\bar{t} = t_1$ and $t_2 = 0$, (A.33) and (A.34) can be written as:

$$\theta\nu\bar{t} \geq \theta(1-\theta)t_0 + \psi, \tag{A.35}$$

$$(\theta^2(1-\nu) + (1-\theta)^2\nu)t_0 \geq (1-\theta)\nu\bar{t} + \psi. \tag{A.36}$$

It is easily shown that the principal's problem implies that both constraints above are binding. This implies $\nu\bar{t}^{2,2} = \frac{p(\underline{\sigma})\psi}{\theta(2\theta-1)(1-\nu)}$ and $t_0^{2,2} = \frac{\psi}{\theta(2\theta-1)(1-\nu)}$. Each expert's rent is

$$U^{2,2} = \nu\bar{t}^{2,2} = \frac{p(\underline{\sigma})\psi}{\theta(2\theta-1)(1-\nu)}. \tag{A.37}$$

Finally, $U^{1,2} > 2U^{2,2}$ amounts to $\nu < \frac{\theta^2}{(2\theta-1)^2}$. The RHS is minimum for $\theta = 1$ and equals 1 so that this inequality always holds. ■

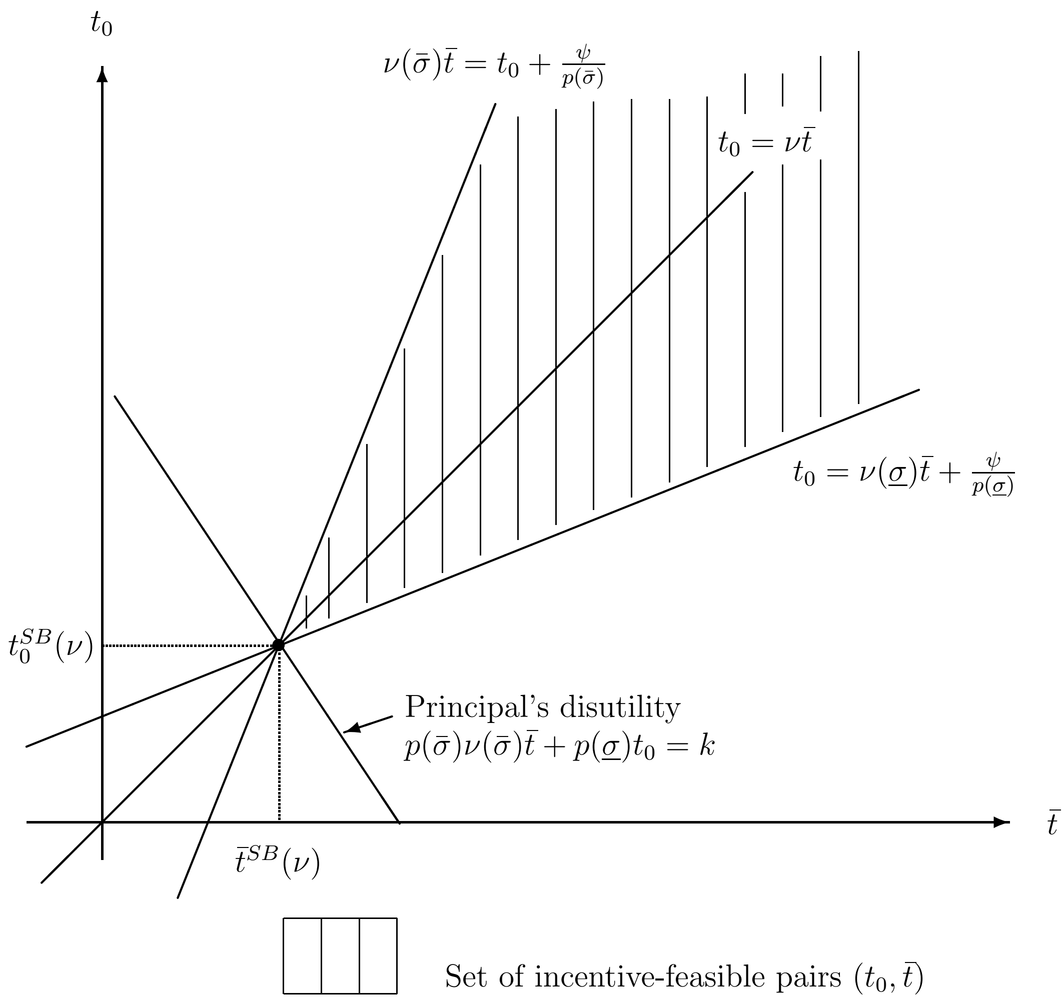

Figure: The set of incentive-feasible pairs $(t_0, \bar t)$.