Cahiers du LASER

n°011-02-04

Signaling and the Design of Delegated Management for Public Utilities

David Martimort[*] *et Wilfried Sand-Zantman*[**]

* Université de Toulouse (IDEI, GREMAQ) et Institut Universitaire de France

** LASER-LAEC, Université de Montpellier 1 et GREMAQ

Laboratoire de Sciences Economiques de Richter
UNIVERSITE DE MONTPELLIER I - Faculté des Sciences Economiques,
Espace Richter - Avenue de la mer, B.P. 9606 - 34 060 Montpellier Cedex, France
Tel : (33) 04 67 15 84 50 Fax : (33) 04 67 15 83 61
E-mail : wzantman@univ-tlse1.fr

Web : http://www.sceco.univ-montp1.fr/laser/accueil.htm

Signaling and the Design of Delegated Management for Public Utilities[1]

David Martimort[2] and Wilfried Sand-Zantman[3]

March 2004

Abstract

We propose a theory explaining the shape of contracts between local governments and the contractors they hire to run public facilities on their behalf. Governments are privately informed over the quality of the facility and risk-averse while risk-neutral contractors are subject to a moral hazard problem. We show how the design of the contract signals the asymmetric information parameter. The higher the quality of the network, the higher the marginal return and the greater the share of operating risk kept by the government. This reduces the agent's marginal incentives, creating a trade-off between signaling and moral hazard. This trade-off is analyzed in different contexts allowing for risk-aversion on the agent's side, double moral hazard and political economy issues. Lastly, a model of delegated signaling is developed highlighting the difficulty of designing separating contracts when governments are under the countervailing influences of both the contractors and the voters.

Keywords: Informed Principal, Signaling Games, Incentives, Delegation.

JEL Classification : H11; D73; D82.

[1]We thank Jean-Jacques Laffont, Radoslava Nikolova, Patrick Rey, Jean Tirole and seminar participants in IDEI-Toulouse for helpful comments.

[2]University of Toulouse, (IDEI, GREMAQ) and Institut Universitaire de France.

[3]University of Montpellier (LASER-LAEC) and GREMAQ.

1 Introduction

Consider a local government, either a district or a city, willing to develop a project. This government, on top of choosing the exact nature of the good or service provided, has also to decide how to supply the good. Either he may manage the service in-house under public ownership or he may prefer to outsource that activity to the private sector. In the case of *delegated management*, a private company is selected following a bidding procedure and a real partnership between the local government and the company is developed. The general goal of this article is to understand the various contractual forms that such public/private partnerships may take. In passing, the analysis of these contractual arrangements may also shed some light on where the boundary between private and public provision lies.

The problem of delegating the management of public utilities is pervasive and covers a whole spectrum of applications. Providing drinking water, cleaning waste water, organizing public transportation or collecting garbage are some highlighting examples of activities which have been more and more delegated to the private sector over the last past years. For those kinds of activities, contracts between the government and the private sector vary from one place to another. This cross-section variation may reflect technical conditions or preferences but, it certainly depends also on how private information affects the transaction between the local government and the potential service providers.

As an example, consider the case of water supply in France. Each locality has to decide whether to delegate production to the private sector or to keep it under its own control.[1] Partnerships between the public and the private sectors for distributing drinking water and treating waste water differ greatly from one municipality to the other. On the one side of the spectrum, one finds the so-called *"régies municipales"* which are public bureaus directly under the control of the local government. On the other side, one may find the case of privatization which is much less frequent in practice. In between, the dominating form over the last past century has been leasing contracts, the so-called *"affermage"*.[2] In this case, a private entity, external and independent of the municipality, is hired to manage the service and operates some facilities which may have been built and often already run in the past by the municipality. There is a clear separation between the tasks devoted to the private sector and those which may remain under direct public control. The private sector operates and maintains the existing assets. The decision to undertake major investments aimed at restructuring an existing network remains instead

[1] This freedom emanates from the principle of *administrative freedom of local authorities* (article 72 of the 1958 French Constitution). It was subsequently enlarged with the delegation of greater authority to local councils under the *Decentralization Laws.*

[2] In France, practitioners are often heard to talk about *le modèle de délégation de service public à la française*. It is fair to say that similar contracting forms can also be found in the U.K. or other places in the world.

under the scope of the municipality's control since it owns the infrastructure. Even within the class of leasing contracts, various kinds of arrangements can be found which differ in terms of how financial and operating risks are shared between a rather badly diversified and thus risk-averse municipality (the principal) and the contractor (his agent), generally a large private company which is much better diversified and thus almost risk-neutral.[3] Those contracts typically involves a lump-sum payment, a fixed regulated price for consumers and a proportional bonus. They thus go from giving the agent very high powered incentives (and, in the case of privatization, full incentives) to exert effort in operating and managing assets to much lower powered incentives as in the case of the *"régies municipales"*.

In this paper, we propose a theory explaining the shape of these contracts and the kinds of public/private partnerships which are likely to emerge. Our starting point is that municipalities are privately informed on the quality of the technology that potential service providers may use. The design of the contract for delegated management acts then as a signal towards the private sector over the quality of the facilities to be run. More specifically, we assume risk-aversion and private information on the principal's side. We then draw some conclusions of those assumptions on the design of contractual arrangements between an informed principal and his delegated agent in a moral hazard environment reflecting the difficulty to control operating decisions once delegated to the private sector. In such environments, the shape of the contract between the municipality and the contractor, i.e., the choice of the fixed and of the variable parts, results from the interaction between two major forces. On the one hand, the principal may want to incentivize his agent to exert the right amount of effort in operating assets. On the other hand, the principal may also be willing to signal the quality of the existing assets to the service provider.

If the quality of the infrastructure was common knowledge, making the agent residual claimant for all financial and operational risks of the activity would always give him the right marginal incentives to exert effort. This can easily be done with a contract letting the agent enjoy all returns and having him pay an up-front payment for the right of operating assets. This fixed-fee would increase with the expected return of the activity and thus with the quality of the assets.

Instead, when the municipality is privately informed on the quality of the assets, a principal who knows that the infrastructure is of a low quality may overstate this quality to extract more from the private sector. To separate from a low quality type and credibly signal a high quality, a principal must accept to bear more risk. This is obviously costly

[3]On this cross-section variation of contractual modes, see the interesting empirical study of Thomas and Reynaud (2000) who show that unobservable characteristics of the infrastructures (among others) explain the choice of management in the case of water supply for some French municipalities.

for two reasons. First, the principal is risk-averse and keeping some risks decreases his expected payoff. Second, reducing the risk borne by the agent also reduces his effort which is costly on the moral hazard side. For signaling reasons, the agent who runs a good technology should not bear all operational and financial risks associated to the project. Low-powered incentives emerge and the agent ends up exerting less than the socially optimal effort even when he is risk-neutral and has unlimited liability. There is thus a trade-off between signaling and moral hazard.

We first build on this trade-off to obtain simple comparative statics. For instance, as the principal's risk-aversion increases or as the performance measure of the agent becomes more noisy, it becomes easier for the principal to signal the quality of the technology by bearing even a tiny amount of risk. The trade-off between signaling and incentives is thus somewhat relaxed and low-powered incentives are less likely to emerge.

We then study how this important trade-off between signaling and incentives may be modified by various modifications of the basic set-up.

In a first extension of our model where the only feasible contracts consist in allocating property rights, this signaling issue advocates for excessive in-house production for the best quality technologies whereas privatization arises for the worst infrastructures, when uncertainty is significative or when municipalities face hard budget constraints.

Second, we consider the case where the agent may also be risk-averse if it faces some financial constraints. Again, this advocates for having the principal bear some risk. In this case, it becomes harder for the principal to credibly signal by keeping some risk since he must keep some anyway. The principal must bear an even greater amount of risk and this exacerbates significantly the moral hazard problem.

Third, the principal may also be involved in the production process by maintaining assets through some heavy investments or by financing required modernizations.[4] Double moral hazard justifies in the first place that the principal also bears some risk to have incentives to make those investments. This effect tends again to make signaling more difficult and low powered incentives more attractive.

Lastly, we discuss some political economy issues. Since the signaling distortions depends on the principal's willingness to bear risk, differences between the median and the average risk-aversion can immediately be translated into differences in the signaling distortions. If the median is more risk-averse than the average,[5] there would be excessively high-powered incentives resulting from the political game.

[4] In the case of drinking water production, this case is particularly relevant.

[5] By average risk-aversion, we mean the harmonic mean of the distribution of risk-aversion. That inequality always occurs for a symmetric distribution of risk-aversion parameters in the population within the municipality.

In practice, principals who delegate contracting to the private sector are only representatives of dispersed voters and, as a result, may at least partially follow their own incentives. The last section of the paper analyzes the consequences of an agency problem between voters and their delegated political principal on the incentives to signal the quality of the technology. When the principal's objective function is somewhat congruent with that of the industry, the optimal contract for delegated management cannot be separating and remains thus uninformative on the quality of the technology. Intuitively, the political principal is trapped between two countervailing forces. On the one hand, the principal may want to please the industry by understanding the state of the technology so that up-front fixed-fees are lower. On the other hand, satisfying the electorate calls for overstating the state of the technology to increase these fixed-fees.

Let us now turn to a review of the literature. The assumption that the principal representing the public is risk-averse has been defended by Lewis and Sappington (1995).[6] They model instead adverse selection on the agent's side and argue that the trade-off between rent extraction and incentives is tilted towards excessive efficiency. In such a framework, introducing shareholders of the private company as active players helps in providing insurance and improving this trade-off.

Our focus on the principal's information and his signaling incentives puts our model in the realm of informed principal theory. Because the agent's expected return depends on the type of technology he is running, the model is one of common values à la Maskin and Tirole (1992) with the added complexity that the agent exerts a non-verifiable effort. In a context that differs from ours both in terms of modeling technology and focus, Beaudry (1994) also analyzes an informed principal's problem under moral hazard on the agent's side. He shows that an employer may want to decrease bonus and gives some positive rent to a risk-neutral employee to signal a good technology.[7] In our model instead, rent extraction always occurs.

Also, the idea that an informed risk-averse party may want to keep part of the financial risk associated to a project in order to signal the quality of the technology to risk-neutral financiers is clearly reminiscent of the finance literature starting with the seminal paper by Leland and Pyle (1977). In this work, the cost of signaling is imperfect risk-sharing whereas, because of moral hazard on the agent's side, the cost of signaling in our model also incorporates the worsening of the moral hazard problem. Hence, there still exists a cost of signaling even with a risk-neutral principal.

Even though it is not our main focus, our work is naturally linked to the literature

[6]See also Laffont and Martimort (2002, Chapter 2) for a simplified model.

[7]Differences include the space of contracts available and the nature of the randomness in performances. Beaudry (1994) focuses on the case of two outcomes only whereas we have a continuum. Moreover, the employer is always risk-neutral.

on privatization and lively debate on the scope between private and public production. There is an important benchmark in this literature which is provided by the *"Irrelevance Theorem"*, due to Sappington and Stiglitz (1987). This Theorem states that under quite reasonable assumptions, a principal (a government) loses nothing from delegating a productive task to an agent (a private firm). Even though informational problems may plague the relationship between the government and the private sector, the agency cost of delegated management under both adverse selection and/or moral hazard remain null. Sappington and Stiglitz interpret their Theorem as saying that privatizing the provision of the service entails no cost even though control of the productive assets gives an informational advantage to the private firm running the assets.[8] We depart from the assumptions underlying the Irrelevance Theorem by assuming that the principal possesses private information at the time of contracting with the private sector. This underscores a case where these authors predicted the possible failure of their result. In our framework, the principal becomes an active player with his own incentives to manipulate information. The cost of signaling to agents outside the public sector the exact value of the technology makes full privatization less attractive. In an extension of the model where the only available contracts consist in allocating ownership rights on the stream of profits generated by the activity, we obtain interesting trade-offs between in-house production and outsourcing. [9]

By stressing asymmetric information on the principal's side at the time of contracting, we model a setting where the principal has in fact a limited commitment ability since no ex ante contracting is indeed possible. Limited commitment has being underscored by Sappington and Stiglitz (1987) as a crucial incomplete contracting assumption needed to break the Irrelevance Theorem. This is particular true in our model but as argued above, we need more and, most specifically, that the only feasible contracts consist in allocating ownership rights. Other articles model imperfect commitment to study the pros and cons of privatization but in rather different manners.[10] None of these papers has studied the

[8]Implicit in this statement is the first assumption that under public provision, the bureaucrat who manages the assets exerts an effort which is observable whereas, under private ownership, this observability is lost. For similar assumptions in the vertical integration literature see Arrow (1975) and Riordan (1990). A second assumption is that public and private managements are endowed with the same technology.

[9]Bajari and Tadelis (2001) propose a complementary theory explaining the shape of delegation contracts in an incomplete contracts framework, for which they provide an explicit measure, without private information on the principal's side. Focusing on the choice between fixed-price and cost plus agreements, they show why the latter may be preferred to allow for ex post efficient renegotiation in spite of the ex ante inefficient effects on the cost reduction efforts made by the agent. They interpret then cost plus as in-house production while fixed-price is seen as outsourcing

[10]In this literature, some authors assume that changes in ownership structure leads to a change in the way information is spread in the economy (as in Riordan (1990) and Shapiro and Willig (1990)), with sometimes the additional assumption that the managers' preferences differ for exogenous reasons between private and public firms (Schmidt (1996)). Others have analyzed the effects of incomplete contracting *à la* Grossman and Hart (1986) on the optimal ownership structure, different structures giving different residual rights of control and therefore different incentives. For example, Hart, Shleifer and Vishny (1997)

issue of private information on the principal's side.

Section 2 describes our model. Section 3 presents a benchmark case where the technology is common knowledge. Section 4 is the core of the paper since we introduce there asymmetric information on the technology. We show the basic trade-off between signaling and incentives and provide some comparative statics. Section 5 explores several extensions of the model. Section 6 discusses the problem of delegated signaling in the public sector. Section 7 concludes.

2 The Model

We consider the relationship between a risk-averse principal and a risk-neutral entrepreneur to whom the task of producing a public service is delegated. This principal can be thought of as a small and not-well diversified locality for whom the project represents a significant part of its overall budget. The risk-neutral entrepreneur represents instead a large firm which is well-diversified since it operates in several similar markets. This hierarchical relationship can be viewed as the archetypical model of the delegated management of public services for water, garbage collection, or public transportation.

The gross social consumer surplus generated by the project is S which is common knowledge to both the principal and the agent.

The project yields a profit $\tilde{\pi}$ which depends on the innate quality θ of the technology. In the case of water supply, this can be viewed as the quality of the water network which is, to a large extend, only known by the principal (having maybe built and run the service himself for a long time) at the time of delegating management for the first time.[11] [12] We will assume that θ belongs to $[\underline{\theta}, \bar{\theta}]$ and is drawn with an atomless distribution $F(\cdot)$ having everywhere positive density $f(\cdot)$. We denote $E(\theta)$ the average type. We will sometimes assume that the monotone hazard rate property (MHR) holds, i.e., $\frac{d}{d\theta}\left(\frac{F(\theta)}{f(\theta)}\right) > 0$.

and Hart (2003) argue that public management leads to too few cost reductions, since employees only receive a fraction of the return, whereas private management induces too strong cost reductions, and has then an adverse impact on quality. Still driven by the specific analysis of the case of water supply, quality does not seem to us as a relevant variable. It is highly observed and used as a contract variable in this field for obvious reasons. Our own analysis is different since its only departure from the standard Principal-Agent paradigm is to assume that ex ante contracting is not feasible. A related paper by Bentz, Grout and Hallonen (2002) analyzes in a comprehensive contracting environment the same set of issues as Hart, Shleifer and Vishny (1997)

[11]Following Arrow (1975), Williamson (1985) and Riordan (1990), we may assume that the principal owns the infrastructure as in the case of delegated management and that with ownership comes private information on the quality of this infrastructure.

[12]This can also be viewed as a reduced form for a dynamic model in which, even though the principal has already delegated management in the past, there still remains some incomplete information on the quality of the technology.

By exerting an effort e which costs him $\psi(e) = \frac{e^2}{2}$, the agent increases the realized profits. This effort is supposed to be non-observable so that there is moral hazard in outsourcing public service to the private sector.

Realized profits are also affected by some shock $\tilde{\varepsilon}$ which is normally distributed with mean zero and variance σ^2 ($\varepsilon \sim N(0, \sigma^2)$). That randomness captures all the financial and operational risks that the operator may face.[13]

Finally, realized profits are linked to the innate quality of the technology, the manager's effort and the random shock through the simple additive formula[14]:

$$\tilde{\pi} = \theta + e + \tilde{\varepsilon}.$$

Those realized profits are the only observables available to write down a contract between the risk-averse principal and his agent.

Since profits are observable, this is a matter of convention to assume that the principal benefits directly from those profits and pays to the agent a transfer $t(\tilde{\pi})$ to perform the public service on his behalf.

The principal has a CARA utility function, v, with a coefficient of risk-aversion being $r > 0$. That assumption may be justified in the case of a small municipality for which the service to be delegated represents a significant share of its overall budget.[15] It may also cover the case of a larger municipality when its access to the financial markets is not as easy because, for instance, of private information on its financial needs.

We will focus on linear profit-sharing contracts of the form $t(\tilde{\pi}) = b\tilde{\pi} - a$. The fraction b represents the marginal incentives of the firm whereas a represents a fixed-fee paid up front by the entrepreneur to get the right to perform the task. In practice, contracts for delegated management involve the payment by a company of a lump-sum and a proportional bonus.

From a theoretical viewpoint those linear contracts can be rationalized in such contexts with CARA utility functions and shocks normally distributed if we follow Holmström and Milgrom (1987 and 1991) and view such models as reduced forms of a more complex dynamic environment. The optimality of linear contracts was then derived when the technology θ is common knowledge. In this paper, we are mainly interested in the case where θ is private information for the principal. To the best of our knowledge, it is not known whether linearity is still a feature of optimal contracts. However, linear contracts lead us to a quite tractable analysis and makes particularly clear any comparison with the benchmark of complete information.

[13]In the case of water supply, this may be random perturbations or incidents on the network but also unpredictable variations in the costs of various inputs to the production process.

[14]A multiplicative formulation is considered in the Appendix.

[15]The case of water supply is again particularly relevant here.

Note that, with our accounting conventions, only a fraction $1 - b$ of the profit finally benefits the principal. Henceforth, the principal's certainty equivalent of his utility can be written as:

$$V = E\left[S + (1-b)\tilde{\pi} + a|\theta\right] - \frac{r(1-b)^2}{2} \text{ var } (\tilde{\pi}|\theta)\,.$$

Similarly, the risk-neutral agent's expected utility is:

$$U = E(b\tilde{\pi} - a - \psi(e)|e).$$

We assume that the agent's outside opportunity gives him a reservation payoff exogenously normalized at zero and that the principal has all bargaining power in contracting with the agent. This captures the existence of an ex ante competition between identical potential providers of the service. Competitive bidding leads them to be on their reservation payoff.[16]

3 Benchmark: Complete Information on the Technology

Let us first suppose that the innate quality of the infrastructure θ is common knowledge. The contractual solution to the risk-averse principal's problem is then well-known. It consists in selling to the risk-neutral agent the technology for a fixed-fee $a^*(\theta)$ and letting that agent bear the full consequences of his own choices of effort by choosing $b^*(\theta) = 1$. With such a scheme, the agent has the right incentives to exert effort. Cost minimization leads to a first-best effort level which is independent of the technology $e^*(\theta) = e^*$ with $\psi'(e^*) = e^* = 1$.

Moreover, with this *sell-out contract*, the principal gets also full insurance. Finally, the fixed-fee $a^*(\theta)$ charged to the agent by the principal extracts all his expected profit from running the facilities so that:

$$a^*(\theta) = \theta + e^* - \psi(e^*). \tag{1}$$

In this article, we will sometimes refer to an activity as being privately controlled when the managers of the public utility enjoys all the marginal returns of their activity. When the technology (more exactly its innate quality) is common knowledge, the task of providing the public service can be then easily delegated to the private sector at no cost for the

[16] Loeb and Magat (1979) already noticed that an ex ante competitive bidding among potential service providers helps a regulator to achieve the first-best in cases where only those firms are potentially informed on their costs. See also Sappington and Stiglitz (1987) on that.

principal. The *Irrelevance Theorem* of Sappington and Stiglitz (1987) gets here its full strength.

Importantly, the principal extracts more from the agent as the technology is more efficient ($a^*(\theta)$ increases with θ). This clearly points at the principal's incentives to overstate the quality of the technology in settings where the latter is non-observable by the agent. That particular incentive problem puts thus a limit to the relevance of the Irrelevance Theorem. Indeed, asymmetric information on the quality of the technology will induce the existence of a cost of signaling information to the uninformed private sector. We investigate that signaling cost in the next section.

It is interesting to remark that a sell-out contract would still be optimal if the principal could commit to a contract ex ante, i.e., before he knows θ. With such a sell-out contract, the principal would then be totally insured against both operational and quality shocks, the agent would still have maximal incentives and all his expected profit could again be extracted. In the context developed below, there is no opportunity for writing such contract ex ante and the sell-out contract will not solve all contracting problems. We are thus modelling an incomplete contracting setting where the Irrelevance Theorem will generally fail.

4 Informed Principal

Let us now suppose that only the principal knows the parameter θ at the time of contracting. The principal's problem is to design a mechanism to induce an effort from the risk-neutral agent and, at the same time, to signal the value of the technology.

From a theoretical viewpoint, we face an informed principal problem in a moral hazard environment with some common value aspects since the principal's type θ affects directly the agent's expectation over the realized profits. Although the modeling technology due to Maskin and Tirole (1992) to deal with such problems was developed in a pure adverse selection environment, we will follow these authors in describing the Rothschild-Stiglitz-Wilson least-cost separating allocation (thereafter RSW allocation). These authors describe the perfect Bayesian equilibria of a three-stage game, in which first the principal offers a mechanism which may allow for further communication with the agent, second the agent chooses action (to participate or not), third the principal may communicate his type to the uninformed agent. In such an environment, Maskin and Tirole (1992) show that offering the RSW allocation is an equilibrium of the three-stage game which satisfies the Cho and Kreps (1987) criterion and that all other allocations which Pareto dominate that outcome are also equilibria. The first result allows a drastic simplification of the analysis of the game. Instead of looking at a three-stage game, one may as well look at a two-stage game as far as the modeler is concerned with the RSW allocation. In this game, all information on θ is revealed to the uninformed party through the mere offer of a contract $t(\pi|\theta)$ which is "simple" in the sense that it stipulates no later communication stage.

We will follow this simple path in this paper focusing on the RSW allocation. Our model differs nevertheless from Maskin and Tirole (1992) by appending on a moral hazard problem on the agent's side. In response to a contract offer, the agent not only chooses to participate but also how much effort he supplies. Nevertheless, it is straightforward to extend their framework to our case.

It differs also because we allow for a continuum of types for the principal whereas they allow a finite discrete type space. The fact that there is a continuum of types allows us to use the techniques of Mailath (1987) to find out and characterize the unique separating equilibrium.[17] To describe this RSW allocation, first let us define a separating contract as a family of profit-sharing schemes $\left\{t(\pi,\hat{\theta})\right\}_{\hat{\theta}\in\Theta}$. Equivalently, given the linearity of the contracts, those schemes can be completely defined in terms of the pairs $\{(a(\hat{\theta}),b(\hat{\theta}))\}_{\hat{\theta}\in\Theta}$.

Definition 1 *: A separating contract is a family of profit sharing pairs* $\left\{(a(\hat{\theta}),b(\hat{\theta}))\right\}_{\hat{\theta}\in\Theta}$ *which is injective, i.e., such that* $(a(\theta),b(\theta))\neq(a(\theta'),b(\theta'))$ *for* $\theta\neq\theta'$*.*

Consider such a separating contract. The mere offer of a scheme contract $(a(\hat{\theta}),b(\hat{\theta}))$ signals to the agent that the technology's innate quality is $\hat{\theta}$. Using that information, the agent chooses his effort level $e(\hat{\theta})$ so that:

$$e(\hat{\theta})=\arg\max_{e}E\left(b(\hat{\theta})\tilde{\pi}-a(\hat{\theta})|\hat{\theta}\right)-\psi(e).$$

The first-order necessary and sufficient condition for this problem is:

$$b(\hat{\theta})=e(\hat{\theta})\quad\text{for all }\hat{\theta}\text{ in }\Theta.\tag{2}$$

From which we deduce that the fixed-fee $a(\hat{\theta})$ extracts all expected profit from the agent when:

$$a(\hat{\theta})=b(\hat{\theta})\hat{\theta}+\frac{b^2(\hat{\theta})}{2},\quad\text{for all }\hat{\theta}\text{ in }\Theta.\tag{3}$$

We can define now a *separating perfect Bayesian Equilibrium* of our contractual game.

Definition 2 *: A separating perfect Bayesian equilibrium of the game of contractual offer is such that:*

[17] For completeness, we provide an example of pooling equilibrium in the Appendix.

- *A risk-averse principal with type θ offers a contract $t(\pi,\theta) = -a(\theta) + b(\theta)\pi$ with $b(\theta)$ being injective and*

$$a(\theta) = b(\theta)\theta + \frac{b^2(\theta)}{2}, \qquad \textit{for all } \theta \textit{ in } \Theta.$$

- *Given the offer $t(\pi,\hat{\theta})$, the risk-neutral agent chooses to participate to the contract and exerts the effort $e(\hat{\theta})$.*

- *A principal with type θ prefers to offer $t(\pi,\theta)$ rather than $t(\pi,\hat{\theta})$, i.e.:*

$$E\left(\upsilon(S + \pi - t(\pi,\theta))|\theta\right) \geq E\left(\upsilon(S + \pi - t(\pi,\hat{\theta}))|\theta\right). \tag{4}$$

- *Following any unexpected offer $t(\pi) \notin \{t(\pi,\hat{\theta})\}_{\hat{\theta}\in\Theta}$ (or alternatively $(a,b) \notin (a(\hat{\theta}), b(\hat{\theta}))_{\hat{\theta}\in\Theta}$) the agent holds pessimistic beliefs and believes with probability one that the principal has type $\underline{\theta}$,*

$$\mu(\underline{\theta}|t(\pi)) = 1.$$[18]

Let us characterize more precisely the principal's incentive compatibility constraints (4). Manipulating (4) by using (2) leads to:

$$\theta = \arg\max_{\hat{\theta}} \left\{ S + a(\hat{\theta}) + (1 - b(\hat{\theta}))(\theta + b(\hat{\theta})) - \frac{r\sigma^2}{2}(1 - b(\hat{\theta}))^2 \right\},$$

Or, to put it differently by using (3),

$$b(\theta) - \frac{r\sigma^2}{2}(1 - b(\theta))^2 - \frac{b^2(\theta)}{2} \geq b(\hat{\theta}) + b(\hat{\theta})(\hat{\theta} - \theta) - \frac{r\sigma^2}{2}(1 - b(\hat{\theta}))^2 - \frac{b^2(\hat{\theta})}{2} \tag{5}$$

From these incentive constraints, we can characterize the RSW equilibrium allocation.

Lemma 1 *: In any separating perfect Bayesian equilibrium, $b(\cdot)$ is monotonically decreasing and thus almost everywhere differentiable, $\dot{b}(\theta) \leq 0$.*

Using this lemma and the general techniques of Mailath (1987) for signaling games with a continuum of types, we can prove:

[18]Note that we incorporate into the definition of the separating allocation, the refinement criterion on beliefs *à la* Cho-Kreps.

Proposition 1 *: There exists a unique separating perfect Bayesian equilibrium, the RSW allocation* $(a^S(\cdot), b^S(\cdot))$*, characterized by the following conditions:*

$$\bullet \quad b^S(\underline{\theta}) = 1, \tag{6}$$

$$\bullet \quad \dot{b}^S(\theta) = -\frac{b^S(\theta)}{(1+r\sigma^2)(1-b^S(\theta))}. \tag{7}$$

$$\bullet \quad a^S(\theta) = b^S(\theta)\theta + \frac{(b^S(\theta))^2}{2}. \tag{8}$$

- *Out-of equilibrium beliefs*

$$\mu(\underline{\theta}|(a,b)) = 1 \quad \textit{for any} \quad (a,b) \notin \{a^S(\theta), b^S(\theta)\}_{\theta\in\Theta}.$$

- *That separating equilibrium survives Cho-Kreps criterion.*

The "local" incentive constraint (5) taken between types θ and $\theta + d\theta$ yields by simple differentiation the differential equation (7). Clearly, the "full-information on θ" outcome $b^*(\theta) = 1$ can never solve this differential equation. To separate himself from the nearby types $\theta - d\theta$ ($d\theta > 0$) the principal with a more valuable technology θ is willing to bear part of the risk associated to the project. By doing so, this principal can convince the agent of the quality of the technology and thus extract more from the agent with the fixed-fee. Of course, because of his own risk-aversion, doing so is costly. Less than the full marginal return of the project is left to the risk-neutral agent, $1 - b^S(\theta) < 0$ for all $\theta > \underline{\theta}$. Low-powered incentives result from the principal's willingness to signal his type. Because the risk-neutral agent is no longer residual claimant for the project returns, he has less incentives to provide effort than if θ were known. This points at the fundamental trade-off faced by the informed principal in this environment: selling the firm for a fixed-fee would provide full insurance and first-best incentives. However, it does not allow to convey information on the technology to the uninformed agent. Keeping some risk helps to signal a good technology and extract more from the agent but it has a detrimental cost on the latter incentives since it exacerbates moral hazard. We formalize this important insight in the next proposition.

Proposition 2 *: In the unique separating perfect Bayesian equilibrium:*

- *The risk-averse principal always bears some risk except when he has the worst technology* $\underline{\theta}$*:* $0 < b^S(\theta) < 1$ *for all* $\theta > \underline{\theta}$*;*

- *The profit sharing parameter* $b^S(\theta)$ *is greater as* r *and* σ^2 *increase;*

- *The risk-neutral agent exerts less than the first-best effort:* $e^S(\theta) < 1 = e^*$ *for all* $\theta < \bar{\theta}$*.*

The interesting new insight at this point comes from the comparative statics with respect to the principal's degree of risk-aversion r and the variance of the noise on the agent's performance σ^2. As the principal becomes more risk-averse or performances are more noisy, the cost of bearing some risk increases from the principal's viewpoint. It is not necessary for him to distort too much the slope of the incentive scheme to already credibly signal that the technology is efficient. The risk-neutral agent receives thus higher-powered incentives and $b^S(\cdot)$ is uniformly greater for all values of θ as r and σ^2 increases.

By the same token, the greatest distortion arises when the principal is risk-neutral. This means that, as the local government becomes bigger and maybe better diversified, it is more likely that contract for delegated management have very low powered incentives.

To represent this schedule, one may get an explicit expression for the equilibrium strategy, expressing θ as a function of the slope of the incentive scheme b using the fact that $b^S(\cdot)$ is invertible. Let denote $\theta^S(\cdot)$ this inverse function. We have:

$$\frac{d\theta^S}{db} = -(1 + r\sigma^2)\frac{(1-b)}{b}$$

and thus

$$\theta^S(b) - \underline{\theta} = (1 + r\sigma^2)(b - 1 - \log b). \tag{9}$$

We draw on Figure 1 that schedule for various values of $r\sigma^2$.

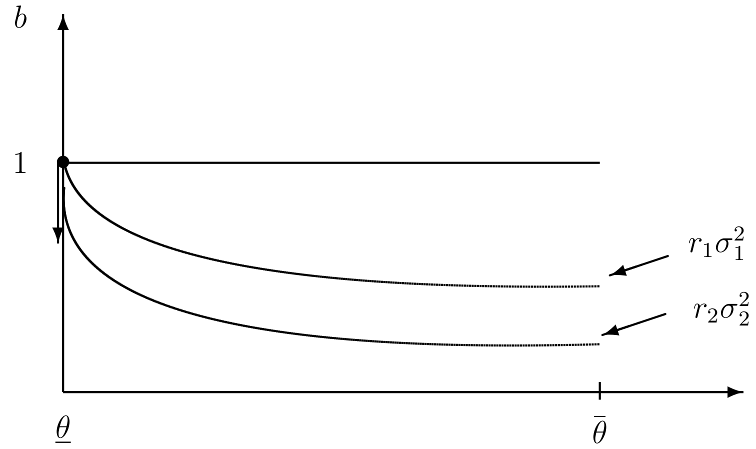

Figure 1: Equilibrium Schedules $r_1\sigma_1^2 > r_2\sigma_2^2$.

5 Extensions

5.1 Ownership Structures

Following Sappington and Stiglitz (1987), it is worth reinterpreting our results in terms of ownership structures. The principal with an inefficient technology finds it worth selling the whole activity to the private sector for a fixed-fee. It looks like privatizing management. Instead, the principal with a more efficient technology chooses to keep ownership of the productive assets and enjoy the return on these assets. He hires an external agent and proposes an incentive scheme which provides the agent less than the first-best incentives to exert effort even though the agent is risk-neutral and has unlimited liability.

To model ownership issues in a crude way, let us suppose, as most of the property right literature does, that profits are non-verifiable so that contracts are incomplete and cannot make use these profits as contracting variables. We follow Holmstrom and Milgrom (1991) and others in assuming that whoever owns the asset enjoys the full return streams on these assets. In our framework, this amounts to restricting the space of contracts available so that either $b = 1$ in the case of privatization or $b = 0$ in the case of in-house production. That strong restriction in the space of possible signals that may be used makes it of course impossible to sustain a fully separating equilibrium. Nevertheless, the principal may still set different lump-sum payments a_1 and a_2 depending on whether he chooses out-sourcing or in-house production.

Indeed, we are now looking for a semi-separating equilibrium with a cut-off rule θ^*. The principals with the most inefficient technologies ($\theta \leq \theta^*$) choose to privatize whereas those with the best technologies choose in-house production. In the first case, the agent exerts the first-best effort $e^* = 1$ whereas, no effort whatsoever is exerted under in-house production. This immediately yields that $a_2 = 0$ and

$$a_1 = \frac{1}{2} + \frac{\int_{\underline{\theta}}^{\theta^*} \theta f(\theta) d\theta}{F(\theta^*)}.$$

The cut-off type θ^* is just indifferent between the two strategies so that:

$$\theta^* = \frac{1 + r\sigma^2}{2} + \frac{\int_{\underline{\theta}}^{\theta^*} \theta f(\theta) d\theta}{F(\theta^*)}. \tag{10}$$

Obviously, θ^* is interior when:

$$\bar{\theta} > \frac{1 + r\sigma^2}{2} + E(\theta), \tag{11}$$

i.e., when there is enough uncertainty on the quality of the technology.

Proposition 3 : *Assume that (11) and (MHR) hold. When the only feasible contracts consist in allocating ownership rights, there exists a semi-separating perfect Bayesian equilibrium such that principals with types $\theta \leq \theta^*$ choose to privatize whereas principals with types $\theta > \theta^*$ choose in-house production. The cut-off θ^* is an increasing function of r and σ^2.*

That proposition shows that relying on the private sector is more likely as uncertainty is large or as the principal is more risk-averse. This suggests that municipalities who face a harder budget constraint and thus may be modeled as being more risk-averse are also more likely to privatize.

5.2 Risk-Averse Firms

The benchmark setting we started with was such that under complete information on θ, all risk should be shifted to the risk-neutral agent. In practice, firms are not as well diversified and may still be (at least to some extent), risk-averse when their access to the capital market is constrained.[19] In a situation where no asymmetry of information prevails (and even in the absence of moral hazard), the partnership between the public and the private sectors should optimally allocate risk according to the risk tolerances of both partners. Thus, the need for coinsurance determines a risk allocation which is less clear cut than what we saw in Section 3.

Let us denote by ρ the constant positive degree of risk-aversion of the agent. If the technology θ was common knowledge, the agent would choose an effort $e(\theta)$ such that

$$e(\theta) = \arg\max_e E\left(-a(\theta) + b(\theta)\tilde{\pi}|\theta, e\right) - \frac{\rho b^2(\theta)}{2} \text{ var } (\tilde{\pi}|\theta, e) - \psi(e)$$

and we find again

$$b(\theta) = \psi'(e(\theta)) = e(\theta). \tag{12}$$

To induce the agent's acceptance of the contract, the fixed-fee must be such that

$$\theta b(\theta) + \frac{(1 - \rho\sigma^2)b^2(\theta)}{2} - a(\theta) \geq 0. \tag{13}$$

Because inducing participation requires to leave a risk-premium to the agent, the principal cannot increase the fee $a(\theta)$ as much as with risk-neutrality.

[19] For instance, Leland and Pyle (1977) have argued that asymmetric information between a firm and outside investors who may help cofinancing its projects may be an obstacle to complete diversification.

The principal's problem becomes then

$$\max_{\{a(\theta),b(\theta)\}} a(\theta) + (\theta + b(\theta))(1 - b(\theta)) - \frac{r\sigma^2}{2}(1 - b(\theta))^2$$

subject to (13).

Obviously, the agent's participation constraint (13) is binding at the optimum. Inserting the expression of $a(\theta)$ into the maximand and optimizing with respect to $b(\theta)$ yields

$$b^*(\theta) = \frac{1 + r\sigma^2}{1 + (r + \rho)\sigma^2} < 1. \tag{14}$$

When the technology is common knowledge, the principal still bears a positive share of the risk to insure, at least partially, the risk-averse agent against fluctuations in profits. The higher the agent's degree of risk-aversion, the lower the power of his incentives and thus the lower the effort he provides.

Under asymmetric information on θ, let us still focus on the separating equilibrium, sustained with the same pessimistic out-of equilibrium beliefs as before. Given that (13) is again binding for such an equilibrium, we are looking for a schedule $b(\cdot)$ which satisfies:

$$\theta = \arg\max_{\hat{\theta}} \left(S + (\theta + b(\hat{\theta}))(1 - b(\hat{\theta})) - a(\hat{\theta}) - \frac{r\sigma^2}{2}(1 - b(\hat{\theta}))^2 \right)$$

where

$$a(\hat{\theta}) = \hat{\theta} b(\hat{\theta}) + \frac{(1 - \rho\sigma^2) b^2(\hat{\theta})}{2}.$$

This leads to the following incentive constraints:

$$\theta = \arg\max_{\hat{\theta}} \left\{ (\theta - \hat{\theta}) b(\hat{\theta}) - \frac{b^2(\hat{\theta})}{2}(1 + \rho\sigma^2) - \frac{r\sigma^2}{2}(1 - b(\hat{\theta}))^2 \right\}. \tag{15}$$

Using standard revealed preference arguments, we deduce that the equilibrium schedule $b^S(\cdot)$ is monotonically decreasing and thus almost everywhere differentiable with

$$\dot{b}^S(\theta) = -\frac{b^S(\theta)}{1 + r\sigma^2 - (1 + (r + \rho)\sigma^2) b^S(\theta)}, \quad \text{and} \quad b^S(\underline{\theta}) = b^*(\underline{\theta}). \tag{16}$$

Clearly, the qualitative behavior of the solution is much alike that of Section 3. In particular, we have:

Proposition 4 *: In the unique separating perfect Bayesian equilibrium, the risk-averse principal bears more risk than under complete information on θ: $b^S(\theta) \leq b^*(\theta)$ with equality only at $\underline{\theta}$. Moreover, as the agent becomes more risk-averse, $b^S(\theta)$ decreases.*

As the agent becomes more risk-averse, it becomes at the margin more difficult for the principal to signal the quality of his project by increasing the share of the risk he bears. As a result, greater distortions are needed under asymmetric information.

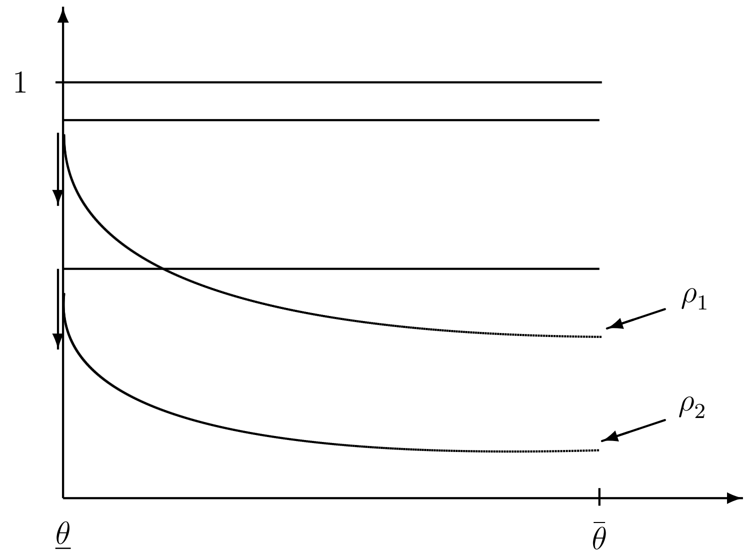

Figure 2: Impact of the agent's risk-aversion $\rho_1 < \rho_2$.

5.3 Double Moral Hazard

Let us now suppose that the principal has also to exert a non-verifiable maintenance effort or investment e_p to improve the quality of the infrastructure. The realized profit becomes

$$\tilde{\pi} = \theta + e + \alpha e_p + \tilde{\varepsilon},$$

where e_p cost $\psi(e_p) = \frac{e_p^2}{2}$ to the principal and α is a normalization parameter capturing the importance of the principal's investment into the project. This can be viewed as a modeling of the separation between the task of building and running public facilities that often takes place in private/public partnerships.

The organization faces a double moral hazard problem and, as a result, part of the risk must be borne by the risk-averse principal even under complete information on the technological parameter θ [20]. Let us start with this benchmark and denote by $(a(\theta), b(\theta))$

[20]Even though linear contracts are known not to be always optimal in this double moral hazard en-

a contract. The moral hazard incentive constraint of the principal can now be written as

$$\alpha(1 - b(\theta)) = e_p(\theta). \tag{17}$$

So that the principal's problem becomes

$$\max_{\{a(\theta),b(\theta)\}} S + a(\theta) + (1 - b(\theta))(\theta + e(\theta) + \alpha e_p(\theta)) - \frac{e_p^2(\theta)}{2} - \frac{r\sigma^2}{2}(1 - b(\theta))^2,$$

subject to (17) and

$$b(\theta) = e(\theta), \tag{18}$$

$$\theta b(\theta) + \alpha^2(1 - b(\theta))b(\theta) + \frac{b^2(\theta)}{2} - a(\theta) \geq 0, \tag{19}$$

where (18) and (19) are respectively the incentive and participation constraints of the agent. Of course the latter constraint is binding and the principal's objective function can be expressed in terms of $b(\theta)$ only as:

$$S + \theta + b(\theta) + \alpha^2(1 - b(\theta)) - \frac{b^2(\theta)}{2} - \frac{(r\sigma^2 + \alpha^2)}{2}(1 - b(\theta))^2. \tag{20}$$

Direct optimization leads to

$$b^*(\theta) = \frac{1 + r\sigma^2}{1 + r\sigma^2 + \alpha^2} < 1. \tag{21}$$

As his effort becomes more essential, providing incentives to the principal becomes then crucial. To do so, the principal must bear more risk and $b^*(\theta)$ decreases with α.

Let us now analyze the case of asymmetric information on the technological parameter θ. Proceeding as before, a separating equilibrium defined in terms of the $b(\cdot)$ schedule satisfies the following incentive constraints.

$$\theta = \arg\max_{\hat{\theta}} \left\{ S + \theta + b(\hat{\theta})(1 - \theta + \hat{\theta}) + \alpha^2(1 - b(\hat{\theta}))b(\hat{\theta}) - \frac{b^2(\hat{\theta})}{2} - \frac{(r\sigma^2 + \alpha^2)}{2}(1 - b(\hat{\theta}))^2 \right\}.$$

vironment (non-differentiable schemes may allow to implement the first-best efforts in teams), they are quite often used for their tractability. Romano (1994) analyzes the case of manufacturers/retailers relationships and shows that they implement the optimal levels of effort when the principal and the agent are both risk-neutral. In a more general framework allowing for partial observability of effort, Demski and Sappington (1991) exhibit a simple buy-out mechanism which gets rid of these double moral hazard problems.

From this, we deduce again that $b(\cdot)$ is monotonically decreasing, almost everywhere differentiable and that the equilibrium strategy $b^S(\cdot)$ satisfies:

$$\dot{b}^S(\theta) = -\frac{b^S(\theta)}{1 + r\sigma^2 - (1 + r\sigma^2 + \alpha^2)b^S(\theta)} \text{ and } b^S(\underline{\theta}) = b^*(\underline{\theta}). \tag{22}$$

Summarizing the previous lines and using the same technics as before, we can state the following proposition.

Proposition 5 *: In the unique separating perfect Bayesian equilibrium, the risk-averse principal bears more risk than under complete information on θ:*

$$b^S(\theta) \leq b^*(\theta) \text{ with equality at } \underline{\theta}.$$

As the principal's effort becomes more essential (α increases), $b^S(\theta)$ decreases. On the contrary, a greater risk-aversion or a more noisy performance leads to reduce $b^S(\theta)$.

As his effort is more valuable to the project, it becomes at the margin more difficult for the principal to signal the efficiency of his technology. Not only providing low-powered incentives to the agent signals that the technology is of a good quality but it increases the principal's own effort. Therefore, adding a double moral hazard problem tends to decrease the cost of signaling and more distortions are needed to credibly transmit information to the agent. Coming back on the interpretation of our model in terms of ownership structures, double moral hazard makes it very attractive to keep production in-house.

This increased cost of signaling suggests that the task of improving the quality of the facilities by making investments should also be delegated to the manager who runs the assets even in the absence of any technological complementarity between those two tasks.[21]

5.4 Political Economy

The fact that the equilibrium contract offered to the private sector depends explicitly on r under asymmetric information opens the door to differences in the contracts proposed to the private sector as political principals who differ in terms of their risk-tolerance hold office. Those policy differences may arise even though, when θ is common knowledge, any political principal, irrespectively of his own risk-tolerance, would choose to make the firm residual claimant.[22]

[21] On the issue of the optimal split between building and running public facilities see Bennet and Iossa (2002) and Hart (2003).

[22] On the role of incentive constraints in creating differences in the policies chosen by political principals, see Laffont (1996).

To draw consequences of that simple point on the kind of arrangements that emerge when political constraints are taken into account, consider an heterogenous population of agents who have risk-aversion r distributed according to the distribution $G(.)$ on an interval $[0, \bar{r}]$ with density $g = G'$. We denote r_m the median of a distribution and assume the distribution is symmetric around that median (which is also the mean) so that $r_m = \frac{\bar{r}}{2}$. Otherwise agents have the same share of the firm's profit and enjoy equally well the service.

It is well known that,[23] if the agents could coinsure among themselves, the aggregate expected welfare maximized by a social planner putting equal weight on all agents would also correspond to that of an agent having a degree of risk-aversion r_M being the harmonic mean of the population, namely

$$\frac{1}{r_M} = \int_0^{\bar{r}} \frac{g(r)}{r} dr.$$

Note that, for a symmetric distribution, Jensen inequality implies that $r_M < r_m$.

When markets are incomplete so that coinsurance is no longer feasible and when no redistributive policies among groups are available whatsoever, all agents are subject to the same risk. Suppose they vote *ex ante*, i.e., before θ is known to the political principal in office, over the latter's identity. Black Theorem applies and thus the median type ends up choosing the policy. Because $r_M < r_m$, this choice tends to induce excessively high-powered incentives with respect to those chosen if coinsurance was feasible.

The imperfection of the political process may justify an excessive trend towards high-powered incentives. Coming back to the interpretation of our model in terms of property rights, there may be excessive privatization induced by the political side of the game.

6 Delegated Signaling

6.1 Presentation

So far our model has neglected the fact that, political decision-makers are themselves delegated principals who act on behalf of society or on behalf of the various groups which compose it. Political principals receive their mandates from voters and may respond to various stimuli both from voters and from the industry with whom they interact.

An important issue is to understand how the agency problem between voters and political decision-makers affects the incentives to manipulate information towards the industry. Let us suppose that the political-decision maker in charge of choosing the firm's

[23] See Gollier (2001, Section 21.4).

contract $t(\pi, \theta)$ still knows the quality of the technology θ whereas voters remain ignorant of its value.

The political principal has preferences somewhat aligned with those of the industry and gives a positive weight $\alpha \in (0,1)$ to the firm's expected profit U in his objective function. This congruence may reflect the existence of political pressures exerted by the industry on the political principal maybe by means of lobbying or regulatory capture. At the same time, the political principal wants to please the electorate.

To deal with this important issue, we will first consider a very simple reduced form for the decision-makers utility function. Then, we will analyze more in depth the relationship between voters and the decision-maker and build a full model of *delegated signaling*.

6.2 An Ad Hoc Formulation

Suppose then that the political principal's utility function is defined in an ad hoc way as aggregating the interests of voters and the firm:

$$V = W + \alpha U$$

With this simple form, we do not yet model the contract between voters and the principal. Nevertheless, the mere fact that the latter takes into account not only voters' welfare but also the firm's utility modifies the contract offered to the private sector. Using the expressions for W and U, the principal's expected objective writes as:

$$E\left(S + \tilde{\pi}(1 - b(1-\alpha)) + (1-\alpha)a - \frac{\alpha e^2}{2}|\theta\right) - \frac{r\sigma^2}{2}(1-b)^2.$$

The solution under complete information still entails making the agent residual claimant by choosing $b^*(\theta) = 1$. Let us focus on the asymmetric information case and look at the separating equilibrium. Since $\alpha < 1$, the participation constraint of the agent will again bind and the fixed-fee is then defined by :

$$a(\hat{\theta}) = b(\hat{\theta})\hat{\theta} + \frac{b^2(\hat{\theta})}{2}, \quad \text{for all } \hat{\theta} \text{ in } \Theta. \tag{23}$$

In a fully separating equilibrium, the expected utility of a type θ principal who chooses to mimic a type $\hat{\theta}$ is:

$$S + \theta + b(\theta) + (1-\alpha)b(\hat{\theta})(\hat{\theta} - \theta) - b(\hat{\theta})(1-\alpha) - \frac{b^2(\hat{\theta})}{2} - \frac{r\sigma^2}{2}(1 - b(\hat{\theta}))^2 \tag{24}$$

Following the same steps as before, incentive constraints are easily deduced as well as the fact that $b(.)$ is monotonically decreasing:

$$\dot{b}(\theta) = -\frac{(1-\alpha)b(\theta)}{(1+r\sigma^2)(1-b(\theta))} \text{ and } \quad b^S(\underline{\theta}) = b^*(\underline{\theta}). \tag{25}$$

Since the principal takes into account the profit of the firm, he somewhat internalizes its incentives not to exert too much effort. The principal's incentives to lie about his type being smaller, the amount of separation needed for the schedule to be revealing is reduced. There is less risk-taking as α increases to one. In this case, in spite of the countervailing incentives that the principal is facing, he is still able to propose a credible separating equilibrium. When the contract between this principal and the voter is explicitly analyzed and modeled, this possibility vanishes as we see in the next section.

6.3 A Complete Model of Delegated Signaling

Now, we formally introduce the decision maker's benefits from holding office by considering the benefit T given from voters. This benefit can be viewed as the monetary equivalent of the discounted private benefit that the political decision-maker will obtain from keeping office in the future if he has sufficiently pleased the electorate. T can also be the campaign contribution that the principal may raise from the electorate. We will assume that T is a cost for the electorate. This is consistent with both interpretations above since, in the first case, voters suffers the opportunity cost of not electing a (potentially better) political principal tomorrow; in the second case, voters directly bear the monetary cost of the campaign contribution. His utility function is then written as :

$$V = T + \alpha U.$$

The voters' welfare W can still be expressed as before:

$$W = v(S + \pi - t(\pi, \theta) - T).$$

We will assume that the uninformed electorate offers first a contract to the political decision-maker. This contract aims at influencing the latter's choice to signal the technology to the firm.

Invoking the Revelation Principle, this contract stipulates the transfer $T(\hat{\theta})$, the fixed-fee $a(\phi(\hat{\theta}))$ and the slope of the firm's incentive scheme $b(\phi(\hat{\theta}))$ as a function of the delegated principal's *private report* $\hat{\theta}$ to the electorate and the *public report* $\phi(\hat{\theta})$ made to the firm. Of course, in a separating perfect Bayesian equilibrium, the optimal public manipulation $\phi(\cdot)$ will be equal to the identity and writing the corresponding incentive constraints for the coalition made of the voters and the political principals will give us monotonicity conditions on the $b(\cdot)$ schedule exactly as in the case of direct signaling.

For any $\phi(\cdot)$ function, the political principal's expected payoff when θ realizes and he reports privately $\hat{\theta}$ to the electorate can be written as:

$$U(\theta, \hat{\theta}) = T(\hat{\theta}) + \alpha \left((\theta + e(\phi(\hat{\theta})))b(\phi(\hat{\theta})) - \frac{e^2}{2}(\phi(\hat{\theta})) - a(\phi(\hat{\theta})) \right)$$

where $e(\phi) = b(\phi)$ for any ϕ from the firm's moral hazard incentive constraint.

Moreover, there is no loss of generality in imposing

$$a(\phi) = \phi b(\phi) + \frac{b^2(\phi)}{2}, \tag{26}$$

so that all the firm's expected profit can be extracted with this fee.

The delegated principal's incentive compatibility constraints for truthfully reporting θ to the electorate become (slightly abusing notations):

$$U(\theta) = \max_{\hat{\theta}} \left\{ T(\hat{\theta}) + \alpha(\theta - \phi(\hat{\theta}))b(\phi(\hat{\theta})) \right\}. \tag{27}$$

Of course, the political principal will participate if and only if

$$U(\theta) \geq 0. \tag{28}$$

Using the Envelop Theorem, we get:

$$\dot{U}(\theta) = \alpha b(\phi(\theta)), \tag{29}$$

with the second-order condition

$$\dot{b}(\phi(\theta))\dot{\phi}(\theta) \geq 0, \tag{30}$$

which simplifies to

$$\dot{b}(\theta) \geq 0, \tag{31}$$

when $\phi(\cdot) = Id$.

The electorate commits to the contract $\{T(\cdot), \phi(\cdot) = Id, b(\cdot), a(\cdot)\}$ before knowing the true value of θ. This contract should maximize the expected welfare of the electorate. Expressing $T(\theta)$ using (27), we can rewrite this problem as:

$$(P): \quad \max_{\{b(\cdot),\phi(\cdot),T(\cdot)\}} \int_{\underline{\theta}}^{\bar{\theta}} f(\theta) v \Bigg(S + \theta + \frac{1}{2} - \frac{(1 + r\sigma^2)}{2}(1 - b(\phi(\theta)))^2$$
$$+(1-\alpha)b(\phi(\theta))(\phi(\theta) - \theta) - U(\theta) \Bigg) d\theta$$

subject to (29) and (30),

with the added condition that $\phi^*(\cdot) = Id$ is the solution at the separating equilibrium, if any exists.

Because of the voters' risk-aversion, the solution to this problem is difficult to characterize in a very explicit way. To simplify, we will assume that $\Delta\theta = \bar{\theta} - \underline{\theta}$ is small enough so that voters are almost risk-neutral with respect to shocks on the quality of the technology. Problem (P) can thus be rewritten with $v(\cdot) = Id$.

Solving for the optimal contract, we then find:

Proposition 6 *: Assume that $(1-\alpha)\theta + \alpha\frac{1-F(\theta)}{f(\theta)}$ is increasing in θ. Then there cannot be a separating equilibrium. Voters offer to the political principal a contract which entails full pooling and low-powered incentives for the firm:*

$$b^p(\theta) = b^p = \max\left\{1 - \frac{\alpha}{1+r\sigma^2}(E(\theta) - \underline{\theta}), 0\right\}. \quad (32)$$

The intuition behind the pooling result is straightforward. Because his objective function is partly congruent with the firm's own objective, the delegated principal has incentives to understate the quality of the technology so that a smaller fixed-fee is paid by the agent. At the same time, voters would like to induce the delegated principal to overstate the technology to extract more from the firm. From those two countervailing forces, it results that no type-contingent contract can be used and thus $b(\cdot)$ must be constant.

Even with a pooling contract, higher values of b make it more valuable for the delegated principal to manipulate information *towards* the electorate as it can be seen from the incentive constraint (27). Reducing b puts thus a constraint on the delegated principal's discretion. Low powered incentives are again offered to the firm and a significant share of the risk remains kept by the electorate.

Note that this model of delegated signaling borrows quite a bit from Caillaud and Hermalin (1993) who were the first to model the use of an agent as a signaling device. The concerns of their paper is rather different from ours since they provide a general theory[24] where adverse selection in the relationship between the principal and the agent undermines but does not destroy (as here) incentives to separate. Our result on a non-informative equilibrium also bears some resemblance with signaling models where an agent signals his type simultaneously to multiple audiences which have conflicting interests as in Gertner, Gibbons and Sharfstein (1988) and Spiegel and Spulber (1997).

7 Conclusion

The goal of this article was to understand the various contractual forms that public/private partnerships may take. We argued that contracts result from a trade-off between the desire

[24] With discrete types whereas we use a continuum.

of localities to provide first-best incentives to the private sector in running and operating assets and their own incentives to signal the quality of the technology on sale. We then analyze how this trade-off would be modified by various considerations: political economy, double moral hazard, imperfect risk-sharing, delegated decision-making. All those considerations distort the cost of signaling and thus change the terms of trade-off between signaling and incentives.

In passing, our analysis has also shed some light on where the boundary between the private and the public sector should lie. Let us again follow Sappington and Stiglitz (1987) in interpreting residual claimancy contracts as private ownership. Then, our model predicts a strong negative correlation between the extent of private ownership and the power of incentives on the one hand and the quality of the network on the other hand. Varying the degree of risk-aversion of the principal, the size of the underlying uncertainty, or other organizational parameters, this interpretation of our model predicts the nature of the relationship between the government and the manager of the public utilities. Public ownership is more likely when high quality facilities are on stake, when principals are less risk-averse or when the noise in measuring the agent's performance is lower.

When the signaling issues stressed in this paper are taken into account, one is led to take with caution any empirical studies comparing efficiency and prices for the provision of services either by the public or the private sector. High quality infrastructures tend to be kept under public provision and thus that effect may mask any other fundamental advantages that private service providers may have.[25]

It would be worth to provide a number of extensions to our framework. A first obvious one would be to consider the case where the agent has also private information on his technology. Private information on the agent's side requires to leave some information rent to the agent in order to elicit information revelation. Following Laffont and Tirole (1993), we know the trade-off between rent extraction and efficiency tilts the contract towards being low-powered. This suggests that a principal may find it more difficult to signal his high quality technology in such a context and may thus push even further incentives towards being low-powered.

Still in a static framework, it would be worth to understand more properly how competitive bidding affects contractual terms. In our framework, we have supposed that potential service providers are all alike from an ex ante viewpoint. In reality, bidders may have also some private signals on the technology on sale. Those signals may come from having run this technology in earlier periods in the case of contract renewal or from having run a nearby facility. Bidders will bid differently depending on their signals and

[25]The existence of those advantages may come because private providers may benefit from some learning curve by being active on several markets at the same time or because they have more incentives to build a good reputation to conquer other markets.

the extent by which the principal will distort incentives for signaling reasons may depend on the precision of these signals.

Also, partnership between the public and the private sectors are most often durable commitments lasting over several years. Those commitments are not frozen and may vary constantly throughout the life of the contract to adapt to new conditions and to the adoption of new techniques. It would be important to understand how contracts are renegotiated in these environments. Our model differs from standard models of renegotiation in the literature[26] both in terms of the distribution of private information but also in terms of how information is learned over time. Indeed, not only the offer of a first period contract will signal endogenously information to the agent before later contracting but some information may also be learned by looking at the first realization of the profits. The pattern of information revelation in such settings is worth to analyze.

Lastly, our model supposes, as most of the literature on incentives does, that contracts are perfectly enforced. However, our framework may also be used as a building block towards the analysis of cases where those contracts are signed in environments where enforcement is more of an issue like in developing countries. Indeed, even though investments in key infrastructures like water networks is crucial to economic growth of such countries, contracts for concessionaries have been subject to much renegotiation which have often impeded development.[27]

We hope to investigate those issues in future research.

References

Arrow, K. (1975), “Vertical Integration and Communication,” *Bell Journal of Economics*, 6: 173-183.

Bajari, P. and S. Tadelis (2001), ”Incentives versus transaction costs: a theory of procurement contracts”, *RAND Journal of Economics*, 32: 387-407.

Beaudry, P. (1994), “Why an Informed Principal May Leave Rents to an Agent”, *International Economic Review*, 35: 821-832.

Bennet, J., and E. Iossa, (2002), “Building and Managing Public Services”, mimeo Brunel University.

Bentz, A., P. Grout and M. Halonen, (2002), “What Should the State Buy?”, mimeo University of Bristol.

[26] See Laffont and Tirole (1993, Chapter 10), Laffont and Martimort (2002, Chapter 9) and references therein.

[27] See Guash, Laffont and Straub (2002) for an empirical analysis of these costs with a reduced form model.

Caillaud, B. and B. Hermalin (1993), "The Use of an Agent in a Signalling Model", *Journal of Economic Theory*, 60: 83-113.

Cho, I. and D. Kreps (1987), "Signaling Games and Stable Equilibria", *Quarterly Journal of Economics*, 102: 179-222.

Demski, D. and D. Sappington (1991), "Resolving Double Moral Hazard Problems with Buyout Agreements", *Rand Journal Economics*, 22: 232-240.

Grossman, S. and O. Hart (1986), "The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration", *Journal of Political Economy*, 94: 691-719.

Gertner, R., R. Gibbons and D. Scharfstein (1988), "Simultaneous Signalling to the Capital and Product Market", *Rand Journal Economics*, 19: 173-190.

Gollier, C. (2001), *The Economics of Risk and Time*, MIT Press.

Guasch, L., J.J. Laffont and S. Straub (2002), "Renegotiation of Concession Contracts in Latin America", mimeo IDEI.

Hart, O., A. Schleifer and R. Vishny (1997), "The Proper Scope of Government: Theory and an Application to Prisons", *Quarterly Journal Economics*, 112: 1091-1126.

Hart, O., (2003), "Incomplete Contracts and Public Ownership: Remark and an Application to Public-Private Ownerships", *Economic Journal*, 113: 69-76.

Holmstrom, B. and P. Milgrom (1987), "Aggregation and Linearity in the Provision of Intertemporal Incentives," *Econometrica*, 55: 303-328.

Holmstrom, B. and P. Milgrom (1991), "Multi-Task Principal-Agent Analysis: Incentive Contracts, Assets Ownership and Job Design", *Journal of Law, Economics and Organization*, 7: 24-52.

Laffont, J.J. (1996), "Industrial Policy and Politics", *International Journal of Industrial Organization*, 14: 1-27.

Laffont, J.J. and D. Martimort (2002), *The Theory of Incentives: The Principal-Agent Model*, Princeton University Press.

Laffont, J.J. and J. Tirole (1993), *A Theory of Incentives in Procurement and Regulation*, MIT Press.

Leland, H. and D. Pyle (1977), "Informational Asymmetries, Financial Structure and Financial Intermediation", *The Journal of Finance*, 32: 371-387.

Lewis, T. and D. Sappington (1995), "Optimal Capital Structure in Agency Relationship", *Rand Journal of Economics*, 26: 343-361.

Loeb, M. and W. Magat (1979), "A Decentralized Method of Utility Regulation", *Journal of Law and Economics*, 22: 399-404.

Mailath, G. (1987), "Incentive Compatibility in Signaling Games with a Continuum of Types", *Econometrica*, 55: 1349-1365.

Maskin, E. and J. Tirole (1992), "The Principal-Agent Relationship with an Informed Principal 2: Common Values", *Econometrica*, 58: 379-410.

Riordan, M. (1990), "What is Vertical Integration", in M. Aoki, B. Gustaffson and O. Williamson, eds., *The Firm as a Nexus of Treaties*, Free Press.

Romano, R. (1994), "Double Moral Hazard and Resale Price Maintenance", *Rand Journal Economics*, 25: 455-466.

Sappington, D. and J. Stiglitz (1987), "Privatization, Information and Incentives", *Journal of Policy Analysis and Management*, 6: 567-582.

Schmidt, K. (1996), "The Costs and Benefits of Privatization: An Incomplete Contract Approach", *Journal of Law, Economics and Organization*, 12: 1-24.

Shapiro, C. and R. Willig (1990), "Economic Rationales for the Scope of Privatization", J.M. Ohlin Program for the Study of Economic Organization and Public Policy: 41.

Spiegel, Y. and D. Spulber (1997), "Capital Structure with Countervailing Incentives", *Rand Journal Economics*, 28: 1091-1126.

Thomas, A. and A. Reynaud (2000), "Demande Domestique en Eau et Choix de Délégation", *forthcoming Annales d'Economie et de Statistiques*.

Williamson, O. (1985), *The Economic Institutions of Capitalism*, Free Press.

Appendix

- **Proof of Lemma 1:** Using (5) and permuting θ and $\hat{\theta}$, we get:

$$-\frac{r\sigma^2}{2}(1-b(\hat{\theta}))^2 - \frac{b^2(\hat{\theta})}{2} \geq b(\theta)(\theta-\hat{\theta}) - \frac{r\sigma^2}{2}(1-b(\theta))^2 - \frac{b^2(\theta)}{2}. \tag{A1}$$

Summing (5) and (A1) yields

$$0 \geq (b(\theta)-b(\hat{\theta}))(\theta-\hat{\theta})$$

and thus $b(\theta)$ is monotonically decreasing and thus almost everywhere differentiable. ■

• **Proof of Proposition 1:** From (5), we have

$$\theta = \arg\max_{\hat{\theta}} \left\{ b(\hat{\theta})(1+\hat{\theta}-\theta) - \frac{r\sigma^2}{2}(1-b(\hat{\theta}))^2 - \frac{b^2(\hat{\theta})}{2} \right\}$$

which admits the necessary first-order condition

$$b(\theta) + (1+r\sigma^2)(1-b(\theta))\dot{b}(\theta) = 0. \tag{A2}$$

Note that $\dot{b}(\theta)$ is decreasing only when $b(\theta) \leq 1$. Candidate equilibria have thus to lie below 1 everywhere on $[\underline{\theta}, \bar{\theta}]$. They are all characterized by the initial value $b(\underline{\theta}) \leq 1$.

Moreover, given the out-of-equilibrium beliefs used, the best contract that $\underline{\theta}$ can choose is $b(\underline{\theta}) = 1$ with $a(\underline{\theta}) = \underline{\theta} + \frac{1}{2}$.

Still, given these out-of-equilibrium beliefs, a principal with type θ never chooses to offer another contract $(a, b) \notin \{a^S(\hat{\theta}), b^S(\hat{\theta})\}_{\hat{\theta}\in\Theta}$. To see why, note that the maximal payoff of such a deviation is achieved when $a = b\underline{\theta} + \frac{b^2}{2}$ and that

$$V(\theta) = b^S(\theta) - \frac{r\sigma^2}{2}(1-b^S(\theta))^2 - \frac{(b^S(\theta))^2}{2} \geq \max_{b\in[0,1]} \left\{ b(1+(\underline{\theta}-\theta)) - \frac{r\sigma^2}{2}(1-b)^2 - \frac{b^2}{2} \right\}. \tag{A3}$$

Note also that the maximand of the right-hand side is maximized for $b = 1$ and is worth $V(\underline{\theta}) - (\theta - \underline{\theta})$. Since the left-hand side of (A3) can be written as:

$$V(\theta) = V(\underline{\theta}) - \int_{\underline{\theta}}^{\theta} b^S(x)dx.$$

Condition (A3) holds when

$$1 > \int_{\underline{\theta}}^{\theta} b^S(x)dx,$$

for all $\theta > \underline{\theta}$ which holds since $b^S(x) < 1$ for all x in $[\underline{\theta}, \theta]$. ■

• **RSW allocation with a multiplicative technology:** As an alternative to the assumption made in the main text, consider the following form for the profit function:

$$\tilde{\pi} = \theta e + \tilde{\varepsilon}.$$

The complete information benchmark still leads to choose $b = 1$. Indeed, as usual, this financial contract at the same time provides full insurance to the principal and gives the maximal incentives to the now residual claimant agent.

In the asymmetric information case, the optimal separating contract is characterized by the following conditions:

$$* \quad b(\underline{\theta}) = 1 \tag{A4}$$

$$* \quad \dot{b}(\theta) = -\frac{\theta b(\theta)}{(\theta^2 + r\sigma^2)(1 - b(\theta))} \tag{A5}$$

$$* \quad a(\theta) = \frac{(\theta b(\theta))^2}{2}. \tag{A6}$$

With this multiplicative formulation, incentives compatibility conditions require that $(1-b(\theta))b(\theta)\theta$ be increasing. It turns out that with the previous solution (A5), this condition is always satisfied.

This necessary condition also determines the boundary condition, $b(\underline{\theta}) = 1$. Indeed,

$$(1 - b(\theta))b(\theta)\theta \text{ increasing} \Leftrightarrow \dot{b}(\theta)b(\theta)(1 - 2b(\theta)) + (1 - b(\theta))b(\theta) > 0 \tag{A7}$$

If $b(\theta) > 1$, we need $\dot{b}(\theta) < 0$ to satisfy the previous inequality. But, using (A5), this cannot be true. Therefore, $b(\theta) \leq 1$. Using this result and (A5), the boundary condition can be written as in the additive case as $b(\underline{\theta}) \leq 1$. And the best contract $\underline{\theta}$ can choose is still $b(\underline{\theta}) = 1$.

Therefore, the conclusions drawn from our additive model (partial insurance, $b(\cdot)$ decreasing with respect to θ and with a slope inversely related to the coefficient of risk-aversion) are robust. ■

• **Example of a pooling equilibrium:** Consider the following contract (a^p, b^p) defined by:

$$* \quad b^P = 1 \tag{A8}$$

$$* \quad a^p = E(\theta) + \frac{1}{2} \tag{A9}$$

and supported by the usual pessimistic out-of-equilibrium belief $\mu(\underline{\theta}|(a,b) \neq \{a^p, b^p\}) = 1$. In this equilibrium, the agent pays a fixed-fee equal to the average value of the project as long as he chooses the first best level of effort. This strategy is an equilibrium as long as the following condition holds :

$$E(\theta) - \underline{\theta} - \frac{(\overline{\theta} - \underline{\theta})^2}{2(1 + r\sigma^2)} \geq 0$$

Suppose on the contrary that the average quality $E(\theta)$ is close to the minimal quality $\underline{\theta}$ and consider the behavior of a principal with a high θ. As long as he follows this strategy, he his totally insured but only gets as a fixed-fee the average value (thus less than the real value of the project). When $E(\theta)$ is close to $\underline{\theta}$, this principal loses too much by making the agent residual claimant at this price. He is better off by choosing a small value of a but also a smaller b so as to benefit from the marginal return of his good technology. ■

• **Proof of Proposition 3:** To sustain that semi-separating equilibrium, suppose that any other offer is interpreted as coming from the principal with type $\underline{\theta}$ with probability 1. Clearly no type within $[\underline{\theta}, \theta^*]$ wants to deviate by still privatizing since the fee that could be extracted thereby is lower than a_1. The best deviation for in house production gives zero payoff to any of those principal and is thus dominated also.

Types within $[\theta^*, \bar{\theta}]$ never want also to deviate by privatizing because the fixed-fee they can get is always lower than a_1.

Let us finally conclude on the partition structure of the equilibrium. Denote $\phi(x) = \left(x - \frac{1+r\sigma^2}{2}\right) F(x) - \int_{\underline{\theta}}^{\theta^*} \theta f(\theta) d\theta$. θ^* is the only root of $\phi(x) = 0$ greater than $\underline{\theta}$ (note that $\phi(\underline{\theta}) = 0$. Note that $\phi'(x) = F(x) - \frac{1+r\sigma^2}{2} f(x)$. From (MHR), $\phi'(\cdot)$ changes sign at most once on $[\underline{\theta}, \bar{\theta}]$ and is first negative before being positive. θ^* is thus unique.

Moreover, denoting $\theta^*(r\sigma^2)$ the solution as a function of risk-aversion and the variance of profits, we have:

$$\phi(\theta^*(r_1\sigma_1^2)) = \frac{1}{2}(r_1\sigma_1^2 - r\sigma^2) F(\theta^*(r_1\sigma_1^2)) > 0$$

when $r_1\sigma_1^2 > r\sigma^2$. Hence, $\theta^*(r_1\sigma_1^2) > \theta^*(r\sigma^2)$. ■

• **Proof of Proposition 4:** Denote $b^S(\theta, \rho)$ the unique solution to (16) and note that $b^S(\underline{\theta}, \rho_1) > b^S(\underline{\theta}, \rho_2)$ for $\rho_1 < \rho_2$. Suppose there exists $\theta_1 > \underline{\theta}$, the lowest value of θ such that $b^S(\theta_1, \rho_1) = b^S(\theta_1, \rho_2)$. Then at that point, we have $\dot{b}^S(\theta_1, \rho_2) < \dot{b}^S(\theta_1, \rho_1) < 0$ and thus $b^S(\theta_1, \rho_1) > b^S(\theta, \rho_2)$ for θ in $[\theta_1 - \varepsilon, \theta_1]$ for ε small enough. A contradiction. ■

• **Proof of Proposition 6:** Let us first neglect the second-order condition of the political principal's problem (30).

From (28) binding at $\underline{\theta}$ only and (29) , we get

$$U(\theta) = \alpha \int_{\underline{\theta}}^{\theta} b(\phi(x)) dx. \tag{A10}$$

Inserting into the voters' objective function and integrating by parts yields a new expression for (P)

$$(P)': \quad \max_{\{\phi(\cdot), b(\cdot)\}} \int_{\underline{\theta}}^{\bar{\theta}} f(\theta) \Bigg(S + \theta + \frac{1}{2} - \frac{(1 + r\sigma^2)}{2}(1 - b(\phi(\theta))^2$$
$$+ (1-\alpha) b(\phi(\theta))(\phi(\theta) - \theta) - \alpha \frac{1 - F(\theta)}{f(\theta)} b(\phi(\theta)) \Bigg) d\theta. \tag{A11}$$

Pointwise optimization shows that $\phi^*(\theta) = \theta$ is the solution of this problem when

$$-\frac{(1+r\sigma^2)}{2}(1-b(\theta))^2 - \alpha\frac{1-F(\theta)}{f(\theta)}b(\theta)$$
$$\geq -\frac{(1+r\sigma^2)}{2}(1-b(\hat{\theta}))^2 + (1-\alpha)b(\hat{\theta})(\hat{\theta}-\theta) - \alpha\frac{1-F(\theta)}{f(\theta)}b(\hat{\theta}), \quad \text{(A12)}$$
$$\text{for all } (\theta,\hat{\theta}) \text{ in } \Theta^2.$$

Adding (A13) with a similar condition obtained by permuting θ and $\hat{\theta}$ yields

$$(b(\hat{\theta}) - b(\theta))\left((1-\alpha)\hat{\theta} + \alpha\frac{1-F(\hat{\theta})}{f(\hat{\theta})} - \left((1-\alpha)\theta + \alpha\frac{1-F(\theta)}{f(\theta)}\right)\right) \leq 0. \quad \text{(A13)}$$

Assuming that $(1-\alpha)\theta + \alpha\frac{1-F(\theta)}{f(\theta)}$ is increasing with θ yields that $b(\theta)$ should be monotonically decreasing and thus almost everywhere differentiable with

$$\dot{b}(\theta) \leq 0. \quad \text{(A14)}$$

Clearly, (A14) and (32) are conflicting and there cannot be any fully separating equilibrium.

Let us look for a pooling equilibrium (sustained with passive beliefs) such that $b(\theta) = b^p$ for all θ in Θ.

Inserting into (A11) and optimizing in the case of a pooling contract yields

$$(1+r\sigma^2)(1-b^p) - \alpha\int_{\underline{\theta}}^{\bar{\theta}}(1-F(\theta))d\theta = 0,$$

and thus b^p is given by (32). ■