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

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Abstract

This article analyzes the shape of contracts between local governments and the contractors they hire to run public facilities on their behalf. Governments are privately informed about the quality of the facility while risk neutral contractors undertake a non-verifiable operating effort. The design of the contract signals the quality of the facility in such a way that the better this quality, the greater the share of operating risk kept by the government. This feature reduces the agent's marginal incentives, creating a trade-off between signaling and moral hazard. We provide extensions of our framework in several directions allowing for risk aversion on the agent's side, double moral hazard and political delegation. The model is supported by some stylized facts from the water industry.

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1 Introduction

Consider a local government seeking to procure a public good or service on behalf of its citizens. On top of choosing the exact nature of the good or service provided, the government has also to decide the production mode. It may either manage the service itself under public ownership or outsource the activity to the private sector. In that case, a private company is selected following a bidding procedure. A partnership is then developed between the local government and the company which provides the service. The goal of this paper is to understand the contractual forms that such delegated management may take when the quality of the infrastructure is key to the social value of the service.

Although the scope of our analysis is more general, the water industry provides a meaningful illustration of this problem. Local governments have indeed to decide whether to delegate water production to the private sector or to maintain it under their own control. Partnerships between the public and the private sectors for distributing drinking water or treating waste water differ greatly from one municipality to the next. In France for instance, although some localities still manage production through public agencies – the so-called *régies municipales* – the dominating contractual form over the past century has been leasing contracts or *"affermage"*.[1] In this case, a private entity, independent of the local government, is hired to manage the service and operate facilities. These facilities may have been built and operated in the past by the municipalities themselves. In the course of such operations, municipalities acquire private knowledge about the quality of the existing assets.[2] Within this class of leasing contracts, various kinds of arrangements can be found which differ in terms of how financial and operating risks are shared. Those contracts typically involve a lump-sum payment, a fixed regulated price for consumers and a share of the realized profit. Depending on the share left to the contractors, the contracts may embody high power incentives to exert effort in operating and managing assets, or instead implement much lower power incentives.

One critical feature of the water industry is the fact that, although the quality of the infrastructure drives the price paid by consumers, the quality of the service, here water supply, is easily verifiable. Indeed, either in the U.S. with the Safe Drinking Water Act or in France with the 1992 Water Act, the minimal water quality standards are the same for all water providers and are quite easily checked by regulators. A second important feature of this activity, as for many public services,[3] is that rather small and poorly diversified local governments delegate to private contractors - typically, large private companies operating on several markets - the management of assets on which the local governments have a priori private information.

[1] Similar contracting forms can be found in the U.K. and elsewhere in the world. In the US, 2400 municipally owned water utilities are operated in partnership with private contract operators. This business has grown an average 19% per year over the last seven years.

[2] For instance, a municipality may learn which of the existing assets (pumps, water pipes, metering systems, etc...) should be renovated and when.

[3] Water wastes, waste disposal and transportation would be other significant examples.

Starting from those specific features, this paper presents a theory explaining the shape of delegation contracts and the kinds of public/private partnerships which can emerge in practice. When a local government (hereafter the principal) is privately informed about the quality of the infrastructure that a potential service provider (the agent) will use, the design of concession contracts acts as a signal of the facility quality to the private sector. We analyze how this signaling issue interacts with the moral hazard problem that the local government faces when it delegates production to the private sector.

Local governments are assumed to be risk averse. In a regulatory context, this assumption has been defended by Lewis and Sappington (1995) who argue that it can be viewed as a convenient short-cut to model financial constraints especially when those regulators represent small localities. Had the quality of the infrastructure been common knowledge, risk aversion on the principal's side would justify shifting all risk to the private sector not only for insurance reasons but also because it provides full incentives when the agent's effort in running assets is non-observable in a moral hazard environment.

Instead, when the local government is privately informed on the assets quality, contract design results from the interaction between two major forces. On the one hand, by keeping a share of the financial and operational risk, the local government credibly conveys information on the quality of the infrastructure. On the other hand, by keeping some risk, the local government reduces the agent's incentives to exert an effort. There is thus a trade-off between signaling and moral hazard. At a separating equilibrium of our game of contractual offers, local governments with a high quality infrastructure are ready to pay a premium to separate themselves from those with a low quality one.

Our model provides a number of sharp predictions. First, in the fully separating perfect Bayesian equilibrium we select, the amount of risk kept by the local government increases with the quality of the infrastructure. The private sector is made residual claimant only for the worst infrastructures. When profit results both from the intrinsic quality of the infrastructure and from the contractor's effort, profit is a U-shaped function of the infrastructure quality. Second, full privatization emerges only for the worst quality infrastructures whereas the best ones remain under public management. Indeed, because sometimes profits are not easily verifiable, profit-sharing schemes between the public and the private sectors cannot always be written. In this case, the only signaling tool available to the local government is whether it retains assets ownership or not. Fully separating allocations can certainly no longer occur in such environments because the crude allocation of property rights cannot account for the continuum of possible values of the assets quality. A semi-separating equilibrium may nevertheless arise where public ownership and low power incentives come with the high quality assets whereas private ownership and high power incentives prevail otherwise.

The empirical evidence on the impact of ownership on performance are hard to interpret, since most of them are rather partial, and often suffer from an endogeneity bias - ownership being itself something to be explained. Nevertheless, the few studies taking into account this bias are consistent with our main prediction, i.e., the positive relationship between public ownership/low power incentives and infrastructure quality.

Let us now review the relevant literature. Although our primary concern is on the shape of concession contracts, this paper is also more broadly related to the literature on privatization and to the lively debate on the boundary between the private and the public sectors. An important benchmark is given there by the *"Irrelevance Theorem"* due to Sappington and Stiglitz (1987). This Theorem establishes that, provided contracting takes place ex ante (i.e., before any uncertainty is resolved) between a risk neutral private firm and a government, delegating production to the private sector comes with no loss even though control of the productive assets may give an informational advantage to the operating firm. We depart from their assumptions by assuming that the principal already possesses private information at the time of contracting with the private sector. The principal becomes then an active player with his own incentives to manipulate information. This cost of signaling makes full privatization less attractive than in Sappington and Stiglitz (1987) and provides a fresh perspective on the make-or-buy problem.[4] Other authors, such as Hart, Shleifer and Vishny (1997) and Hart (2003), have analyzed the impact of allocating residual rights of control à la Grossman and Hart (1986) on incentives to perform specific investments. For instance, Hart, Shleifer and Vishny (1997) have investigated the costs and benefits of private ownership in a framework where the quality of the service is non-verifiable. They highlight a trade-off between an excessive tendency to reduce both quality and cost under private ownership and an incentive to reduce only quality under public ownership. Although it applies reasonably well for some public services (like prison management for instance), this trade-off does not seem so relevant for others like water supply, waste disposal, and transportation, where the major concern is with the existing quality of the infrastructure not with the quality of the service itself which is observable and heavily regulated.

The idea that an informed and risk averse party may want to bear part of the financial risk of a project to signal its quality to risk neutral parties is well known in the finance literature beginning with the seminal paper by Leland and Pyle (1977). Building on a similar insight, Perotti (1995) has shown how partial privatization may in fact help a government to signal its willingness not to behave opportunistically once the sector is privatized. Contrary to this literature, profits are endogenous in our paper and depend on the effort of the agent to whom the production task is delegated. This leads to an interesting trade-off between signaling and moral hazard which explains the existing mixed evidence on ownership patterns and efficiency.

Bajari and Tadelis (2001) also discuss delegation to the private sector versus direct public management. Focusing on the choice between fixed-price and cost plus contracts, they show why

[4] 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 ex ante contracting is no longer possible.

the latter may be preferred. Cost-plus contracts allow ex post efficient renegotiation in spite of their perverse impact on the agent's cost reducing effort. They interpret cost-plus contracts as in-house production while fixed-price contracts are identified with outsourcing. There as well as in Levin and Tadelis (2004), the analysis follows an incomplete contracting approach where quality which is an essential feature of the service remains non-verifiable. As we argued above, this assumption does not seem to correspond to cases where the quality of the service is in fact regulated by law. We see thus our approach as complementary to theirs.

Lastly, our model belongs to the realm of informed principal theory. Because the agent's expected returns depend on the quality of the assets he operates, the model entails common values *à la* Maskin and Tirole (1992) with the added twist that the agent exerts a non-verifiable effort. Since we consider instead a model with a continuum of possible quality levels for the infrastructure, we have to rely on the tools developed by Mailath (1987) to characterize fully separating allocations. 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 the principal may want to decrease the bonus and, when types are discrete and sufficiently apart, give some positive rents to a risk neutral employee to signal a good technology. In our model with a continuous level of quality, rent extraction always occurs for the separating equilibria we focus on.

Section 2 describes the model. Section 3 presents the case where the quality of the infrastructure is common knowledge. Section 4 is the core of the paper. We introduce there private information on the principal's side, highlight the basic trade-off between signaling and incentives and discuss its impact on the ownership structure. Section 5 explores several extensions of the model. Section 6 discusses our findings in view of the empirical literature on the efficiency of the private and the public sectors in the water industry. Section 7 concludes. Proofs are relegated to an Appendix.

2 The Model

We consider the relationship between a risk averse principal and a risk neutral agent producing a public service on behalf of the principal. To produce, the agent uses assets whose quality is only known by the principal. This principal can be thought of as a small and poorly diversified locality. The risk neutral agent represents instead a large firm which is generally well-diversified since it might operate also in a large number of similar markets. Although we keep in mind water supply as the main application of the paper, this hierarchical relationship can also be viewed as a canonical model for the delegated management of most public services.

The gross consumer's benefit from the project is exogenously fixed at S which is known by both the principal and the agent. The project yields a random profit $\tilde{\pi}$ to the agent. This profit depends first on the innate quality θ of the facility used to provide the service. In the case of water supply, this can be viewed as the quality of the water network which is, to a large extent, only known by the principal at the time of delegating its management. This assumption is certainly relevant when the principal has already built and run the service himself for a long time under some form of public ownership.

The quality parameter θ belongs to the set $[\underline{\theta}, \bar{\theta}]$. It is drawn from an atomless distribution $F(\cdot)$ having an everywhere positive density $f(\cdot)$. We denote by $E(\theta)$ the average quality of the infrastructure.

By exerting an effort e which has a non-monetary cost $\psi(e) = \frac{e^2}{2}$, the agent increases realized profits. This effort is supposed to be non-observable so that the principal faces a moral hazard problem when delegating production to the agent.

Realized profits are also affected by some random shock $\tilde{\varepsilon}$ which is normally distributed with zero mean and variance σ^2. This randomness captures all the financial and operational risks the operator may face.[5]

Finally, realized profits increase with the innate quality of the technology, the manager's effort and the random shock through the simple additive formula:

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

Those realized profits are the only observable variables available to write a contract between the principal and his agent. Since profits are verifiable, this is a matter of convention to assume that the principal enjoys directly those profits and pays the agent a transfer $t(\tilde{\pi})$ to perform the public service on his behalf.[6]

The principal has a CARA utility function, $\upsilon(\cdot)$, with a coefficient of risk aversion $r > 0$. Risk aversion is justified in the case of a local government for which the service to be delegated represents a significant share of its overall budget.[7]

For tractability, we will focus on linear profit-sharing contracts between the principal and his agent. Those contracts are of the form $t(\tilde{\pi}) = b\tilde{\pi} - a$. The fraction $b \in [0, 1]$ represents a bonus parameter proportional to the realized profit. This bonus will determine the agent's marginal incentives to provide effort whereas a is a fixed-fee paid by the agent to the local government to get access to the assets. Those contracts are thus similar to those found in practice. Indeed, contracts for delegated management involve generally the payment by a company of a lump-sum and a proportional bonus. Of course, restricting the analysis to those linear contracts may entail a loss of generality. Nevertheless, we will see below that linear contracts are already enough to implement the optimal outcome when the quality of the infrastructure

[5] 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.

[6] Things are of course different in the case of non-verifiable profits analyzed in Section 4.2.

[7] Again, this is certainly the case for water supply.

θ is common knowledge. Under asymmetric information, optimality of the linear contracts is generally not obtained.[8] However, restricting the analysis to simple linear contracts leads us to a quite tractable analysis which shows simply how signaling issues affect contracting. Maintaining this linearity assumption allows also for clearer comparisons with the benchmark of complete information.

Following our conventions, only a fraction $1-b$ of the profit is kept by the principal. Henceforth, the certainty equivalent of the principal's utility can be written as:

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

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

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

The agent's outside opportunity gives him a reservation payoff that is exogenously normalized to zero. The fact that the principal has all bargaining power in contracting with the agent captures the existing ex ante competition among identical potential service providers.

3 Complete Information

When the quality of the infrastructure θ is common knowledge, signaling is not a concern. The contractual solution is then well-known. The principal can achieve the first-best outcome by selling to the risk neutral agent the rights to provide the service for a fixed-fee $a^*(\theta)$ and letting that agent bear the full consequences of his effort choice which amounts to set a maximal bonus $b^*(\theta) = b^* = 1$.[9] Accordingly, in some of the interpretations of our model below, we will sometimes refer to an activity as being privately controlled when the manager of the public utility enjoys all the marginal returns of his activity.

With this linear *sell-out contract*, the agent has full incentives to exert effort and cost minimization leads to a first-best effort level e^* which is independent of the technology, $\psi'(e^*) = e^* = 1$. This scheme provides also full insurance to the principal since he enjoys a fixed return $a^*(\theta)$ whatever the operational costs. Finally, the fixed-fee $a^*(\theta)$ is set by the principal to extract the whole expected profit from running the facilities made by the agent so that:

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

Importantly, the principal extracts more from the agent as the technology improves (the fixed-fee $a^*(\theta)$ increases with θ). The principal has thus strong incentives to overstate the

[8] We are not aware of any work deriving fully optimal contracts in our signaling environment.

[9] A sell-out contract would also still be optimal if the principal could commit ex ante, i.e., before he knows θ. With such a contract, the principal would then be fully insured against both operational and quality shocks, the agent would still have maximal incentives and his expected profit could again be extracted.

quality of the technology when it is non-observable by the agent. Asymmetric information on the quality of the technology will induce a cost of signaling information to the uninformed agent if the principal wants to credibly convince this agent that the infrastructure is of a good quality. We investigate the nature of that cost in the next section.

4 Delegated Management

4.1 Profit Sharing Schemes and Separating Contracts

Let us now suppose that only the principal knows θ at the time of contracting. The principal wants to design a mechanism which both induces effort from the risk neutral agent and signals the value of the assets. From a theoretical viewpoint, this is an informed principal problem in a moral hazard environment with common values since the principal's type θ affects directly the agent's expectations over the realized profits. [10]

To describe separating equilibrium allocations, we first define a separating contract as a family of profit-sharing schemes $\left\{t(\pi,\hat{\theta})\right\}_{\hat{\theta}\in\Theta}$ such that different types of principals offer different schemes. Given the linearity of the contracts, those schemes are fully defined in terms of the pairs $\{(a(\hat{\theta}),b(\hat{\theta}))\}_{\hat{\theta}\in\Theta}$.[11]

The mere offer of such a separating contract $\{(a(\theta),b(\theta))\}_{\theta\in\Theta}$ signals to the agent the innate quality of the assets θ. The agent chooses then both whether to participate or not and the effort level $e(\theta)$ he will undertake.

Using the concavity of the agent's objective function, this effort is fully defined from the bonus as:

$$e(\theta) = \arg\max_{e} E\left(b(\theta)\tilde{\pi} - a(\theta)|\theta, e\right) - \psi(e) = b(\theta) \quad \text{for all } \theta \text{ in } \Theta. \tag{2}$$

This effort choice is thus independent of the fixed-fee. However, this fixed-fee has an impact on the agent's decision to participate which requires:

$$a(\theta) \le E\left(b(\theta)\tilde{\pi}|\theta, e(\theta)\right) - \psi(e(\theta)) = \theta b(\theta) + \frac{(b(\theta))^2}{2} \quad \text{for all } \theta \text{ in } \Theta. \tag{3}$$

[10] Because we model a game with a continuum of types, Maskin and Tirole (1992)'s methodology for informed principal games does not directly apply. In their approach, the principal can a priori offer a mechanism including an extra round of communication ex post, i.e., when the agent has already accepted the contract and the principal communicates his type. We will reduce the space of available mechanisms by suppressing this communication stage. The mere offer of a linear contract signals through the choice of the fixed-fee and the bonus the principal's innate type. With this simplifying feature in hands and a simple equilibrium refinement that we describe below, we will be able to use the techniques developed by Mailath (1987) for signaling games with a continuum of types to derive fully separating allocations.

[11] Separating equilibria are attractive in our context because the equilibrium allocation does not depend on the probability of the different types. Moreover, in a discrete two-type version of our model, it can be shown that the least-costly separating allocation that we select survives standard refinements for signaling games like the Cho-Kreps criterion (Cho and Kreps (1987)) and Divinity (see Banks and Sobel (1987)).

We can now define a *separating perfect Bayesian equilibrium* of our contractual game as follows:

Lemma 1 *: A separating perfect Bayesian equilibrium of the game of contractual offer is a family of linear contracts $t(\pi,\hat{\theta}) = -a(\hat{\theta}) + b(\hat{\theta})\pi$ for all $\hat{\theta} \in \Theta$ such that:*

- $t(\pi,\cdot)$ *is a one-to-one mapping from* Θ *into the space of linear contracts of the form* $-a+b\pi$.
- *Given the offer* $t(\pi,\hat{\theta})$*, the risk neutral agent accepts the contract and exerts the effort* $e(\hat{\theta})$.
- *A principal with type* θ *prefers to offer* $t(\pi,\theta)$ *rather than* $t(\pi,\hat{\theta})$*:*

$$\theta = \arg\max_{\hat{\theta}} \left\{ S + a(\hat{\theta}) + (1-b(\hat{\theta}))(\theta + b(\hat{\theta})) - \frac{r\sigma^2}{2}(1-b(\hat{\theta}))^2 \right\}. \tag{4}$$

- *Following any unexpected offer* $t(\pi) = -a + b\pi \notin \{t(\pi,\hat{\theta})\}_{\hat{\theta}\in\Theta}$*, the agent holds the most pessimistic beliefs* [12] $\mu(\underline{\theta}|t(\pi)) = 1$ *which implies that the principal prefers the equilibrium contract* $t(\pi,\theta)$ *to any other unexpected offer that may be accepted by the agent:*

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

$$\max_{\{b\in[0,1], a\leq\underline{\theta}b+\frac{b^2}{2}\}} \{S + a + (1-b)(\theta+b) - \frac{r\sigma^2}{2}(1-b)^2\}. \tag{5}$$

There are many possible schedules $a(\cdot)$ which satisfy both the agent's participation constraint (3) and the principal's incentive constraints (4) and (5). Among these equilibria, we shall focus on the *undominated* ones from the principal's viewpoint. For those allocations, the agent's participation constraint (3) is in fact binding. We thereby easily derive the fixed-fee from this binding constraint and rewrite the principal's incentive compatibility constraint (4) as:

$$\theta = \arg\max_{\hat{\theta}} \left\{ S + \theta + \frac{1}{2} + (\hat{\theta}-\theta)b(\hat{\theta}) - \frac{(1+r\sigma^2)}{2}(1-b(\hat{\theta}))^2 \right\}. \tag{6}$$

Therefore, in any undominated separating equilibrium, the signal used by the principal ends up being really one-dimensional. This allows us to apply the techniques due to Mailath (1987) to characterize the unique undominated separating equilibrium of our game.

Lemma 2 *: In any undominated separating perfect Bayesian equilibrium,* $b(\cdot)$ *is monotonically decreasing and thus almost everywhere differentiable with* $\dot{b}(\theta) \leq 0$.

[12] Those pessimistic beliefs are similar to those used in Mailath (1987). This allows us to adapt his findings to our setting even though, a priori, the principal can signal his type through a two-dimensional vector (a,b) whereas Mailath (1987) considers only one-dimensional signaling.

Using Lemma 2, we get the following characterization:

Proposition 1 *: Assume that $\bar{\theta} - \underline{\theta} < \frac{1}{2}(1 + r\sigma^2)$.*[13] *There exists a unique undominated separating perfect Bayesian equilibrium $(a^S(\cdot), b^S(\cdot))$ characterized as follows:*

- $$b^S(\underline{\theta}) = 1, \tag{7}$$
- $$\dot{b}^S(\theta) = -\frac{b^S(\theta)}{(1 + r\sigma^2)(1 - b^S(\theta))}. \tag{8}$$
- $$a^S(\theta) = b^S(\theta)\theta + \frac{(b^S(\theta))^2}{2}. \tag{9}$$

This equilibrium is sustained with pessimistic out of equilibrium beliefs:

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

The "local" incentive constraint (6) taken between two nearby types θ and $\theta - d\theta$ yields (8) by simple differentiation. Clearly, the "full-information" outcome $b^*(\theta) = 1$ never solves this differential equation. To separate himself from the nearby type $\theta - d\theta$ ($d\theta > 0$), a principal with type θ must keep a share of the operational risk associated to the project.

By incurring those signaling costs, the principal can convince the agent of the quality of the infrastructure and extract more from the agent with the fixed-fee. Of course, the agent no longer enjoys the full return on any profit-enhancing effort he may undertake. Formally, $1 - b^S(\theta) > 0$ for all $\theta > \underline{\theta}$. Low power incentives result then from the principal's willingness to signal his type. This points at the fundamental trade-off faced by the informed principal in this environment. Selling the firm for a fixed-fee would provide the agent with first-best incentives. However, it does not convey information to the uninformed agent and, accordingly, the principal would have to offer a lower fixed-fee to convince the agent to participate. Keeping part of the operational risk signals a better technology to the agent. This strategy has nevertheless two costly drawbacks. On the one hand, the risk averse principal is no longer fully insured. On the other hand, since the risk neutral agent no longer enjoys the full return on his effort, the incentives to work are reduced.

We formalize these important insights in the next proposition.

Proposition 2 *: Assume that $\bar{\theta} - \underline{\theta} < \frac{1}{2}(1 + r\sigma^2)$. The unique undominated separating perfect Bayesian equilibrium has then the following features:*

- *The risk averse principal always bears a share of the operational risk except when assets are of the worst quality $\underline{\theta}$, $0 < b^S(\theta) < 1$ for all $\theta > \underline{\theta}$;*

[13] This qualifier ensures that unexpected deviations are never profitable when the equilibrium is sustained with pessimistic out-of-equilibrium beliefs.

- *The profit sharing parameter $b^S(\theta)$ is greater as r and σ^2 increase and as θ decreases;*
- *The risk neutral agent exerts less than the first-best effort except for the worst quality assets, $e^S(\theta) \leq 1 = e^*$ for all $\theta \leq \bar{\theta}$ with equality only at $\bar{\theta}$.*

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. The more risk averse the principal is and the noisier the agent's performance, the more the principal's expected utility decreases after a small reduction in b. As the local government becomes more risk averse or performances are more noisy, signaling becomes easier because even keeping only a small share of the risk may have a significant cost in terms both of risk borne and of dampened incentives. The agent is under high power incentives and $b^S(\cdot)$ is uniformly greater for all values of θ as r and σ^2 increases. At the extreme, the greatest distortion arises when the principal is risk neutral since the cost of signaling due to the loss of insurance now disappears.

Henceforth, if one thinks of risk aversion as a modeling short-cut for fiscal or financial constraints at the local government level, our model predicts that relaxing those constraints reduces the incentive power of concession contracts.

So far our results suggest that, since efficient management and first-best incentives only come with the worst technologies, there could be a strong negative profit relationship between infrastructure quality and performances. This view is in fact only partially correct as shown in the next proposition:

Proposition 3 *Assume that $(log2 - \frac{1}{2})(1 + r\sigma^2) < \bar{\theta} - \underline{\theta} < \frac{1+r\sigma^2}{2}$. Then, there exists $\hat{\theta} \in [\underline{\theta}, \bar{\theta}]$ such that the firm's expected profit in equilibrium is decreasing with θ as long as $\theta < \hat{\theta}$ and increasing otherwise.*

To understand how profit changes with the quality of the infrastructure, one must take into account two conflicting effects. First, increasing the quality raises the level of profit for a given effort level. Second, since effort is equal to the bonus parameter, it decreases with the quality of the infrastructure. The first of these effects may dominate only for large uncertainty on quality whereas the first one is always present even for the worst technologies. The total impact on the equilibrium profit level may therefore be ambiguous and profit as a function of θ may be U-shaped.

4.2 Ownership Structures

It is worth reinterpreting our results in terms of ownership structures. To model ownership in a crude way, let us suppose, as the property right literature does, that profits are non-verifiable so that contracts are incomplete and profit-sharing schemes are not feasible. We follow Holmström and Milgrom (1991) and others in assuming that whoever owns the assets enjoys the full return streams on these assets.[14] If assets are under public ownership, the principal enjoys all return streams on those assets even though he may not run those assets himself and still has to hire a civil servant or to set up a bureau to operate them. If assets are privately owned, the operating agent enjoys the returns.

In our framework, distinguishing between those two ownership structures amounts to restricting the space of contracts available so that either $b = 0$ under public ownership or $b = 1$ under private ownership. This restriction on the space of possible signals that the principal may use makes it of course impossible to sustain a fully separating equilibrium. The principal may nevertheless still set different lump-sum payments a_1 and a_2 depending on whether he relies on private or public ownership even though he is no longer able to fine tune contract design to the quality of the infrastructure.

Let us thus look for a semi-separating equilibrium with a cut-off rule θ^*. A principal having a sufficiently bad quality infrastructure ($\theta \leq \theta^*$) chooses to privatize whereas he chooses public production otherwise. In the first case, the agent exerts the first-best effort $e^* = 1$ whereas, no effort whatsoever is exerted under public ownership. 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 privatizing or not 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 4 *: Assume that (11) and* $\frac{d}{d\theta}\left(\frac{F(\theta)}{f(\theta)}\right) > 0$ *hold. When the only feasible contracts consist of allocating ownership rights ex ante, there exists a semi-separating perfect Bayesian equilibrium such that a principal with type* $\theta \leq \theta^*$ *chooses to privatize whereas he chooses public ownership when his type* $\theta > \theta^*$*. The cut-off* θ^* *increases with* r *and* σ^2*.*

A local government with a low quality infrastructure finds it worth selling the assets to the private sector for a fixed-fee. Instead, a local government with a high quality infrastructure chooses to keep ownership of the productive assets and to enjoy all returns on these assets.

[14] The implicit assumption here is that whoever owns the asset has all the ex post bargaining power in the negotiation that may take place between the principal and the agent to share ex post profit. This assumption although very convenient from a modeling standpoint could be relaxed.

Proposition 4 suggests that local governments who face a harder budget constraint and thus could be modeled as being more risk averse are also the more likely to privatize.

Public ownership is more likely when high quality facilities are at stake, when principals are less risk averse or when the noise in measuring the agent's performance is lower. The fact that high quality infrastructures tend indeed to be kept under public ownership may thus mask any other cost advantages that private service providers may have.

5 Extensions

5.1 Risk Averse Firms

With a risk neutral firm and under complete information on θ, all operational risks should be shifted to the agent. In practice, firms are not as well diversified. Because of the large scale projects they sometimes manage, they may be modeled (at least to some extent) also as being risk averse.[15] Even when the quality of the infrastructure is common knowledge, an optimal partnership between the local government and the firm should allocate risk according to the risk tolerances of both parties. Concerns for coinsurance determine a risk allocation which is less extreme than what we saw in Section 3.

Let us denote by ρ the constant degree of risk aversion of the agent, assuming that the agent's preferences are represented by a CARA utility function. If the quality parameter θ is common knowledge, the agent chooses an effort $e(\theta)$ such that

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

and we find again that $e(\theta)$ is given by (2).

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

$$\theta b(\theta) + \frac{(1-\rho\sigma^2)}{2} b^2(\theta) - a(\theta) \geq 0. \tag{12}$$

Because the agent must receive a risk-premium to participate, the principal cannot increase the fee $a(\theta)$ as much as with a risk neutral firm.

Under complete information on θ, 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 (12).

The agent's participation constraint (12) is binding at the optimum. Inserting the corresponding expression of $a(\theta)$ into the maximand and optimizing with respect to $b(\theta)$ yields the

[15] This is particularly the case when their access to the capital market is restricted.

expression of the optimal bonus:

$$b^* = \frac{1 + r\sigma^2}{1 + (r + \rho)\sigma^2} < 1. \tag{13}$$

Note that this bonus is independent of θ.

When the quality of the assets is common knowledge, the principal still bears a positive share of the operational risk to, at least partially, insure 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 moral hazard.

Let us now turn to the case of interest where there is asymmetric information on θ, still focusing on the undominated separating equilibrium such that the agent's participation constraint (12) is binding and sustained with the same pessimistic out-of-equilibrium beliefs as before. We are looking for a decreasing schedule $b(\cdot)$ which satisfies:

$$\theta = \arg\max_{\hat{\theta}} \left(S + \theta + \frac{1}{2} + (\hat{\theta} - \theta)b(\hat{\theta}) - \frac{(1 + r\sigma^2)}{2}(1 - b(\hat{\theta}))^2 - \frac{\rho\sigma^2}{2} b^2(\hat{\theta}) \right). \tag{14}$$

Standard revealed preferences arguments show that the equilibrium schedule $b^S(\cdot)$ is monotonically decreasing and thus almost everywhere differentiable. Following the same steps as in Proposition 1, this schedule satisfies:

$$\dot{b}^S(\theta) = -\frac{b^S(\theta)}{(1 + r\sigma^2)\left(1 - \frac{b^S(\theta)}{b^*}\right)}, \quad \text{and} \quad b^S(\underline{\theta}) = b^*. \tag{15}$$

Clearly, the qualitative behavior of the solution is much like that of Proposition 1. In particular, we have:

Proposition 5 *: Assume that $\bar{\theta} - \underline{\theta}$ is small enough. In the unique undominated separating perfect Bayesian equilibrium, the risk averse principal bears more risk than under complete information on θ: $b^S(\theta) \leq b^*$ 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 is more difficult for the principal to signal the quality of the infrastructure by increasing the share of the operational risk he bears since he must already bear some risk for coinsurance purposes. Therefore, credibly conveying information on the quality of the infrastructure requires to significantly distort the bonus below its value had quality being common knowledge. Formally, $b^S(\theta)$ decreases with the agent's risk aversion ρ. Reinterpreting this result in terms of ownership structures along the lines of Section 4.2., risk aversion on the agent's side makes the case for public ownership stronger.

5.2 Double Moral Hazard

As an owner of the infrastructure, the local government may also have to undertake a non-verifiable investment e_p to improve or maintain the quality of the existing infrastructure. The realized profit that the firm may get now depends not only on the agent's effort but also on the principal's investment as follows:

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

where e_p costs $\psi(e_p) = \frac{e_p^2}{2}$ to the principal and α is a normalization parameter capturing the importance of the principal's investment into the project. Thanks to our additive formulation, there is some substitutability between the investment made by the principal and the agent's effort which is a distinguishing feature of most public/private partnerships.[16]

Because investment is non-verifiable, the design of the concession contract must now solve a double moral hazard problem. A share of the operational risk should also be borne by the risk averse principal even if the quality of the infrastructure were common knowledge, just to give him incentives to invest. Let us start with this benchmark. The first-order condition for the principal's moral hazard incentive constraint is:

$$e_p(\theta) = \alpha(1 - b(\theta)). \tag{16}$$

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 (2), (16) and

$$\theta b(\theta) + \alpha^2(1 - b(\theta))b(\theta) + \frac{b^2(\theta)}{2} - a(\theta) \geq 0, \tag{17}$$

where (17) is now the agent's participation constraint. Of course, this last constraint is binding and direct optimization leads to an optimal bonus independent of θ:

$$b^* = \frac{1 + r\sigma^2}{1 + r\sigma^2 + \alpha^2} < 1. \tag{18}$$

As his investment becomes more essential, providing incentives to the principal is more of a concern. The principal must thus bear more risk and the agent's bonus b^* decreases with α.

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

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

[16] On this substitutability between investment and operating effort, see for instance Daniels and Trebilcock (2002).

From this, we deduce again that the equilibrium strategy $b^S(\cdot)$ is monotonically decreasing, almost everywhere differentiable and that $b^S(\cdot)$ satisfies again (15).

Proceeding as before, we can state the following proposition.

Proposition 6 *: Assume that $\bar{\theta} - \underline{\theta}$ is small enough. In the unique undominated separating perfect Bayesian equilibrium, the risk averse principal bears more risk than under complete information on θ: $b^S(\theta) \leq b^*$ with equality at $\underline{\theta}$ only. As the principal's effort becomes more essential (α increases), $b^S(\theta)$ decreases. On the contrary, greater risk aversion of the principal and noisier performance of the agent increase $b^S(\theta)$.*

As his effort becomes more valuable to the project, the principal finds it more difficult to signal the quality of the assets. Providing low power incentives to the agent both signals that the technology is good and increases the principal's own effort. Under double moral hazard, the cost of signaling decreases and more distortions are needed to credibly signal the quality of the infrastructure. Should we interpret our model in terms of ownership structures as in Section 4.2, double moral hazard would make it very attractive to keep public ownership.

This increase in the cost of signaling might also suggest that the task of improving the quality of the facilities should also be delegated to the manager who runs the assets even in the absence of any technological complementarity between those two tasks.[17]

5.3 Delegated Signaling

So far we have crudely modeled the behavior of the local government. We have assumed away two possible conflicts of interests which may impact on the design of concession contracts. First, there might be a conflict between uninformed voters and the informed public decision-maker who may want to please the labor force employed in these utilities[18] or to cajole the firm's shareholders in view of raising future campaign contributions. Second, even when political principals are benevolent representatives of the electorate, there may still be a conflict between elected political principals and the technical bureaus in charge of designing concession contracts and restructuring ownership patterns.

To model these conflicts and analyze their impact, we envision now a hierarchy consisting of a top principal representing voters and an intermediate principal whose objectives are partly aligned with those of the industry and who has private information on the quality of the infrastructure. We are interested in the extent to which the design of concession contracts as well

[17] On the issue of the optimal split between building and running public facilities, see Bennet and Iossa (2002) and Hart (2003) in incomplete contracting models and Martimort and Pouyet (2005) in an agency framework.

[18] In this respect, the ownership structure does not really affect this congruence of interests between the decision-maker and the firm's labor force. Of course, it is clear that under public ownership, political decision-makers may find a source of jobs in public utilities to get political support. However, private owners are often contractually forced not to undertake any downsizing of the labor force.

as the decision to rely on public or private management reflect these possible conflicts of interests and whether this extra degree of delegation biases the choice of the ownership structures in any direction.

To capture the different political stimuli that may affect decision-making in local governments, we assume that the intermediate principal has preferences which give a positive weight $\alpha \in (0,1)$ to the firm's expected profit U in his objective function. This congruence of interests with the industry may reflect the existing political pressures exerted by the firm and its labor force on this principal. At the same time, this principal wants to please voters and respond to their incentives.

More precisely, let us suppose that incentives to this intermediate principal are provided by means of a monetary transfer T obtained from voters. Although having the intermediate principal respond to monetary incentives may be viewed as an ad hoc assumption, this approach is quite tractable and provides a convenient modeling short-cut to encompass the discounted private benefit that this principal obtains from retaining office by sufficiently pleasing the electorate. Alternatively, this transfer T can also be viewed as the campaign contribution that the principal may raise from the electorate. We will assume that T is costly to provide for the electorate. This is consistent with both interpretations above. In the first case, voters suffer from the cost of not electing a (potentially better) political principal tomorrow. In the second case, they directly bear the monetary cost of the campaign contributions.

Taking into account both the electorate and the industry's stimuli, the intermediate principal's utility function can then be written as :

$$V = T + \alpha U$$

where the weight on the firm's profit, α, is less than one.

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

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

where, for simplicity, we assume from now on that voters are risk neutral.

The uninformed electorate first offers a contract to the political decision-maker. This contract aims at influencing the latter's choice of bonus that signals quality to the firm. More specifically, viewed as an indirect mechanism, the incentive contract $T(b)$ offered by the electorate specifies a monetary reward for the intermediate political principal as a function of his choice of a bonus for the firm. We assume that the contract between the electorate and the principal is not observable by the firm. Only the choice of a bonus made by the intermediate principal is.[19]

[19] Caillaud and Hermalin (1993) also modeled the use of an agent as a signaling device. Their concern is rather different from ours since they provide a general theory with discrete types where adverse selection in the principal-agent relationship undermines but does not destroy incentives to separate.

Of course, in a separating equilibrium (if any exists), the equilibrium bonus $b^e(\theta)$ is invertible. The firm then infers that assets are of quality $(b^e)^{-1}(b)$ if it observes that the principal chooses any bonus b in the range of $b^e(\cdot)$, $rg(b^e)$. When choosing a bonus b in that range and the true quality of the infrastructure is θ, the political principal gets an expected payoff:

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

where $e = b$ from the agent's incentive constraint and $a = (b^e)^{-1}(b)b + \frac{b^2}{2}$ so that the fixed-fee extracts all the firm's expected profit when the firm infers that the assets quality is $(b^e)^{-1}(b)$.

In any separating equilibrium, the intermediate principal's incentive compatibility constraints can be expressed as:

$$U(\theta) = \max_{b \in rg(b^e)} \left\{T(b) + \alpha(\theta - (b^e)^{-1}(b))b\right\}. \tag{19}$$

The electorate commits to the contract $T(b)$ before knowing the true value of θ. This contract should thus maximize the expected welfare of the electorate and leads to a separating allocation $b^e(\cdot)$. Solving for such separating equilibrium, we then find:

Proposition 7 *: Assume that $(1-\alpha)\theta + \alpha\frac{1-F(\theta)}{f(\theta)}$ is increasing in θ. Then there cannot be any separating equilibrium.*

There exists instead a pooling equilibrium such that the intermediate principal offers a constant bonus whatever the quality of the infrastructure:

$$b^p(\theta) = b^p = \max\left\{1 - \alpha(E(\theta) - \underline{\theta}), 0\right\} < 1. \tag{20}$$

The intuition behind the pooling result is straightforward. Because his objective function is partly congruent with the firm's own objective, the intermediate principal wants to understate the quality of the technology so that a smaller fixed-fee is paid by the firm and the latter gets an information rent. At the same time, the basic signaling force of the previous sections still matters so that voters would like to induce the intermediate principal to overstate the technology to extract more from the firm. Because of those two countervailing forces, no type-contingent contract can be used. Instead, a pooling equilibrium may be sustained.

Even with a pooling contract, higher values of the bonus b increase the information rent that the intermediate principal can pocket. Indeed, the intermediate principal knows the realized value of θ and has an objective partly congruent with the residual profit of the firm, i.e., whatever the firm really gets minus the constant fixed-fee. A greater bonus increases this rent which is socially costly. A lower value of b reduces this rent and thereby puts a constraint on the discretion of the intermediate principal. Low power incentives are again offered to the firm and a significant share of the risk is retained by the electorate.[20]

Should we interpret of our model in terms of ownership structures as before, the existing conflict of interests between voters and delegated principals would call now for an unconditional shift towards more public ownership whatever the quality of the infrastructure.

6 Evidence From Water Utilities

The main prediction drawn from our theoretical model is that local governments rely more heavily on high power incentives and on the private sector as the quality of the infrastructure decreases.

In the empirical literature, a first approach examines the links between ownership and performance by estimating an aggregate cost function for water utilities. Ownership effects are usually captured by means of a dummy variable. For the U.S., Renzetti and Dupont (2003)[21] show that this method does not allow us to draw robust conclusions in favor of a specific ownership structure.

One of the key assumptions of this approach is that firms, either public or private, minimize costs. The agency literature shows that this assumption should be made with caution.[22] Other empirical studies have thus tried to compare private and public performances using a different approach. For example, Bhattacharyya *et al* (1995) use a stochastic production frontier approach to measure the impact of ownership on efficiency for water utilities in the U.S.. They show that ownership matters and that public firms are more efficient than private firms.

One may nevertheless argue that even those empirical studies focusing on cost-minimization distortions may not give a full account of the links between ownership structure and efficiency. Some studies for France (Orwin (1999)) and for a sample of Californian communities (Houtsma (2003)) tend to show that the private sector prices exceed those in the public sector by about 20%. This is often explained (Buller (1996)) by the fact that privatized utilities are more numerous in areas where costs of supply are higher. This piece of evidence suggests that there exists a strong technological bias in the choice of the ownership structure.[23]

The empirical investigation made by Reynaud and Thomas (2005) of the water industry in

[20] Our result on a non-informative equilibrium bears some resemblance with pure signaling models where an agent signals his type simultaneously to multiple audiences with conflicting interests as in Gertner, Gibbons and Sharfstein (1988) and Spiegel and Spulber (1997).

[21] See also earlier studies by Crain and Zarkoohi (1978), Bruggink (1982) and Feigenbaum and Teeples (1983).

[22] Gagnepain and Ivaldi (2002) uses a production frontier analysis which takes seriously this agency problem. Although their concern is not water utilities but transportation in French local communities and they focus on private information on the contractor's side, they also recognize that the quality of service aggregates both an adverse selection and a moral hazard component which are estimated.

[23] See also Duso and Röller (2003) for a similar point.

the South-West of France is probably the best available evidence of this technological bias and, as such, it provides strong evidence for our theory. They recognize that it is misleading to treat ownership as an exogenous variable when estimating the cost function of water utilities. Taking into account the technological bias, Reynaud and Thomas (2005) investigate the determinants of water demand for more than one hundred French cities or communities (which is a group of cities that collectively engage in water distribution). They ask whether delegation to the private sector has any impact on water demand estimates and which characteristics, either observable or unobservable, determine the choice to delegate to the private sector. When one estimates water demand for a given community, it is quite natural to consider as explanatory variables data concerning its population (age, wealth), the city itself (size, density) and possibly the choice between direct and delegated management. This method, however, is potentially biased since the last variable is certainly endogenous. A two-stage procedure is more appropriate and this is the route followed by Reynaud and Thomas (2005). The first stage models the choice between direct and delegated management. The second one integrates the previous result in the demand equation. We are mainly interested in the first stage of the estimation procedure. In addition to the standard explanatory variables (size, population density, industrial density), Reynaud and Thomas (2005) also allow the quality of the network to predict whether direct or delegated management is chosen. In the water industry, greater leakage is a property of a lower efficient network. Since leakage occurs between the production stage and the distribution (which is metered and billed), a natural measure of network quality, is the ratio of billed water to produced water. The results of Reynaud and Thomas (2005) are clear: the higher the ratio, the greater the probability that the municipally chooses direct management. This relationship is significant at the 1% level. Even though Reynaud and Thomas (2005) do not present a full economic model of choice between direct and delegated management, their empirical results are consistent with our theory.

7 Conclusion

The goal of this article was to understand the various contractual forms that delegated management of public utilities may take. We argued that the shape of those contracts results from a trade-off between the desire of local governments to provide first-best incentives to the private sector in running and operating assets and their own incentives to signal the quality of these assets. We then analyze how this trade-off would be modified by various considerations: double moral hazard, imperfect risk-sharing, or delegated decision-making. All those considerations distort the cost of signaling and thus change the terms of trade-off between signaling and incentives. These extensions have all in common that low power incentives (its extreme form being public ownership in incomplete contracting environments) prevail for a large set of parameters and that there exists a negative correlation between the power of incentives and the quality of the infrastructure.

This analysis has thus shed some light on where the boundary between the private and the public sector should lie. Following Sappington and Stiglitz (1987) in interpreting residual claimancy contracts as private ownership, 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 infrastructure on the other hand. In the case of the water industry, some empirical studies seem to confirm this prediction.

It would be interesting to study several other extensions of our framework. First, it would be worth understanding more properly how competitive bidding affects contractual terms. We have supposed that potential service providers are identical from an ex ante viewpoint. In reality, bidders may have also some private signals on the assets to be used. 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 with similar features, a case which is particularly relevant for water utilities. Bidders will then bid differently depending on their signals and the extent by which the principal will distort incentives for signaling reasons may depend on the precision of these signals.

Second, a standard paradigm in the analysis of procurement contracts has been to model firms as having private information on their cost. Extensions of our framework to this double-asymmetric information setting would be worth undertaking. The standard lessons in the literature is that extracting the service provider's information rent calls for reducing the power of incentives (see Laffont and Tirole (1993) for instance). Cast in terms of our model, bonuses should be reduced. It is easy to extrapolate some of our findings to that case. We expect adverse selection to increase the cost of signaling, calling for even lower power incentives and, again broadening interpretation, an even stronger bias towards public ownership.

Also, partnerships between the public and the private sectors are most often durable commitments lasting over several years. Those commitments are not frozen and may vary 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. A dynamic version of our model would differ from standard models of renegotiation in the literature (see Laffont and Tirole (1993) or Laffont and Martimort (2002)) 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 endogenously signal information to the agent before later stages of 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 would be worth analyzing.

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 concession contracts are signed in environments where enforcement is a real concern like, for instance, in some developing countries. Indeed, even though investments in key infrastructures like for water or transportation are crucial to the economic growth and welfare of such countries, contracts for concessionaries have been subject to much renegotiation which have often impeded development.[24] Renegotiation would be interesting to study within the framework of this paper. We hope to investigate those issues in future research.

Appendix

• **Proof of Lemma 1:** The proof is straightforward and follows directly from the definition of a separating perfect Bayesian equilibrium when off equilibrium path deviations induce pessimistic beliefs. ■

• **Proof of Lemma 2:** Using (6) for types θ and $\hat{\theta}$, we get:

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

Permuting types, we get instead:

$$-\frac{(1+r\sigma^2)}{2}(1-b(\hat{\theta}))^2 \geq b(\theta)(\theta-\hat{\theta}) - \frac{(1+r\sigma^2)}{2}(1-b(\theta))^2. \tag{A2}$$

Summing (A1) and (A2) 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 (6), we have

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

which admits the necessary first-order condition

$$b(\theta) + (1+r\sigma^2)(1-b(\theta))\dot{b}(\theta) = 0. \tag{A3}$$

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 $b(\underline{\theta}) \leq 1$. Indeed, given the out-of-equilibrium pessimistic beliefs used, the best contract that the principal can offer when his type is $\underline{\theta}$ is $b(\underline{\theta}) = 1$ with $a(\underline{\theta}) = \underline{\theta} + \frac{1}{2}$. Together with (A3), this initial condition defines uniquely the equilibrium schedule $b^S(\theta)$.

Given pessimistic out-of-equilibrium beliefs, a principal with type θ never chooses to offer another contract $(a, b) \notin \{a^S(\hat{\theta}), b^S(\hat{\theta})\}_{\hat{\theta}\in\Theta}$ when condition (5) holds. To see why, note that the

[24] An empirical analysis of these costs with a reduced form model is proposed in Guash, Laffont and Straub (2002).

maximal payoff of such a deviation is achieved when $a = b\underline{\theta} + \frac{b^2}{2}$ and the maximum payoff from such a deviation for principal θ is

$$\max_{b\in[0,1]} S + \underline{\theta}b + \frac{b^2}{2} + (1-b)(\theta+b) - \frac{r\sigma^2}{2}(1-b)^2.$$

This maximum is achieved for $b^{off}(\theta) = 1 - \frac{\theta-\underline{\theta}}{1+r\sigma^2}$ which is a positive number when $\bar{\theta}-\underline{\theta} \leq 1+r\sigma^2$. An unexpected deviation yields thus to the principal at most:

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

Denote by $V^S(\theta)$ the equilibrium value of the principal's payoff. By definition, we have $V^S(\underline{\theta}) = V^{off}(\underline{\theta})$, $\dot{V}^S(\theta) = 1 - b^S(\theta)$ and $\dot{V}^{off}(\theta) = 1 - b^{off}(\theta)$. Hence, a sufficient condition to ensure that $V^S(\theta) \geq V^{off}(\theta)$ is $b^S(\theta) \leq b^{off}(\theta)$.

First, note that $b^S(\underline{\theta}) = b^{off}(\underline{\theta}) = 1$ and that $\dot{b}^S(\underline{\theta}) = -\infty < \dot{b}^{off}(\underline{\theta}) = -\frac{1}{1+r\sigma^2}$ so that $b^S(\theta) < b^{off}(\theta)$ on a right-neighborhood of $\underline{\theta}$. Let us find a condition ensuring that this inequality remains true over the whole domain of definition $[\underline{\theta}, \bar{\theta}]$. Denote then by θ_1 the first value of $\theta > \underline{\theta}$ such that $b^S(\theta) = b^{off}(\theta)$. At this point, if it exists on $[\underline{\theta}, \bar{\theta}]$, we should have $\dot{b}^S(\theta_1) = -\frac{b^{off}(\theta_1)}{(1+r\sigma^2)(1-b^{off}(\theta_1))} \geq \dot{b}^{off}(\theta_1) = -\frac{1}{1+r\sigma^2}$. This cannot occurs for any $\theta_1 \in [\underline{\theta}, \bar{\theta}]$ if $b^{off}(\theta_1) > \frac{1}{2}$. This gives us the condition $\bar{\theta} - \underline{\theta} < \frac{1+r\sigma^2}{2}$. ■

• **Proof of Proposition 3:** The agent's expected profit conditional on the quality of the infrastructure, $E(\pi|\theta)$, is defined as $E(\pi|\theta) = \theta + b(\theta)$. Using the expression of $\dot{b}^S(\theta)$, we find:

$$\frac{dE(\pi|\theta)}{d\theta} = 1 + \dot{b}^S(\theta) = 1 - \frac{b^S(\theta)}{(1+r\sigma^2)(1-b^S(\theta))}. \tag{A4}$$

which is positive if and only if $b^S(\theta) \leq b^S(\hat{\theta}) = \frac{1+r\sigma^2}{2+r\sigma^2}$, i.e., for $\theta \geq \hat{\theta}$ large enough since $b^S(\cdot)$ is decreasing. Note that $b^S(\hat{\theta}) \geq \frac{1}{2}$, so that[25] $\hat{\theta} - \underline{\theta} < (log2 - \frac{1}{2})(1+r\sigma^2) < \frac{1+r\sigma^2}{2}$ and thus such $\hat{\theta}$ exists within $[\underline{\theta}, \bar{\theta}]$ when $(log2 - \frac{1}{2})(1+r\sigma^2) < \bar{\theta} - \underline{\theta} < \frac{1+r\sigma^2}{2}$. ■

• **Proof of Proposition 4:** To sustain that semi-separating equilibrium, suppose that any other unexpected offer[26] is interpreted as coming from the principal with type $\underline{\theta}$ for sure. 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 public production gives zero payoff to any of those principals and is thus dominated also.

Types within $[\theta^*, \bar{\theta}]$ never want to deviate by privatizing and offering an off the equilibrium fixed-fee which is acceptable because the fixed-fee they can get is always lower than a_1 and they already choose not to take it.

[25]Let $\theta^S(\cdot)$ denote the inverse function of $b^S(\cdot)$. We have $\frac{d\theta^S}{db} = -(1+r\sigma^2)\frac{(1-b)}{b}$ and thus $\theta^S(b) - \underline{\theta} = (1+r\sigma^2)(b - 1 - \log b)$. We use this expression to compute an upper bound on $\hat{\theta}$.

[26]Since the two feasible bonus 0 and 1 are indeed used on the equilibrium path, the only concerns for unexpected deviations come from the specification of the fixed-fee.

Let us finally conclude on the partition structure of the equilibrium. Denote $\phi(x) = \left(x - \frac{1+r\sigma^2}{2}\right) F(x) - \int_{\underline{\theta}}^{x} \theta f(\theta) d\theta$. 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 5:** Denote $b^S(\theta, \rho)$ the unique solution to (15) and note that $b^S(\underline{\theta}, \rho_1) > b^S(\underline{\theta}, \rho_2)$ for $\rho_1 < \rho_2$. Suppose there exists $\theta_1 > \underline{\theta}$, where θ_1 is the lowest value of θ such that $b^S(\theta_1, \rho_1) = b^S(\theta_1, \rho_2)$. Then at that point, from (15) we have $0 > \dot{b}^S(\theta_1, \rho_1) > \dot{b}^S(\theta_1, \rho_2)$ and thus $b^S(\theta, \rho_2) > b^S(\theta, \rho_1)$ for θ in $[\theta_1 - \varepsilon, \theta_1]$ for ε small enough. A contradiction. ■

• **Proof of Proposition 7:** Using the Envelope Theorem, we get from (19):

$$\dot{U}(\theta) = \alpha b(\theta), \tag{A5}$$

with the second-order condition

$$\dot{b}(\theta) \geq 0. \tag{A6}$$

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

$$U(\theta) \geq 0. \tag{A7}$$

We now conjecture the existence of a separating equilibrium implementing a bonus schedule $b^e(\theta)$ and we will show that this leads to a contradiction. If such an equilibrium exists, the optimal contract offered by the electorate (or top principal) to the delegated principal must maximize the following objective:

$$\int_{\underline{\theta}}^{\bar{\theta}} f(\theta)\left(S + (1 - b(\theta))(\theta + b(\theta)) + (b^e)^{-1}(b(\theta))b(\theta) + \frac{b^2(\theta)}{2} + \alpha(\theta - b^{e-1}(b(\theta)))b(\theta) - U(\theta)\right)d\theta$$

subject to (A5) and (A6),

with the added equilibrium condition that $b^e(\theta)$ is the solution to this problem. Note that we have expressed $T(b(\theta))$ using (19) to rewrite the maximand.[27]

[27] Also, note that, following any unexpected offer (corresponding to $b \notin rg(b^e)$), we don't need to specify the firm's beliefs. In particular, they may not necessarily be the most pessimistic ones. The corresponding incentive constraints preventing such unexpected deviations are indeed not used in the rest of the proof below to get that no separating equilibrium may arise. Only those incentive constraints stating that $b^e(\theta)$ is preferred in state θ to $b^e(\hat{\theta})$ for any $\hat{\theta}$ are used.

Let us first neglect the second-order condition (A6). ¿From (A7) binding at $\underline{\theta}$ only and (A5), we get

$$U(\theta) = \alpha \int_{\underline{\theta}}^{\theta} b(x)dx. \tag{A8}$$

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

$$\int_{\underline{\theta}}^{\bar{\theta}} f(\theta)\left(S+(1-b(\theta))(\theta+b(\theta))+b^{e-1}(b(\theta))b(\theta)+\frac{b^2(\theta)}{2}+\alpha(\theta-b^{e-1}(b(\theta)))b(\theta)-\alpha\frac{1-F(\theta)}{f(\theta)}b(\theta)\right)d\theta. \tag{A9}$$

Optimizing pointwise and taking into account that the optimum must be achieved at $b^e(\theta)$ at a separating equilibrium, we get the following incentive compatibility condition that states that $b^e(\theta)$ is preferred in state θ to $b^e(\hat{\theta})$ for any $\hat{\theta}$:

$$\theta + b^e(\theta) - \frac{(b^e(\theta))^2}{2} - \alpha\frac{1-F(\theta)}{f(\theta)}b^e(\theta)$$

$$\geq (1-b^e(\hat{\theta}))(\theta+b^e(\hat{\theta}))+\hat{\theta}b^e(\hat{\theta})+\frac{(b^e(\hat{\theta}))^2}{2}+\alpha(\theta-\hat{\theta})b^e(\hat{\theta})-\alpha\frac{1-F(\theta)}{f(\theta)}b^e(\hat{\theta}) \quad \text{for all } (\theta,\hat{\theta}) \text{ in } \Theta^2. \tag{A10}$$

Adding (A10) with a similar condition obtained by permuting θ and $\hat{\theta}$ yields

$$(b^e(\hat{\theta}) - b^e(\theta))\left((1-\alpha)\theta + \alpha\frac{1-F(\theta)}{f(\theta)} - \left((1-\alpha)\hat{\theta} + \alpha\frac{1-F(\hat{\theta})}{f(\hat{\theta})}\right)\right) \geq 0. \tag{A11}$$

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

$$\dot{b}^e(\theta) \leq 0. \tag{A12}$$

Clearly, (A12) and (20) are conflicting and there cannot be any fully separating equilibrium.

Let us now look for a pooling equilibrium sustained with passive beliefs (whatever the bonus offered off the equilibrium, the firm continues to hold prior beliefs) such that $b(\theta) = b$, the principal receives a fixed payment T and the fixed-fee in the firm's contract is fixed for all θ in Θ.

Now the firm's effort is $e = b$ for any θ and acceptance of the contract occurs when the pooling fixed-fee is such that $a \leq E(\theta)b + \frac{b^2}{2}$. Again, we focus on the case where this fixed-fee just extracts all the firm's expected profit.

When choosing a pooling bonus b, the electorate anticipates that the principal obtains thus a rent

$$U(\theta, b) = T + \alpha(\theta - E(\theta))b.$$

To ensure participation by all types, it must be that

$$T \geq \alpha(E(\theta) - \underline{\theta})b,$$

and of course the transfer to the intermediate principal is minimized when this constraint is binding.

Inserting this expression of T into the electorate's objective function gives us a new expression of the electorate's maximization program

$$\max_{\{b\}} \int_{\underline{\theta}}^{\bar{\theta}} f(\theta)\left(S+(1-b)(\theta+b)+E(\theta)b+\frac{b^2}{2}-\alpha(E(\theta)-\underline{\theta})b\right)d\theta. \tag{A13}$$

Optimizing for positive bonus gives then (20). ■

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