Bundling Tasks and Contracts
The Case of Public-Private Partnerships

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Abstract

Recent contributions to the literature on Public-private Partnerships identify conditions that support task bundling vis-à-vis a conventional model of procurement in which the State delegates investments and operations into different firms. When asymmetric information between agents is a concern, the literature finds that risk allocation, long term contracting, and commitment matter for sector performance. Naturally, ownership has an important say in the debate but does not matter if complete contracts can be written. When non-contractible situations do arise, the owner of the asset can benefit from a renegotiation capturing profits otherwise held by the agent that operates the asset and thus reducing investments in asset-specific human capital or in other specific investments. In this article, we look for conditions that are beyond ownership to analyze task bundling. We find that a PPP better internalizes the externalities between activities thus limiting the need of transferring costly informational rents. This advantage disappears if the government cannot separate incentives at the service provision stage according to the builder's efficiency or when it implements a conventional model. Conversely, the latter may perform better than a PPP if the government can obtain some advisory services from the service provider about the builder's construction cost.

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1 Introduction

Public-Private Partnerships (PPPs) have been adopted worldwide as an alternative solution to the SOE model for infrastructure service delivery or to full delegation into a private but regulated type of business.

In the 80's, during a first wave of reform, many governments privatized services traditionally provided by the public sector (IMF 2004). In the last years, however, there was a new trend towards public-private partnerships. The global growth of PPPs was impressive. In the period from 1990 to 2008 nearly 4,200 infrastructure projects in developing countries involved private participation, with a combined value of $961 billion (World Bank PPI database). A large share of these investments was PPP, although the impact differs across infrastructure sectors (Oppenheimer and MacGregor 2004).

There is a large range of options to define PPPs. At one end of the spectrum is a management or service contract, where a private company is paid a fee for a service. At the other end is full privatization or divestiture. There are also hybrid models that often rely on simpler contractual arrangements and blend public and private money to diversify risks. Indeed, such contractual arrangements have been the response from the government to different issues including delegation (in-house or contracting out), task bundling (construction and operation), how to select contractors, and how to introduce incentives in contract (Estache *et al.* 2009).

Recent contributions to the literature of PPPs identify conditions that support task bundling in PPPs vis-à-vis a conventional model of procurement in which the State delegates investments and operations into different firms including public owned firms. This literature focused on asymmetric information between agents (government, PPP, builders, service providers, etc.) to analyze task bundling. Risk allocation, long term contracting, and commitment matter in terms of sector performance. Naturally, ownership has an important say in the debate. However, ownership does not matter in the literature of asymmetric information if complete contracts can be written – any contingency can be forecasted and included in the contract. Therefore, if contracts are useless as in an incomplete contract approach, ownership may confer some advantages over the residual benefits when a contingency occurs. For instance, when non-contractible situations do arise, the owner of the asset can benefit from a renegotiation capturing profits otherwise held by the agent that operates the asset thus reducing investments in asset-specific human capital or other specific investments by the latter. Reputation in repeated contracts may help to eliminate the hold-up problem. Hart *et al.* (1997) identifies conditions that explain whether the government or the private should own the assets. A similar analysis occurs in Hart (2003), Martimort and Pouyet (2005) Bennett and Iossa (2006a and 2006b), and Iossa and Martimort (2008) - this latter includes long term contracting and risk allocation into the analysis. It is worthwhile mentioning the literature models non-contractible situations as hidden actions (no adverse selection).

In this paper, we propose a different framework to analyze task bundling. Our approach, based in a complete contract framework, relies on different informational problems. From one side, the cost of building an asset is unknown by the government but a complete contract can be written with a firm - an adverse selection environment. On the other side, the supply cost from this asset can be reduced, or differently, the quality of the supply from this asset can be enhanced by a non-contractible action – a moral hazard framework. We can think that the service provider, the agent or firm that operates the assets, can invest in human-specific resources or in other physical assets to reduce the production costs. These actions may not be necessarily observed by the government to contract on them. Conversely, the government could observe whether the service provider is investing in cost-reduction activities but cannot prove it in a court of justice to enforce the contract. To sum up, we adopted a simple model of adverse selection followed by moral hazard to explain task bundling. The objective of this paper is to find conditions where building and operation can be activities decentralized into a single firm or conversely, allocated to different firms.

A similar problem between building and operation has been studied by Bentz *et al.* (2004) although in a model of moral hazard followed by adverse selection. In this setting, cost-reduction activities at the building stage will contribute to reduce the cost of the service provider. However, from a government perspective, these cost reduction activities represent a moral hazard problem while the cost of the service provider, whether efficient or inefficient, it is an adverse selection problem.

Bentz *et al.* (2004) and our paper do not rely on ownership to justify task bundling – a main difference with respect to Hart (2003), Bennett and Iossa (2006a and 2006) Iossa and Martimort (2008). On the contrary, we look for conditions that go beyond ownership. Finally, we believe our framework is well suited to explain greenfield investments where the government a priory does not know the cost of the asset. On the hand, in the incomplete contract framework or in the model of moral hazard followed by adverse selection, actions at the building stage affect quality and not the quantity as if the asset was already built.

2 The model

We adopt a principal-agent model. The government (G), thereafter the principal, decides to decentralize the supply of some infrastructure service delivery into different organizational structures. In our conventional model, G purchases an asset from a private builder (B) and allocates the production into another firm named Service Provider (SP). On the other hand, in a PPP type of arrangement, the government allocate the service to a firm or firms in a Private Consortium (PC) that builds the asset and operates the service.[1] Contrary to Bentz *et al.* (2004), in our model, final users purchase the service in both models. Moreover, in the conventional model, the SP does not pay a user fee for the asset to the government - user tariffs are set to cover capital and operational expenditures. Actually, the literature of PPP is motivated by examples of procurement in areas as health (hospitals, care services), education (schools), defense (prisons). In the last year, however, we observe that PPP are being extensively used for infrastructure utilities and transport (Harris 2003). These are the examples we prefer to analyze in this paper.

In our simple framework, the construction cost an asset of size q is θq. The constant marginal cost θ is positive and can take two values $\overline{\theta} > \underline{\theta}$. We assume, at the contracting stage, that B or PC knows its construction cost but this information is unknown by G. What the government knows is the existence of a uniform distributed population of builders. The probability of selecting an efficient builder is v while a builder will be inefficient with probability $1 - v$.

The consumer surplus of a project of size q is $V(q)$. We assume this function is strictly concave ($V_q(q) > 0$, $V_{qq}(q) < 0$) and positive for $q > 0$

[1] Ownership does not play any role in our model. Actually, our framework applies whenever a principal decentralizes some tasks into different agents. In the PPP, the builder and the service provider can be public company like a SOE in which the government needs to provide incentives to improve sector performance.

and satisfies Inada's conditions.[2] The surplus is also affected by a binary random variable which can increase or decrease the benefits the users get from the service. Surplus can $V^h(q)$ with probability p or $V^l(q)$ with probability $1-p$. The states of nature, low and high, are denoted by the superscript h and l respectively. We assume that $V^h(q) > V^l(q)$ for all positive q with $V_q^h(q) > V_q^l(q)$.

In this setting, the SP or the PC can contribute to improve the likelihood of good state of nature at a private cost. That is, $p = p(e)$ with $p' > 0$ but it costs e units of effort. The disutility of effort is expressed by the convex function $\psi(e)$ that satisfies the Inada conditions on $[0, 1]$.[3] For simplicity, assume $p(e) = e$. Thus, the surplus is also stochactisc even when G knows if the construction cost is high or low:

$$S(q, e) = eV^h(q) + (1-e)V^l(q)$$

The government is looking for the ex-ante best organizational structure - when neither θ or e are known. It can be conventional model in which an firm builds and another firm operates - a principal and two agent framework - or it can be what we call the PPP model where just one firm does both activities. In any case, we assume the G has full bargaining power and can offer different types of contracts. Firms can refuse to participate in such mechanisms.

As a benchmark, we proceed estimating the first best solution in a full information environment - when the G is perfectly informed about the marginal cost of building the asset and the actions implemented to increase the surplus. In this context, the maximization of the net consumer surplus on q and e is the solution of the following program:

$$\underset{\underline{q},\underline{e},\overline{q},\overline{e}}{Max} \quad v[S(\underline{q},\underline{e}) - \underline{\theta}\underline{q} - \psi(\underline{e})] + (1-v)[S(\overline{q},\overline{e}) - \overline{\theta}\overline{q} - \psi(\overline{e})] \tag{1}$$

Hereafter we can reduce notation by denoting $\underline{S}(e) = S(\underline{q}, e)$, $\overline{S}(e) = S(\overline{q}, e)$, $\underline{\psi} = \psi(\underline{e})$, and $\overline{\psi} = \psi(\overline{e})$.

[2]This assumption helps to reject the shut-down policy of the inefficient type.

[3]$\underset{e\to 1}{lim}\ \psi'(e) = \infty$ and $\underset{e\to 0}{lim}\ \psi'(e) = 0$.

Proposition 1 *Under full information, the optimal* q^* *and* e^* *are characterized by:*

$$\underline{q}^{fb} : \underline{S}_q(\underline{e}) = \underline{\theta}, \qquad \underline{e}^{fb} : \underline{S}_e(\underline{e}) = \underline{\psi}',$$
$$\overline{q}^{fb} : \overline{S}_q(\overline{e}) = \overline{\theta}, \qquad \overline{e}^{fb} : \overline{S}_e(\overline{e}) = \overline{\psi}'$$

Proof. The proof rests on the first order conditions of (1) ■

That is, with a fully informed government, the surplus is maximized when the marginal increment in the expected surplus with respect to q and e are equated with the marginal cost of supplying one unit more of q and e respectively. Moreover, this solution can be achieved independently of whether G selects a conventional model or a PPP structure. In this setting, G can set for an efficient builder an asset of size $\underline{q}^{fb}$, while with the SP, the effort that maximizes the likelihood of obtaining a good state of nature is $\underline{e}^{fb}$. Similarly, when the marginal cost is high, the size of the asset is given by $\overline{q}^{fb}$ with $\overline{e}^{fb}$. It is not difficult to show that $\underline{q}^{fb} > \overline{q}^{fb}$ and $\underline{e}^{fb} > \overline{e}^{fb}$. We assumed that for $\theta = \underline{\theta}$ or $\theta = \overline{\theta}$, there is an optimal effort level $\underline{e}^{fb}(\underline{\theta})$ or $\overline{e}^{fb}(\overline{\theta})$ respectively. Suppose that G cannot implement a type dependent effort level. The optimal solution when G cannot implement a type dependent effort level with full information is characterized by:

$$\underline{q}^{fb,e} : \underline{S}_q(e) = \underline{\theta}, \quad \overline{q}^{fb,e} : \overline{S}_q(e) = \overline{\theta}, \text{ and } \ e^{fb} : \underset{\theta}{E}\left[S_e(e)\right] = \psi'$$

where the superscript fb, e denotes first best quantities with a single effort level - the SP, or the PC in its role of SP will implement the same effort to increase the likelihood of a good state of nature independently whether the asset size is $\underline{q}^{fb,e}$ or $\overline{q}^{fb,e}$. The marginal disutility of effort is now equated to the expected marginal surplus for each state of nature - whether the marginal cost is low and high. Certainly, the surplus of this constrained optimization program cannot be higher as when G induces type dependent effort level. It is easy to show that $\underline{q}^{fb} > \underline{q}^{fb,e} > \overline{q}^{fb} > \overline{q}^{fb,e}$ and $\underline{e}^{fb} > e^{fb} > \overline{e}^{fb}$. As we show in the next sections, by inducing the PC in the PPP model with a type dependent effort level, the G will not need to provide with high rents as in the case of a the conventional model. Such an advantage does not exist when the G writes a contract inducing a single effort level.

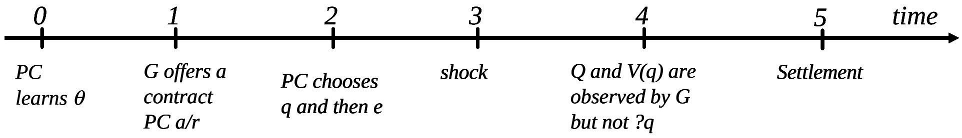

Figure 1: Timing in the Public-Private Partnership model

3 The Public-Private Partnership model

Consider the timing of the game described in Figure 1. We assume the private consortium knows, before it get an offer from the government, the marginal cost of building the asset - which is private information. In period 1, the G offers an stochastic system of transfers that are used to screen the PC's type and to induce effort. Indeed, the contract$\{t_h(\theta), t_l(\theta), q(\theta), e(\theta)\}$ for $\theta = \underline{\theta}$ or $\overline{\theta}$, is stochastic in the sense that a transfer $t_h(\theta)$ (resp. to $t_l(\theta)$) will be paid to the PC when the G observes $V_h(q)$ (resp. to $V_l(q)$). We do need to assume that G contract on the surplus but on some statistics correlated to a good or bad state of nature (high or low surplus).

The PC may accept or not. If not, the game ends. Otherwise the PC builds an asset of size q and operates it to deliver the service by exerting some effort e. At date 3, there is a shock (some unexpected event) that will affect the surplus. At date 4, the G observes the realized surplus (i.e. $V_h(q)$ or $V_l(q)$) and the production q.[4] Transfers are made in the next period conditional on q and $V(q)$.

The proposed mechanism is not the standard one when the exchange of information is completed with the objective to screen the agent's type. Here, in addition to this problem, the principal also suggests a type dependent effort level. To solve the asymmetric information problem we can rely on the Extended Revelation Principle stated by Myerson (1982) and Laffont-Martimort (2003). It specifies a message $m(\theta)$ chosen by the agent and sent to the principal but also suggests the optimal level of effort $e(\theta)$. Denote by $m^*(\theta)$ and $e^*(\theta)$ the optimal message and effort level. Let us define a Direct Revelation Mechanism (hereafter DRM) as the vector $\left\{t_h(\widetilde{\theta}), t_l(\widetilde{\theta}), q(\widetilde{\theta})\right\}$ where $t_h(\widetilde{\theta}) = \widetilde{t}_h(m^*(\widetilde{\theta})), t_l(\widetilde{\theta}) = \widetilde{t}_l(m^*(\widetilde{\theta}))$ and $q(\widetilde{\theta}) = \widetilde{q}(m^*(\widetilde{\theta}))$ for all $\theta \in \{\underline{\theta}, \overline{\theta}\}$.

[4] Note that G observes q but not θq. Otherwise the G can infer θ.

Proposition 2 *There is no loss of generality in restricting the principal to offer a truthful DRM* $\left\{t_h(\widetilde{\theta}), t_l(\widetilde{\theta}), q(\widetilde{\theta})\right\}$ *for all* $\theta \in \{\underline{\theta}, \overline{\theta}\}$ *and to recommend a choice of effort* $e^*(\widetilde{\theta})$. *Which such a mechanism, the agent truthfully reveals her type to the principal and obeys to the recommendation on the choice of effort.*

Proof. See Proposition 7.2 in Laffont-Martimort [2003], ■

The Extended Revelation Principle (ERP) simplifies the analysis by considering a simpler type of contract. The difficulty still arises in describing the set of informational incentive constraints for both adverse selection and moral hazard problems.

From the ERP we know that contracts $\underline{\Gamma} : \{\underline{t}_h, \underline{t}_l, \underline{q}, \underline{e}\}$ and $\overline{\Gamma} : \{\overline{t}_h, \overline{t}_l, \overline{q}, \overline{e}\}$ are adverse-selection-incentive-compatible if they satisfy the Adverse Selection Incentive Constraints (hereafter $ASICs$):

$$\underline{ASIC} : \underline{t}_h\underline{e} + \underline{t}_l(1-\underline{e}) - \underline{\theta}\underline{q} - \underline{\psi} \geq \max_{e\in(0,1)} \{\overline{t}_h e + \overline{t}_l(1-e) - \underline{\theta}\overline{q} - \psi(e)\} \quad (2)$$

$$\overline{ASIC} : \overline{t}_h\overline{e} + \overline{t}_l(1-\overline{e}) - \overline{\theta}\overline{q} - \overline{\psi} \geq \max_{e\in(0,1)} \{\underline{t}_h e + \underline{t}_l(1-e) - \overline{\theta}\underline{q} - \psi(e)\} \quad (3)$$

That is, for any marginal cost, the PC should not find it profitable to mimic the other type by choosing contracts that have not been designed for its true marginal cost. Moreover, the PC can choose its preferred effort level independently of the recommended effort level or even decide to not contribute to increase the chance a good state if it perceives that the payments are not sufficient. However, the incentive compatibility will ensure that rents will be not greater if it chooses the optimal contract independently of the recommended effort level.

Transfers also have to be designed to induce the optimal effort level according to the agent's type. To be moral-hazard-incentive-compatible, they should satisfy the Moral Hazard Incentive Constraints (hereafter $MHICs$):

$$\underline{MHIC} : \underline{t}_h - \underline{t}_l \geq \underline{\psi}'$$

$$\overline{MHIC} : \overline{t}_h - \overline{t}_l \geq \overline{\psi}'$$

The reader can recognize in these inequalities the first order conditions when the agent type θ optimizes over e. As usual, we need to create a gap between transfers to introduce incentives. The gap depends on the PC's type and if the optimal effort levels satisfy $\underline{e} \geq \overline{e}$, then $\underline{t}_h - \underline{t}_l \geq \overline{t}_h - \overline{t}_l$. That is, the gap is larger when the agent is efficient.

To characterize the right hand sides in (2) and (3) it is possible to use the $MHICs$.

Lemma 1 *If the optimal contract satisfies the $MHICs$, then:*

$$\underline{ASIC} : \underline{t}_h\underline{e} + \underline{t}_l(1-\underline{e}) - \underline{\theta}\underline{q} - \underline{\psi} \geq \overline{t}_h\overline{e} + \overline{t}_l(1-\overline{e}) - \underline{\theta}\overline{q} - \overline{\psi}$$

$$\overline{ASIC} : \overline{t}_h\overline{e} + \overline{t}_l(1-\overline{e}) - \overline{\theta}\overline{q} - \overline{\psi} \geq \underline{t}_h\underline{e} + \underline{t}_l(1-\underline{e}) - \overline{\theta}\underline{q} - \underline{\psi}$$

Proof. Consider the PC decision when the marginal cost is type θ but the agent argues it is $\widehat{\theta}$. Denote utility by $\widehat{U}(\theta, e) = \widehat{t}_h e + \widehat{t}_l(1-e) - \theta\widehat{q} - \psi(e)$. The maximum e is obtained when $\widehat{t}_h - \widehat{t}_l = \psi'(\widehat{e})$. Therefore, when the PC pretends to be $\overline{\theta}$ given it is $\underline{\theta}$, the effort level is maximized at $\overline{e}$. The same reasoning applied when is $\overline{\theta}$ but pretends to be $\underline{\theta}$. ∎

This lemma simplifies the analysis by considering only contracts that when deviation (on types) is possible, the effort level chosen follows the same deviation.

To reduce notation, let us denote by $\underline{T}(\underline{t}_h, \underline{t}_l, \underline{e}) = \underline{e}\underline{t}_h + (1-\underline{e})\underline{t}_l$ and $\overline{T}(\overline{t}_h, \overline{t}_l, \overline{e}) = \overline{e}\overline{t}_h + (1-\overline{e})\overline{t}_l$. The notation of PC's utility is reduced to: $\underline{U}(\underline{T}, \underline{q}) = \underline{T}(\underline{t}_h, \underline{t}_l, \underline{e}) - \underline{\theta}\underline{q} - \underline{\psi}$ and $\overline{U}(\overline{T}, \overline{q}) = \overline{T}(\overline{t}_h, \overline{t}_l, \overline{e}) - \overline{\theta}\overline{q} - \overline{\psi}$.

We are in condition now to define the G's optimization program as follows:

$$\underset{\underline{\Gamma},\overline{\Gamma}}{Max} \qquad v[S(\underline{q}, \underline{e}) - \underline{T}(\underline{t}_h, \underline{t}_l, \underline{e})] + (1-v)[S(\overline{q}, \overline{e}) - \overline{T}(\overline{t}_h, \overline{t}_l, \overline{e})]$$

$$st$$

$$\underline{U}(\underline{T}, \underline{q}) \geq \overline{U}(\overline{T}, \overline{q}) + \Delta\theta\overline{q} \qquad (\lambda_1)$$

$$\overline{U}(\overline{T}, \overline{q}) \geq \underline{U}(\underline{T}, \underline{q}) - \Delta\theta\underline{q} \qquad (\lambda_2)$$

$$\underline{t}_h - \underline{t}_l \geq \underline{\psi}' \qquad (\phi_1), \qquad \underline{t}_h - \underline{t}_l \geq \overline{\psi}' \qquad (\phi_2)$$

$$\underline{u}_h = \underline{t}_h - \underline{\theta}\underline{q} \geq 0 \qquad (\eta_1), \qquad \underline{u}_l = \underline{t}_l - \underline{\theta}\underline{q} \geq 0 \qquad (\eta_2),$$

$$\overline{u}_h = \overline{t}_h - \overline{\theta}\overline{q} \geq 0 \qquad (\eta_3), \qquad \overline{u}_l = \overline{t}_l - \overline{\theta}\overline{q} \geq 0 \qquad (\eta_4)$$

where $\Delta\theta = \overline{\theta} - \underline{\theta}$.

The government maximizes the expected surplus where the expectation includes uncertainty on the PC's marginal cost and the state of nature. The program is constrained by the $ASICs$ stated in Lemma 1 and the $MHICs$. Terms between parentheses denote the Lagrangian multipliers. Ex-ante participation constraints are omitted and they will be checked ex-post. Ex-post limited liability constraints are imposed to ensure participation of both types. The optimal second best contract is characterized by the following proposition.[5]

Proposition 3 *In the Public-Private Partnership model, when the Government can induce the SP to exert different actions whether the building cost is low or high, the optimal incentive compatible contract is characterized by:*

$$\underline{q}^{sb} : \underline{S}_q(\underline{e}) = \underline{\theta}, \qquad \overline{q}^{sb} : \overline{S}_q(\overline{e}) = \overline{\theta} + \frac{\lambda_1}{1-v}\Delta\theta,$$

$$\underline{e}^{sb} : \underline{S}_e(\underline{e}) = \underline{\psi}' + \frac{v-\lambda_1}{v}\underline{\psi}''\underline{e}, \quad \overline{e}^{sb} : \overline{S}_e(\overline{e}) = \overline{\psi}' + \frac{1-v+\lambda_1}{1-v}\overline{e}\overline{\psi}'',$$

with $\lambda_1 \in (0, v)$.
That is:
i) non-distortion in production[6] for the efficient type in the sense that the expected marginal surplus is equal to $\underline{\theta}$,
ii) downward distortion in production when $\overline{\theta}$,
iii) downward distortion in both levels of effort.

Proof. See appendix ■

Note that the first best is no longer implemented since the moral hazard effects are spilled over the optimal contract on q. However, allocative efficiency in the asset size is achieved when the marginal cost is low. As shown in the proof, the G cannot implement the first best asset size for the efficient type because it is constrained by the ex-post limited liability. In this case, it finds it optimal to decrease the size of the asset and the effort when the marginal cost is low. This effect is compensated with a decrease in the allocative distortion in production and effort when the agent is inefficient. Figure 2 represents the allocation of production and effort for the efficient type:

As a consequence of Proposition 3 the following corollary can be stated:

[5] Only quantities and effort levels are described in the proposition. Transfers are characterized in the appendix.

[6] We use production and the size of the asset build as the same concept.

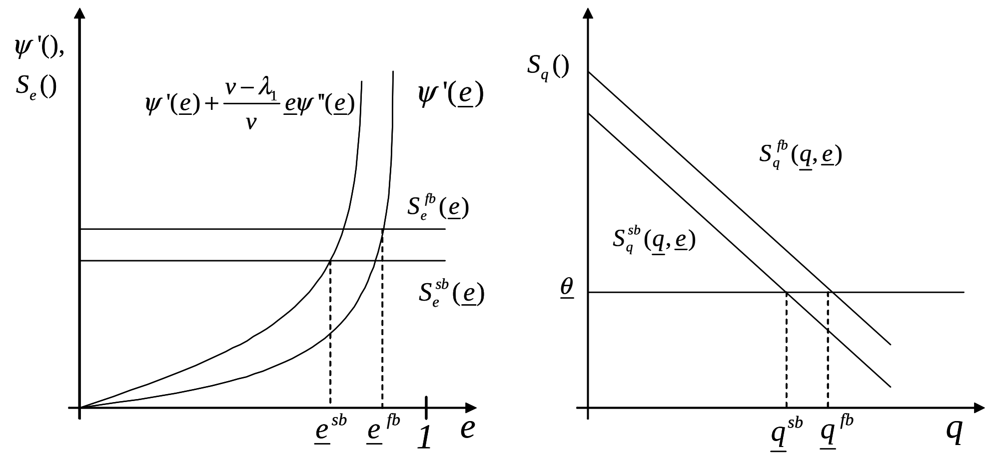

Figure 2: Size of the asset and effort when the PC has low marginal cost

Corollary 1 *i) There is no ex-post informational rents in case of a bad state of nature independently of whether marginal cost is low or high.*
ii) adverse selection informational rents are equated with the incremental moral hazard informational rents or, $\Delta\theta\overline{q}^{sb} = \underline{e}^{sb}\underline{\psi}' - \underline{\psi} - (\overline{e}^{sb}\overline{\psi}' - \overline{\psi})$

Proof. See the proof of Proposition 3 in the appendix. ■

The first part of this corollary is explained by the expost limited liability constraints. Actually, in the optimal contract, the expost participation constraints for the PC with low or high marginal cost are binding if the shock derives in a low state of nature. The PC recovers its capital expenditures but lacks to get it paid for the effort to improve the service - the ex-ante participation constraints are not violated.

In addition, being efficient leads to an increment of the moral hazard rent since $\underline{e}^{sb}\underline{\psi}' - \underline{\psi} - (\overline{e}^{sb}\overline{\psi}' - \overline{\psi}) > 0$. This incremental rent is equated with the adverse selection rent as a consequence of the binding limited liability constraints.[7] Therefore, any increase in the adverse selection informational rents is compensated with a decrease in the increment of the moral hazard informational rents.

Note that it is implicitly assumed that the PC does not have enough assets to be punished in the case of a low state of nature. Certainly, if

[7]The effect of mitigating incentives resembles to the denominated countervailing incentive. Nevertheless, in this model, the outside opportunity option is endogenous and therefore, the principal finds the optimal trade-off between efficiency and rent extraction.

negative transfers can be implemented, the government could implement the first best when the PC is efficient.

Lemma 2 *The incentives to deviate from the optimal contract are reduced for a PC with low marginal cost:*
i) Adverse selection informational rents create incentives to misreport θ *when the true marginal cost is* $\underline{\theta}$
ii) By reporting $\overline{\theta}$ *when it is* $\underline{\theta}$*, the PC reduces moral hazard informational rents.*
Both incentives work in opposite direction reducing the Government's cost on informational rents.

Proof. See appendix ■

The idea behind this lemma is straightforward. It is clear that an agent type $\underline{\theta}$ will claim that it is $\overline{\theta}$ when the principal is no longer informed**.** On the other hand, since the optimal effort level is larger when the agent is efficient and $\psi(\cdot)$ is a strict positive convex function, moral hazard informational rents become larger when the agent is efficient. Therefore, both incentives mitigate the effect of asymmetric information by acting in opposite directions. That is, in aggregate, the cost on informational rents are less than the sum of rents needed if the problems were separated. This issues will be analyzed later on.

This complementarity exists when a single agent plays both tasks but on the contrary, as shown in the next section, this effect disappears when the principal separates the activities into a builder and a service provider. In a different setting, Dana [1993] and Severinov [1999] describe an 'internalization effect' in the one agent structure through a multi-dimensional adverse selection problem.. When the agent reveals information about a product, it considers how the exchange of information will affect the benefit it can obtain from the second product. In the model that we present, revealing information about marginal cost impacts on the optimal private effort level and then, on the moral hazard informational rents. This behavior is consistent with the mentioned effect.

To conclude, allocating the contract of 'building and operation' to the same agent creates some economies of scope on information that reduces the cost faced by the principal. Our result is also consistent with Bentz *et al.* (2004) when the PC has the incentive to build the best asset it can because this maximizes information rent at the service provision stage.

The fact that the G can write a contract to induce effort, contingent on θ and not on the expected θ, contributes to reduce the cost in rents need to provide with the most efficient service in a second best environment. Thus, if the G induces the same effort level, independently of the agent's type, this complementarity effect disappears.

Proposition 4 *In the Public-Private Partnership model, when the Government induces to a pooling equilibrium of effort for the SP, the optimal incentive compatible contract is characterized by:*

$$\underline{q}^{sb,e} : \underline{S}_q(e^{sb,e}) = \underline{\theta}, \qquad \overline{q}^{sb,e} : \overline{S}_q(e^{sb,e}) = \overline{\theta} + \frac{v}{1-v}\Delta\theta,$$
and
$$e^{sb,e} : \underset{\theta}{E}\left[S_e(e)\right] = \psi' + e\psi''$$

That is:
i) non-distortion in the size of the asset for the efficient type in the sense that the expected marginal surplus is equal to $\underline{\theta}$,
ii) downward distortion in production when $\overline{\theta}$ *and in the effort level*
iii) providing incentives for truthful revelation does not require to create a large gap between the expected rents between an efficient and inefficient builder as when the G can induce different effort level at the service provision stage

Proof. *See appendix* ■

The last result is probably the most interesting one in Proposition 4. By Corollary 1, we know that with a type-dependent effort level, the adverse selection rents are equated to the incremental moral hazard informational rents: $\Delta\theta\overline{q}^{sb} = \underline{e}^{sb}\underline{\psi}' - \underline{\psi} - (\overline{e}^{sb}\overline{\psi}' - \overline{\psi})$. Moreover, the gap between expected rents between an efficient and inefficient builder are equated to the adverse selection rent or $\underline{U}(\underline{q}^{sb}, \underline{e}^{sb}) - \overline{U}(\overline{q}^{sb}, \overline{e}^{sb}) = \Delta\theta\overline{q}^{sb}$.In the case of a single effort level, the gap between these rents are also equal to the adverse selection rent $\underline{U}(\underline{q}^{sb}, e^{sb,e}) - \overline{U}(\overline{q}^{sb}, e^{sb,e}) = \Delta\theta\overline{q}^{sb,e}$ but even when $e^{sb,e} > \overline{e}^{sb}$, the difference in the optimal quantities when $\overline{\theta}$ is $\overline{q}^{sb,e} < \overline{q}^{sb}$ and then $\Delta\theta\overline{q}^{sb} < \Delta\theta\overline{q}^{sb,e}$. In that case, by creating a high gap between expected rents, a PC with low marginal cost internalizes the complementarity effect of both tasks in the profit-maximizing strategy. However, a high gap does not mean higher rents as the expected rents (on θ and e) are higher with a pooling effort level. Consequently**,** a policy recommendation claims for suggesting a type dependent effort when it is possible.

The next section considers the conventional model as in a two-agent mechanism.

4 The Conventional model

The conventional model assumes tasks allocated into a builder and a service provider in which agent has specialized skills. It is clear that under full information, the government can implement the same contract and achieve the same welfare independently of the organizational structure. However, under asymmetric information and with two firms, the government may have some coordination problem when offering the contracts. It requires information about the marginal cost before offering the contract to the service provider. Conversely, the government needs to observe whether the size of the asset was $\underline{q}$ or $\overline{q}$ and it may be the case it is not possible to determine the builder marginal cost before offering to the service provider with the right incentive contract. However, the government can learn about the size of the project that has been already chosen using the ex-post surplus but then, it cannot suggest a type dependent effort. The best that the regulator can do is to offer the same effort level. Naturally, the surplus achieved cannot be as large as if this information was possible before contracting. This case will be analyzed in the next section when some signal about marginal cost can be obtained to reduce the informational gaps and the coordination problem.

In this section, we assume that the government can observe the contract chosen by the builder before offering the contract to the service provider. The timing is modified to incorporate this fact. This assumption is not required when the same agent performs both activities since the same mechanism guarantees screening of both types and the SP follows the recommended effort level.

For simplicity in the notation, in the conventional model, we denote production by g and effort by z. Also, transfers to the builder and service provider include the superscript B and SP respectively.

With two firms, the timing of this game is described in Figure 3.

As before, the government designs a contract by maximizing the expected surplus where expectation includes uncertainty on the marginal cost and the state of nature (low or high). The maximization is constrained by the $ASICs$ for the B and the $MHICs$ for the SP. To be precise, the adverse selection

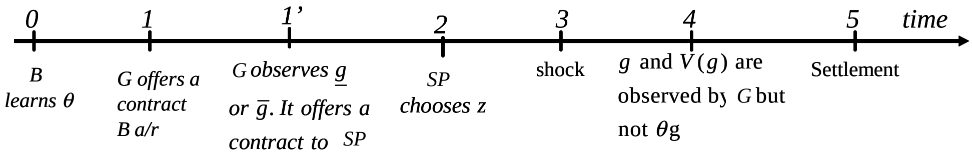

Figure 3: Timing in the Conventional Model of Service Delivery

incentive constraints for the B are:

$$\begin{aligned}\underline{t}^B - \underline{\theta}\underline{g} &\geq \overline{t}^B - \underline{\theta}\overline{g} \\ \overline{t}^B - \overline{\theta}\overline{g} &\geq \underline{t}^B - \overline{\theta}\underline{g}\end{aligned}$$

and the moral hazard incentive constraints for the SP are:

$$\begin{aligned}\underline{t}_h^{SP} - \underline{t}_l^{SP} &= \underline{\psi}' \qquad if \quad g = \underline{g} \\ \overline{t}_h^{SP} - \overline{t}_l^{SP} &= \overline{\psi}' \qquad otherwise\end{aligned}$$

Limited liability constraints prevent the builder from getting negative rents. Ex-ante participation constraints for the service provider are assumed together with non-negative transfers. It can be possible to consider non-negative ex-post rents for the service provider but distortions and rents are larger than using non-negative transfers.

The optimal second best contract is characterized by the following proposition.

Proposition 5 *When the principal contracts with different firms and can observes the builder's marginal cost before contracting with service provider, the optimal incentive compatible contract is characterized by:*

$$\underline{g}^{sb} : \underline{S}_g(\underline{z}) = \underline{\theta}, \qquad \overline{g}^{sb} : \overline{S}_g(\overline{z}) = \overline{\theta} + \frac{v}{1-v}\Delta\theta,$$

$$\underline{z}^{sb} : \underline{S}_z(\underline{z}) = \underline{\psi}' + \underline{\psi}''\underline{z}, \quad \overline{z}^{sb} : \overline{S}_z(\overline{z}) = \overline{\psi}' + \overline{z}\overline{\psi}'',$$

That is:
i) non-distortion in production for an efficient builder in the sense that the expected marginal surplus is equal to $\underline{\theta}$*,*
ii) downward distortion in production when $\overline{\theta}$*,*

iii) downward distortion in both levels of effort.

Proof. See the appendix. ■

In this framework, the optimal contract is solved by backward induction. The government computes the optimal effort levels as a function of $\underline{g}$ or $\overline{g}$. Next, it solves the optimal contract that is adverse-selection-incentive-compatible.

As a consequence of Proposition 5, the following corollary can be established.

Corollary 2 *Asymmetric informational rents are the sum of adverse selection and moral hazard problems.*

Proof. See the proof of Proposition 5 in the appendix. ■

In effect, these rents are the sum of both informational problems because firms, as separated entities, cannot internalize the complementary of task bundling in a profit-maximinzing strategy when the builder is efficient. The distortions created by the incentive contract are larger if we compare them with a PPP model provided that $\lambda_1 < v$ as shown in the proof of Proposition 3. It will lead to the government to prefer the PPP model as long as it can implement a separating equilibrium contract for the effort level. Otherwise, if the government cannot implement such a contract in a PPP model or cannot observe the marginal cost of the builder before contracting with the SP in the conventional model, both organizational structures lead to the same solution.

Boyce and Hollis (2001), analyzing the organization of the transmission system, consider another possibility into the two-agent mechanism. It can be possible that the SP has better information about the marginal cost of the builder. The system operator may have some information about the cost of the network infrastructure while the transmission owner/builder may not necessarily knows the cost and effort to implement a reliable dispatch at minimum cost. We explore this possibility below but certainly, in a more abstract setting, B can supervise the effort exerted by the SP.

4.1 Cost auditing in the conventional model

Suppose the government cannot screen the builder's marginal cost before contracting with the service provider. This assumption limits the possibility of implementing a type-dependent contract. The government does not have any information about the marginal cost of producing g and then, the best that it can do is to set a unique effort level by equalizing the marginal private cost of exerting effort with the expected welfare improvement.[8] In this case, it is clear that welfare cannot be larger than the case when g can be observed.

In the same setting, we assume when B learns its marginal cost, the SP receives a signal that can convey some information about the B's type. The signal, when it is reported truthfully to the government, helps to reduce the informational gaps and it allows for the implementation of a type-dependent effort level.

We provide the service provider with a new role by assuming some communication with the government about the best builder. The government, by contracting with an experienced service provider, can also get an advisory service for a fee. The advisory service, a signal about θ, will be used by the government during the procurement stage of the building process. That is. the SP receives a signal about B's type and reports it to the government. After receiving the report, the government determines which contract will be offered to B and SP.

We adapt the model used in Tirole [1986 and 1992] to introduce a simple technology of supervision. The information acquired by the supervisor is hard information. Conditional on $\theta = \underline{\theta}$, SP observes $\sigma_1$with probability ϵ. Otherwise, it observes a signal σ_2 (with probability $1-\epsilon$) and the B's marginal cost can be low or high. That is, σ_2 does not bring any extra information about θ. A signal σ_1 can be ex-post verified by the government while a signal σ_2 is not informative and not verifiable. Indeed, when the service provider receives no information, the hard information assumption implies that it cannot be possible to write an ex-post verifiable report claiming for an informative σ_1 signal. By reporting σ_1 (resp. σ_2), the SP receives a fee for service s_1 (resp. s_2).[9]

In this framework, the government suggests a type-dependent effort level according to the information available. The timing is summarized in Figure 4.

[8] That is:

$$v\underline{S}_z(z) + (1 - v)\overline{S}_z(z) = \psi' + z\psi''$$

[9] Note that a non-informative σ_2 has no economic value for the government since $\overline{U}^1 = 0$ independently of the signal reported.

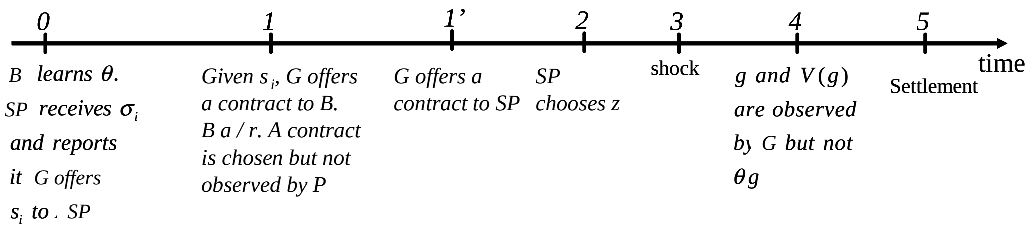

Figure 4: Adding supervision to the conventional model

At period 1, conditional on σ_1 reported by the service provider, the government offers $\{\underline{t}^B(\sigma_1), \underline{g}(\sigma_1)\}$ to the builder and $\{\underline{t}_h^{SP}(\sigma_1), \underline{t}_l^{SP}(\sigma_1), \underline{z}(\sigma_1), s_1\}$ to the service provider. Otherwise, when the signal reported is σ_2 the offer is $\left\{\left(\underline{t}^B(\sigma_2), \underline{g}(\sigma_2)\right), \left(\bar{t}^B(\sigma_2), \bar{g}(\sigma_2)\right)\right\}$ to B and $\{t_h^{SP}(\sigma_2), t_l^{SP}(\sigma_2), z(\sigma_2), s_2\}$ to SP. Note that $z(\sigma_2)$ is not type-dependent since the principal cannot determine the builder marginal cost.

The fee for service s_1 and s_2 have to be incentive compatible. As Lemma 1 suggests, the service provider has incentives to misreport the signal when she receives σ_2 since the expected rents are larger provided that $\underline{z}(\sigma_1) \geq z(\sigma_2)$. However, we rule out this possibility by assuming that the piece of information revealed is hard information. This informational structure reduces the complexity of the analysis by eliminating a certain number of incentive constraints. A more complex structure of information can be studied in this context as in the case of the so-called soft information (see Baliga [1999] and Faure-Grimaud et al. [2003]).

In the context of hard information, in addition to the service provider $MHICs$, there is also a Signal Incentive Constraint (hereafter SIC) characterized by the following lemma.

Lemma 3 *Transfers or fee for service denoted by $s_1 = s(\sigma_1)$ and $s_2 = s(\sigma_2)$ are incentive compatible if:*

$$SIC : s_1 + \underline{U}^{SP}(\sigma_1) \geq s_2 + U^{SP}(\sigma_2)$$

where by definition:

$$\begin{aligned} U^{SP}(\sigma_2) &= U^{SP}(z(\sigma_2)) = z(\sigma_2)t_h^{SP}(\sigma_2) + (1 - z(\sigma_2))t_l^{SP}(\sigma_2) - \psi(\sigma_2) \\ & \quad \textit{and} \\ \underline{U}^{SP}(\sigma_1) &= \underline{U}^{SP}(\underline{z}(\sigma_1)) = \underline{z}(\sigma_1)\underline{t}_h^{SP}(\sigma_1) + (1 - \underline{z}(\sigma_1))\underline{t}_l^{SP}(\sigma_1) - \underline{\psi}(\sigma_1). \end{aligned}$$

Proof. Consider any pairs of effort $\underline{z}', z'$ such that $\underline{z}' \geq z'$. Then, it implies that $\underline{U}^{SP}(\underline{z}') \geq U^{SP}(z')$ since disutility of effort is a strictly positive convex function. Suppose that $\underline{z}' = \underline{z}(\sigma_1)$ and $z' = z(\sigma_2)$. When the service provider receives σ_2, it can claim that the signal was σ_1 because this strategy leads to higher informational rents. We know that it is not possible in this setting of hard information. Nevertheless, with a more general informational structure, transfers s_1, s_2 have to be such that they avoid incentive to misreport the signal. ■

Note that in Tirole [1986 and 1992], the opportunity cost of the supervisor can be normalized to zero. This assumption corresponds to the case in which the principal must hire a supervisor for other purposes than supervision. The opportunity cost of the supervisory function is then zero because of the supervisor's dual role. On the other hand, in the model that we present, the service provider dual role is not neutral since it has special interest when the supervised agent is efficient.

It is worthwhile mentioning that collusion can be an issue since agents can share informational rents. That is, the builder can be better-off when the government cannot screen the marginal cost given that the service provider receives a signal σ_1. If side-payments are feasible, the service provider can receive a transfer that compensates the difference between $\underline{U}^{SP}(\sigma_1)$ and $U^{SP}(\sigma_2)$ while the builder still gets a positive rent. Certainly, collusion will reduce the advantages of introducing supervision even when it is prevented through a contract that is collusion-proofness. We assume that collusion, even when it is profitable, cannot take place.

The following proposition characterizes the optimal solution when monitoring is feasible.

Proposition 6 *Suppose that the government cannot observe the contract chosen by builder before contracting with the service provider. Using a signal reported by the latter, as hard information, it leads to the following optimal* *incentive compatible contract:*

$$\underline{g}^{sb,m}(\sigma_1) : \underline{S}_g(\underline{z}(\sigma_1)) = \underline{\theta}$$

$$\underline{g}^{sb,m}(\sigma_2) : \underline{S}_g(z(\sigma_2)) = \underline{\theta}$$

$$\overline{g}^{sb,m}(\sigma_2) : \overline{S}_g(z(\sigma_2)) = \overline{\theta} + \frac{v(1-\epsilon)}{1-v}\Delta\theta$$

$$\underline{z}^{sb,m}(\sigma_1) : \underline{S}_z(\underline{z}(\sigma_1)) = \underline{\psi}' + \underline{z}(\sigma_1)\underline{\psi}''$$

$$z^{sb,m}(\sigma_2) \quad : ES_z(z(\sigma_2)) = \psi' + z(\sigma_2)\psi''$$

where $ES_z(z(\sigma_2)) = \frac{v(1-\epsilon))\underline{S}_z(z(\sigma_2))+(1-v)\overline{S}_z(z(\sigma_2))}{1-v\epsilon}$ *denotes the expected marginal surplus revised on the basis of the signal* ϵ *.*
That is:
i) non-distortion in production when the builder is efficient in the sense that the expected marginal surplus is equal to $\underline{\theta}$*,*
ii) downward distortion in production when $\overline{\theta}$ *but the size of the inefficiency is reduced (as compared with the conventional model without the advisory service)*
iii) downward distortion in both levels of effort.

Proof. See the appendix. ■

Corollary 3 *The effort level that can be implemented when the service provider reports a non-informative signal cannot be larger than the effort implemented when the reported signal is* σ_1*.*

Proof. See the appendix. ■

As expected, the introduction of the signal softens the informational gap between the agents and the principal. As the probability to receive σ_1 increases, at the limit, there is no distortion in production for both types. The effort levels are increased but the effect of moral hazard on the optimal production levels still prevails.

The assumption of hard information deserves some remarks. Note that when the service provider would like to deviate from a truthful revelation of the signal, that is, when it receives σ_2, is not possible. Otherwise, when it receives σ_1, it does not like to deviate even when it is possible.

Supervision as it was introduced can also be analyzed when the government can observe the contract chosen by the builder. The welfare achieved will be larger in this case. However, the analysis is still robust when the arrival of the signal is used as a mechanism to solve for the coordination problem when the contract entails multiple agents.

4.2 Creating countervailing incentives in the conventional model

We just showed that the conventional model of service procurement does not help to internalize the complementary effect of multiple tasks into a profit-maximizing strategy. Moreover, the conventional model is more demanding in terms of the information required as the government need to determine whether the builder is efficient or inefficient before offering a contract to the service provider. However, the service provider is not neutral as it benefits when the builder is efficient. If the service provider is experienced - it occurs with probability ϵ, it can report to the government some information that prove the builder has low marginal cost. In sum, the cost in informational rents is reduced.

We can explore a second possibility in the conventional model which is to use moral hazard informational rents to create countervailing incentives. Suppose an universe of firms which can play both roles, building and operation, as in the PPP model. Suppose the government implement the following mechanism: firms have to decide whether the prefer to be builders or service providers.

To be completed in the next version.

5 Welfare Implications

We just showed that the first best is no longer able when the builder has low marginal cost in any of the three structures considered. This is explained by moral hazard and the non-separability of the welfare function between effort and production. The effort is reduced to the second best solution in other to be incentive compatible and then reduces the optimal production level.

Proposition 7 *Under asymmetric information, the government is not indifferent between organizations*

i) The PPP model dominates the conventional model (without monitoring),
ii) The ranking between PPP model and the conventional model with monitoring is ambiguous.

Proof. See the appendix. ■

The idea behind this proposition is straightforward. When there is a single agent, it faces some kind of countervailing incentive between production and effort. It leads to a reduction of the informational gaps and an improvement of efficiency. There is a sort of economies of scope in information for the government which is not captured when there are multiple agents. More precisely, in the conventional model, the strategy followed by the builder does not change whether the service provider exerts effort or not. Introducing supervision helps to limit the cost for the supervisor but does not affect the overall strategy.

Also, when there are two firms, the government relies on the observation of the contract chosen by the builder to design the optimal second best effort level. Otherwise, it suggests an effort level which is obtained through the expected marginal surplus.

Comparing the PPP model with respect to the conventional model with supervision, we can find that when the builder is efficient $\underline{q}^{fb} > \underline{q}^{sb} > \underline{g}^{sb,m}(\sigma_1)$ with $\underline{e}^{fb} > \underline{e}^{sb} > \underline{z}^{sb,m}(\sigma_1)$. We know that moral hazard prevents effort from reaching the first best. In addition, the extra distortion due to this effect is larger when there are two agents. Therefore, effort is larger when there is a single agent structure and it implies that $\underline{q}^{sb} > \underline{g}^{sb,m}(\sigma_1)$. When the agent is inefficient, the quantities produced are $\overline{q}^{fb} > (\overline{q}^{sb}, \overline{g}^{sb,m}(\sigma_2)\ )$ with $\overline{e}^{fb} > (\overline{e}^{sb}, z^{sb,m}(\sigma_2))$ but $\overline{q}^{sb} \lesseqgtr \overline{g}^{sb,m}(\sigma_2)$ and $\overline{e}^{sb} \lesseqgtr z^{sb,m}(\sigma_2)$. This is explained by the fact that distortion in production is lower when there is supervision but on the other hand, the moral hazard distortion can be larger in this case. The aggregate effect is ambiguous.

In the limit, when the probability of an informative signal ϵ tends to one, there is no need to pay adverse selection informational rents. The following example will illustrate these results.

Example

Consider the following case. Let $V^h(q) = \alpha q - \frac{q^2}{2}$, $V^l(q) = V^h(q)/2$, $\psi(e) = \frac{e^2}{1-e}$ with $\alpha = 10, \theta \in \{1, 2\}$ and $v = 0.5$. An informative signal arrives with probability $\epsilon \in \{\frac{1}{4}, \frac{1}{2}, \frac{3}{4}\}$. **Table 1** shows the main results.

Table 1: Main Results of the Different Structures

Structure	*First*	*PPP*	*Conventional*	*Conventional Model*		
.	*Best*	Model	*Model*	and *Supervision*		
ϵ	-	-	-	0.250	0.500	0.750
E. Welfare	28.189	21.435	19.984	20.778	21.617	22.496
E. Rents	0.000	4.354	5.267	4.644	3.928	3.130
$\underline{q}$	8.891	8.846	8.752	-	-	-
$\underline{q}(\sigma_1)$	-	-	-	8.752	8.752	8.752
$\underline{q}(\sigma_2)$	-	-	-	8.747	8.747	8.747
$\overline{q}$	7.777	6.266	6.218	6.553	6.867	7.182
$\underline{e}$	0.803	0.732	0.603	0.603	0.603	0.603
$\overline{e}$	0.799	0.525	0.586	-	-	-
z	-	-	-	0.596	0.596	0.597

The conventional model with supervision is preferred for some value of ϵ. Otherwise, PPP model delivers a better outcome. The expected informational rents are less costly for the government when there is a single firm as long as $\epsilon \leq 1/4$ in the two firms structure with supervision.

Regarding to quantities, this example shows that $\underline{q}^{fb} > \underline{q}^{sb} > \underline{g}^{sb,m}(\sigma_1) > \underline{g}^{sb,m}(\sigma_2)$ and $\overline{q}^{fb} > \overline{g}^{sb,m}(\sigma_2) > \overline{q}^{sb}$. The effort follows the same pattern: $\underline{e}^{fb} > \underline{e}^{sb} > \underline{z}^{sb,m}(\sigma_1) > z^{sb,m}(\sigma_2)$ and $\overline{e}^{fb} > z^{sb,m}(\sigma_2) > \overline{e}^{sb}$.

6 Conclusion

We have compared the efficiency of different procurement structures when the government decentralizes the supply of an infrastructure services from the construction of the basic asset to the service provision. In a world of perfect information about actions and costs, the government is certainly indifferent among decentralizing the service into a public-private partnership or into a conventional model.

In practice, the allocation of information is uneven among players and their capacity to screen and identify actions and parameters is limited. In such a world, asymmetric information creates different transactional costs among organizations.

There is a large literature on decentralization when the informational gaps are based on a multi-dimensional adverse selection setting and in multitask moral hazard environment. In the case of PPPs, recent developments identify conditions that support task bundling into a PPP vis-à-vis a conventional model of procurement in which the State delegates investments and operations into different firms including public owned firms. This literature focused on asymmetric information between agents (government, PPP, builders, service providers, etc.) to analyze task bundling. Ownership has an important say in the analysis. However, ownership does not matter in the literature of asymmetric information if complete contracts can be written – any contingency can be forecasted and included in the contract. Therefore, if contracts are useless as in an incomplete contract approach, ownership may confer some advantages over the residual benefits when a contingency occurs.

As in Bentz (2004), we depart from ownership and look for conditions to support task bundling. The model described in this article has two sequential activities which can be interpreted as construction and operation. The government does not know the marginal cost of building the asset and cannot observe the effort or actions implemented by the service provider to obtain a better sector performance. We believe that an adverse selection framework is well suited to explain a greenfield investment instead of adopting a moral hazard environment as in Bentz *et al.* - in particular, when the government had implemented an efficient procurement system. On the other hand, when the government has limited resources and expertise in service provision, the moral hazard framework may be capturing the government's lack of knowledge on how efficiently the asset can be operated.

We have shown that when a single firm vertically integrates building and operation, the incentives to misreport costs and to reduce socially desirable actions are mitigated. When efficient, misreporting marginal cost can be profitable but the private consortium can do even better by accepting the contract designed for a low marginal cost firm which ends up increasing the informational rents at the service provision stage. The firm finds the optimal trade-off between misreporting its marginal cost, which increases informational rents, and increasing the synergies between the two activities. At the end, the government needs to transfer less informational rents to the company from the users. There are some economies of scope in information when both activities are integrated. However, our result is conditional to implement a contract that induces actions at the service delivery stage which are conditional to the marginal cost of the builder. If the contract specifies the same action at the service delivery stage, independently of the builder's marginal cost, the government looses such incentives. Moreover, the expected informational rents at the beginning of the game, when the government does not know θ and e, are higher when the contract induces to the same effort for both types. On the other hand, lower expected rents are required with a type-dependent effort level but the principal needs to structure transfers such the gap between the expected rents when the agent is efficient and inefficient is high compared to the single effort contract. Precisely, the contract for a type-dependent effort relies on more powerful incentives by creating a higher gap in expected rents.

The allocation of construction and operation into different firms yields a lower expected welfare since agents do not internalize the mentioned effect. In addition, more information is needed at the interim stage as the government requires to observe the contract chosen by the builder before contracting with the service provider to induce a type-dependent effort level.

We have also shown that introducing supervision could be better when the expected rent reduction overcomes the internalization effect. The government can rely on the advisory services of an experienced service provider to select the most efficient builder and reduce distortion and informational rents. However, this result is affected by the technology of supervision and the possibility of collusion.

Appendix

Proof of Proposition 3. In this proposition, first order conditions are computed assuming $\underline{ASIC}$ together with the two ex-post limited liability constraints in the low state of nature binding (η_2, η_4 are positive). We have to show not only that the omitted constraints are satisfied but also that I am considering the correct binding constraints. Suppose as in LM that we consider a solution with $\underline{ASIC}$ binding and η_4 positive ($\bar{t}_l - \overline{\theta}\overline{q} = 0$). The ex-post constraint in the bad state of nature when the agent is efficient cannot be binding without violating the incentive constraint. But when effort is type-dependent, it can be the case that $\underline{u}_l = \overline{u}_l = 0$ as we show below in this proof. We proceed as follows. First we show that the omitted constraints are satisfied, that is, at least the solution is feasible. Second, we show that a solution with $\underline{u}_l > 0$ is not feasible. Therefore, the solution characterized by this proposition is feasible and optimal.

Let us begin checking the ex-post limited liability constraints. As shown below in this proof, the set of transfers is such that $\underline{u}_h^{sb} = \underline{\psi}'(\underline{e}) > 0$ and $\overline{u}_h^{sb} = \overline{\psi}'(\overline{e}') > 0$. Then, these omitted constraints are satisfied.

Adding the two $ASICs$ we find that the implementability condition requires that $\underline{q}^{sb} > \overline{q}^{sb}$ which is certainly true. Therefore, the $\overline{ASIC}$ is satisfied. Finally, it is simple to show that ex-ante participation constraints are not violated.

Let us consider another potential solution when $\underline{ASIC}$ and $\overline{u}_l$ are binding (but $\underline{u}_l > 0$). we denote this solution with the superscript 1 and this hypothetical contract is characterized by:

$$\begin{array}{ll} \underline{q}^1 : \underline{S}_q(\underline{e}) = \underline{\theta}, & \overline{q}^1 : \overline{S}_q(\overline{e}) = \overline{\theta} + \frac{v}{1-v}\Delta\theta, \\ \underline{e}^1 : \underline{S}_e(\underline{e}) = \underline{\psi}', & \overline{e}^1 : \overline{S}_e(\overline{e}) = \overline{\psi}' + \frac{\overline{e}\overline{\psi}''}{1-v}, \\ \underline{t}_h^1 = \overline{t}_l + \underline{\psi}', & \underline{t}_l^1 = \Delta\theta\overline{q} - \underline{\omega} + \overline{\omega} + \underline{\theta}\underline{q}, \\ \overline{t}_h^1 = \overline{t}_l + \overline{\overline{\psi}}', & \overline{t}_l^1 = \overline{\theta}\overline{q} \end{array}$$

where by definition $\underline{\omega} = \underline{e}\underline{\psi}' - \underline{\psi}$, $\overline{\omega} = \overline{e}\overline{\psi}' - \overline{\psi}$ and $\Delta\omega = \underline{\omega} - \overline{\omega} > 0$ if $\underline{e} > \overline{e}$. I call $\Delta\omega$ as the incremental moral hazard informational rents.

Comparing the two solutions, I find that $\underline{q}^1 > \underline{q}^{sb}$ since $\underline{e}^1 > \underline{e}^{sb}$. In addition, $\overline{q}^{sb} > \overline{q}^1$ with $\overline{e}^{sb} > \overline{e}^1$. It implies $\underline{\omega}^1 > \underline{\omega}^{sb}$ and $\overline{\omega}^{sb} > \overline{\omega}^1$.

Therefore if $\underline{u}_l^{sb} = \Delta\theta\overline{q}^{sb} - \Delta\omega^{sb} = 0$ then $\underline{u}_l^1(\overline{q}^1, \underline{e}^1, \overline{e}^1) < 0$. It means that the constraint is not satisfied and solution 1 cannot be feasible.

Comparing the optimal solution and the proposed (not feasible) solution, it is clear that $\lambda_1 \in (0, v)$.

Finally, to fully characterize the optimal contract, the set of transfers is:

$$\begin{array}{ll} \underline{t}_h^{sb} = \underline{t}_l^{sb} + \underline{\psi}', & \underline{t}_l^{sb} = \underline{\theta}\underline{q}^{sb}, \\ \overline{t}_h^{sb} = \overline{t}_l^{sb} + \overline{\overline{\psi}}', & \overline{t}_l^{sb} = \overline{\theta}\overline{q}^{sb} \end{array}$$

■

Proof of Lemma 2 . In this type of mixed model, informational rents come from two sources. First, given that the government cannot screen types without paying the agent some rents, there are AS informational rents. In addition, the government cannot observe the effort and then, it should pay some MH informational rents as well. The first type of rents prevent the agent for misreporting the type and the second one induces the agent to follow some level of effort. Note that if there was only AS, without an incentive compatible contract, an efficient agent would misreport her type. On the other side, given that the marginal cost of effort is increasing and $\underline{e}^{sb}$ is larger than $\overline{e}^{sb}$, the MH rents are larger when the efficient agent does not deviate. The two effects work in opposite direction. Moreover, as expressed in Corollary 1, the binding $\underline{ASIC}$ implies that any increase in the AS informational rents $\Delta\theta\overline{q}^{sb}$ must be equated with a reduction in the MH informational rents $\Delta\omega^{sb}$. In some sense, this equality captures the trade-off faced by an efficient agent between deviating in the quantity produced and obeying the recommended effort level. ■

Proof of Proposition 5. Let us solve this game backwards assuming that B reveals that it has marginal cost θ by choosing the contract designed for its type. At period 2, the government observes g and maximizes the expected surplus that characterizes the optimal moral hazard contract:

$$\underset{z|g}{Max} \qquad S(g,z) - T^{SP}(t_h, t_l, z)$$
$$s.t.$$
$$t_h^{SP} - t_l^{SP} = \psi', \qquad t_h^{SP}, t_l^{SP} \geq 0$$
$$U^2 = t_h^{SP} z + t_l^{SP}(1-z) - \psi \geq 0$$

As in standard moral hazard environments, it is optimal to set $t_l^{SP} = 0$ and $t_h^{SP} = \psi'$. The FOC of this problem is:

$$S_z(g,z) = \psi' + \psi'' z$$

Then, for a given $\underline{g}$ and $\overline{g}$, it leads to $\underline{z}^{sb} = \underline{z}(\underline{g})$ and $\overline{z}^{sb} = \overline{z}(\overline{g})$ with $\underline{z}^{sb} > \overline{z}^{sb}$ (provided that $\underline{g} > \overline{g}$).

With this information at period 1 the principal designs the optimal contract for A_1 :

$$\underset{(\underline{t}^1,\underline{g}),(\overline{t}^1,\overline{g})}{Max} \quad v\left[\left(S(\underline{g},\underline{z}(\underline{g}))-\underline{T}^{SP}(\underline{t}_h(\underline{g}),\underline{t}_l(\underline{g}),\underline{z}(\underline{g}))\underline{t}_h^2(\underline{z}(\underline{g}))\right)-\underline{t}^B\right]$$
$$+(1-v)\left[\left(S(\overline{g},\overline{z}(\overline{g}))-\overline{T}^{SP}(\overline{t}_h(\overline{g}),\overline{t}_l(\overline{g}),\overline{z}(\overline{g}))\right)-\overline{t}^B\right]$$
$$s.t.$$
$$\underline{t}^B-\underline{\theta}\underline{g}\geq\overline{t}^B-\underline{\theta}\overline{g}, \qquad \overline{t}^B-\overline{\theta}\overline{g}\geq\underline{t}^B-\overline{\theta}\underline{g}$$
$$\underline{u}^B=\underline{t}^B-\underline{\theta}\underline{g}\geq 0, \qquad \overline{u}^B=\overline{t}^B-\overline{\theta}\overline{g}\geq 0$$

We assume that $\overline{u}^B$ and $\underline{ASIC}$ are binding to solve a relaxed optimization program and I check ex-post if the omitted constraints are satisfied. The reader can verify that the FOCs of this relaxed program together with the FOC of the SP problem lead to the characterization enunciated in this proposition.

Moral hazard informational rents are $\underline{U}^{SP,sb}=\underline{z}^{sb}\underline{\psi}'^{sb}-\underline{\psi}^{sb}$ and $\overline{U}^{SP,sb}=\overline{z}^{sb}\overline{\psi}'^{sb}-\overline{\psi}^{sb}$.

Adverse selection informational rents are $\underline{U}^{B,sb}=\Delta\theta\overline{g}^{sb}$ and $\overline{U}^{B,sb}=0$. It is clear that $\overline{ASIC}$ and $\underline{u}^B$ are satisfied.

Finally, the set of transfers is characterized by:

$$\begin{array}{ll} \underline{t}_h^{SP,sb}=\underline{\psi}', & \overline{t}_h^{SP,sb}=\overline{\psi}', \\ \underline{t}_l^{SP,sb}=0, & \overline{t}_l^{SP,sb}=0 \\ \underline{t}^{B,sb}=\Delta\theta\overline{g}+\underline{\theta}\underline{g}, & \overline{t}^{B,sb}=\overline{\theta}\overline{g} \end{array}$$

■

Proof of Proposition 6. We proceed as in the proof of Proposition 5 solving by backward induction.

Let us consider the optimization program at period 1' when the SP reveals σ_i $(i=1,2)$. To simplify notations, let $\underline{z}=\underline{z}(\sigma_1)$ and $z=z(\sigma_2)$.

$$\underset{\underline{z},z}{Max} \quad v\epsilon\left[\left(S(\underline{g},\underline{z})-\underline{T}^B(\underline{t}_h(\sigma_1),\underline{t}_l(\sigma_1),\underline{z})\right)-\underline{t}^B(\sigma_1)-s_1\right]+$$
$$v(1-\epsilon)\left[\left(S(\underline{g},z)-T^{SP}(t_h(\sigma_2),t_l(\sigma_2),z)\right)-\underline{t}^B(\sigma_2)-s_2\right]$$
$$+(1-v)\left[\left(S(\overline{g},z)-T^{SP}(t_h(\sigma_2),t_l(\sigma_2),z)\right)-\overline{t}^B(\sigma_2)-s_2\right]$$

s.t.

$$\underline{t}_h^{SP}(\sigma_1) - \underline{t}_l^{SP}(\sigma_1) = \underline{\psi}'(\underline{z}) \quad (4)$$
$$t_h^{SP}(\sigma_2) - t_l^{SP}(\sigma_2) = \psi'(z) \quad (5)$$
$$s_1 + \underline{U}^{SP}(\sigma_1) \geq s_2 + U^{SP}(\sigma_2) \quad (6)$$

In addition, all transfers and utility must be non-negative. The last three inequalities represent the moral hazard incentive constraint when the agent reveals σ_1, σ_2, and the supervision incentive constraint respectively.

Consider a solution when $s_1 = s_2 = 0$. The SIC is satisfied when $\underline{z}(\sigma_1) > z(\sigma_2)$ (see the proof of Corollary 3 below). Then, the FOCs are:

$$\begin{aligned} \underline{z}(\sigma_1 \mid \underline{g}_1) &: \underline{S}_z(\underline{z}) = \underline{\psi}'(\sigma_1) + \underline{z}\underline{\psi}''(\sigma_1) \\ z(\sigma_2 \mid \underline{g}_2, \overline{g}_2) &: ES_z(z) = \psi'(\sigma_2) + z\psi''(\sigma_2) \end{aligned}$$

where $ES_z(z) = \frac{v(1-\epsilon))\underline{S}_z(z)+(1-v)\overline{S}_z(z)}{1-v\epsilon}$ denotes the expected marginal surplus revised on the basis of the signal ϵ.

Through this result, the principal solves the maximization problem at period 1 choosing the triple $\left\{\underline{g}_1 = \underline{g}(\sigma_1), \underline{g}_2 = \underline{g}(\sigma_2), \overline{g}_2 = \overline{g}(\sigma_2)\right\}$, which yields in:

$$\begin{aligned} \underline{g}^{sb,m}(\sigma_1) &: \underline{S}_g(\underline{z}(\sigma_1)) = \underline{\theta} \\ \underline{g}^{sb,m}(\sigma_2) &: \underline{S}_g(z(\sigma_2)) = \underline{\theta} \\ \overline{g}^{sb,m}(\sigma_2) &: \overline{S}_g(z(\sigma_2)) = \overline{\theta} + \frac{v(1-\epsilon)}{1-v}\Delta\theta \end{aligned}$$

■

Proof of Proposition 7. *Part i)* It is clear that $\underline{q}^{fb} > \underline{q}^{sb} > \underline{g}^{sb}$ with $\underline{e}^{fb} > \underline{e}^{sb} > \underline{z}^{sb}$. On the other side $\overline{q}^{fb} > (\overline{q}^{sb} \lesseqgtr \overline{g}^{sb})$ with $\overline{e}^{fb} > (\overline{e}^{sb} \lesseqgtr \overline{z}^{sb})$. When the agent is inefficient, we do not know whether $\overline{q}^{sb} \lesseqgtr \overline{g}^{sb}$ and $\overline{e}^{sb} \lesseqgtr \overline{z}^{sb}$. In effect, distortion in production when the agent is inefficient could be lower in the PPP model. On the other hand, the distortion in effort could be lower in the conventional organization. The general effect is ambiguous.

Note that the contracts in the conventional model are incentive compatible in the PPP structure. In effect, it is adverse-selection-incentive-compatible since $\underline{g}^{sb} > \overline{g}^{sb}$ and it is moral-hazard-incentive-compatible if we merge the two-agent system of transfers as follow:

$$\underline{t}_h = \underline{t}_l^2 + \psi'(\underline{z}^{sb}), \quad \underline{t}_l^2 = \underline{\theta}\underline{g}^{sb} + \Delta\theta\overline{g}^{sb},$$
$$\overline{t}_h = \overline{t}_l^2 + \psi'(\overline{z}^{sb}), \quad \overline{t}_l^2 = \overline{\theta}\overline{g}^{sb}$$

Then, among the set of incentive compatible contracts, the one that achieves the higher welfare is $\left\{ \left(\underline{t}_h^{sb}, \underline{t}_l^{sb}, \underline{q}^{sb}, \underline{e}^{sb}\right), \left(\overline{t}_h^{sb}, \overline{t}_l^{sb}, \overline{q}^{sb}, \overline{e}^{sb}\right) \right\}$ but it has not been chosen by the government. Then it is possible to conclude that the PPP model dominates the conventional organization from a welfare perspective.

In terms of rents, they are larger when there are two agents. Suppose that $\overline{q}^{fb} > \overline{g}^{sb} > \overline{q}^{sb}$ with $\overline{e}^{fb} > \overline{z}^{sb} > \overline{e}^{sb}$. Let us denote by $\underline{U}^{sb} = \underline{e}\underline{\psi}' - \underline{\psi}$, $\overline{U}^{sb} = \overline{e}\overline{\psi}' - \overline{\psi}$ the utility of an efficient and an inefficient agent respectively in the single agent structure and by $\underline{U}^{B,sb} = \Delta\theta\overline{g}$, $\overline{U}^{B,sb} = 0$ and $\underline{U}^{SP,sb} = \underline{z}\underline{\psi}' - \underline{\psi}$, $\overline{U}^{SP,sb} = \overline{z}\overline{\psi}' - \overline{\psi}$ the utilities of B and SP respectively in the conventional model.

The expected rent in the PPP mechanism is:[10]

$$\begin{aligned} v\underline{U} + (1-v)\overline{U} &> 0 \\ v\Delta\theta\overline{q} + \left[\overline{e}\overline{\psi}' - \overline{\psi}\right] &> 0 \end{aligned}$$

and in the conventional model the expected rent is:

$$\begin{aligned} v\Delta\theta\overline{g} + v\left[\underline{z}\underline{\psi}' - \underline{\psi}\right] + (1-v)\left[\overline{z}\overline{\psi}' - \overline{\psi}\right] &> 0 \\ v\Delta\theta\overline{g} + EU^{SP} &> 0 \end{aligned}$$

where $EU^{SP} = v\left[\underline{z}\underline{\psi}' - \underline{\psi}\right] + (1-v)\left[\overline{z}\overline{\psi}' - \overline{\psi}\right]$.

Subtracting the last equation from the PC's rent we find that:

$$v\Delta\theta\left(\overline{q} - \overline{g}\right) + \left[\overline{e}\overline{\psi}' - \overline{\psi}\right] - EU^{SP} < 0$$

since by assumption $\overline{q} < \overline{g}$ and $\overline{z} > \overline{e}$.

Part ii) Suppose that ϵ tends to one. In this case, the principal does not need to create an extra distortion in production when the agent is inefficient. It is clear that $\underline{q}^{fb} > \underline{q}^{sb} > \underline{g}^{sb,m}(\sigma_1)$ with $\underline{e}^{fb} > \underline{e}^{sb} > \underline{z}^{sb,m}(\sigma_1)$ as shown in the proof of Corollary 3 (see below).

[10] From now on, in this proof, we remove the superscript denoting second best.

On the other side, when B is inefficient, $\overline{q}^{fb} > (\overline{q}^{sb} \lesseqgtr \overline{g}^{sb,m}(\sigma_1))$ with $\overline{e}^{fb} > (\overline{e}^{sb} \lesseqgtr \overline{z}^{sb,m}(\sigma_1))$. This is explained by the fact that distortion in production is low when there is supervision and the agent is inefficient but on the contrary, the moral hazard distortion is low when one agent performs both activities. The aggregate effect is ambiguous.

Moreover, the principal does not need a high value of ϵ to find cases where the internalization effect enunciated in Lemma 2 does not compensate the advantage of competing for information. ■

Proof of Corollary 3. Assume the opposite, that is $z^{sb,m}(\sigma_2) > \underline{z}^{sb,m}(\sigma_1)$. Therefore, it means that $ES_z(z(\sigma_2)) > \underline{S}_z(\underline{z}(\sigma_1))$. Consider the case where the probability to receive a good signal tends to 1. In this case:

$$\underset{\epsilon \to 1}{Limit} \quad ES_z(z(\sigma_2)) = \overline{S}_z(z(\sigma_2))$$

However, this contradicts the assumption that $z^{sb}(\sigma_2) > \underline{z}^{sb}(\sigma_1)$ since $\overline{S}_z(z(\sigma_2))$ cannot be larger than $\underline{S}_z(\underline{z}(\sigma_1))$ when provided that $\overline{\theta} > \underline{\theta}$. ■

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