Post-Tender Corruption and Risk Allocation: Implications for Public-Private Partnerships*

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Abstract

Whilst a lot has been said about how to fight corruption at tender stage in public procurement, post-tender corruption is an issue that remains almost unexplored. In this paper, we make a step towards filling this gap, by studying the relationship between the quality of a country's institutions, in particular its monitoring technologies and corruption, and the level and form of risk transfer to the contractor. We discuss the desirability of state-contingent clauses, which provide insurance to the contractor but are at high risk of manipulation. We derive implications on the benefit and cost of procurement forms which are based on high levels of risk transfer to the private sector, such as Public Private Partnerships (PPPs).

1 Introduction

One important aim of anti-corruption programs in public procurement is to avoid that corrupted officials alter the auction process so as to ensure a rewarding contract to a contractor in exchange for a bribe.

Corruption deals may take a variety of forms. The demand needs of the public administration may be altered so as to make the winning of a specific contractor inevitable; the call for tender may not be advertised adequately so as to avoid competition from other contractors; the time elapsing between the call for tender and the request

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for proposal may be so short to make it impossible to prepare the bids adequately; the tender specifications may be so contractor-specific to identify already the winner; the tender design and the bids or the award criterion may be manipulated so as to favour a specific contractor, and so on.

Fighting corruption at tendering stage has always been the focus of countries' regulations and academic research. In most countries, rules have been introduced so as to try to ensure more transparency and adequate advertising of tender calls or sufficient time to prepare bids. Further, numerous regulations have been introduced to restrict the discretion that public officials can use when selecting the auction format and when choosing the award criterion. Information technology (procurement) and electronic auctions have been designed to reduce the scope for bids manipulation. See Lengwiler and Wolfstetter (2006) for more details.

But ensuring a fair tendering process does not suffice to protect procurement contracts from corruption. Corruption may take place not only at tendering stage but also at post-tendering stage. Søreide (2002), and references therein, reports many corruption practices taking place during contract execution. The contractor may use sub-standards materials and construction shortcuts without this being reported by a complacent public official. Corrupted officials may protect the contractor when the materials invoicing are falsified; or they may justify price revisions or contract lengthening when specific circumstances arise. Supplementary works may be requested by conditions found after the contract has been drawn, manipulated by the contractor with a complacent public official. The technical expertise of the procurement department can be bribed to ignore part of the contract or to waive penalties for underperformance.[1,2]

In his extensive survey on corruption practices in public procurement, Piga (2011) argues that post-tender corruption is a more serious problem than pre-tender corruption. The award procedure receives the highest level of attention from various stakeholders. This makes it easy to spot changes in tender documents provided by contractors. For instance, IT secure technologies make it difficult to change prices by modification of tender documents received. Awarding the tender at a higher price than the market price could be risky as stakeholders can easily benchmark the outcome with the price available in the market. Changing (favoritism) the required good or service to be purchased, or abusing discretion in the award criterion can also be risky due to, again, the ease of spotting deviations from standard documents used by other procuring entities. Instead, post tender corruption is out of the public eyes and more difficult

[1] As shown by Iossa and Spagnolo (2011) in a relational contracting framework, writing and ignoring explicit contracts (and thus also non enforcing contractually specified penalties) can help facilitate corrupt agreements.

[2] Albano and Zampino (2011) show that in a sample of 800 inspections for Italian procurement contracts between September 2006 and April 2007, 437 were not at the required contractual level. But in only 16 cases (3,66%) were penalties enforced. However, whether these concerns are generated by incompetence or corruption, could not be ascertained by their study.

to spot.[3]

Thus the attention needs shifting to the post-tendering stage. And whilst fighting corruption at tendering stage is a matter of designing the tendering process, fighting corruption at post-tendering stage is more a matter of designing the procurement contract and organizing the contract management and supervision in order to reduce the scope for corruption. This is the focus of this paper. More precisely, we ask how the payment scheme and the risk allocation provided by the contract may have to be altered so as to reduce the scope for corruption at contract execution stage. We derive implications on the benefit and cost of procurement forms which are based on high levels of risk transfer to the private sector, such as Public Private Partnerships (PPPs).

PPPs are procurement contracts where the supplier takes responsibility for both the building of the infrastructure and its managing and maintenance. The DBFO model ('Design', 'Build' 'Finance' and 'Operate'), the BOT model ('Build', 'Operate' and 'Transfer') or the BOO ('Build', 'Own' and 'Operate') are all common contractual modes that feature bundling of building and operation in a single contract with a single contractor (or consortium of contractors). PPPs are used across Europe, Canada, the U.S. and a number of developing countries for the provision of public infrastructures and services in sectors such as transport, energy, water, IT, prisons, waste management, schools, hospitals and others.[4] An important distinction in PPP contracts is the one between the 'concession model' and the 'PFI model'. Transport projects for toll roads, ports and rail typically follow the concession model, where the private provider recoups (part or all of) its initial investment through charges to final users. In PPP hospitals, schools and prisons, instead, where users typically do not pay; it is the public sector that pays the private sector party for the service that it provides to users. This is known as the 'PFI model'. Key to both models is risk transfer. Under a PPP construction and either availability or demand risk are typically transferred to the private contractor, as a way to provide incentives to perform.

Standardized PPP contracts typically provide for 'Specific Circumstances' clauses which list a number of 'supervening events' for which the authority provides some sort of relief for the contractor. 'Compensation Events' for example provide monetary compensations to the contractor for events beyond its control which result in a delay to service commencement and/or increased costs to the contractor. Specific changes in law fall within this category. 'Relief Events' are events which prevent performance by

[3]Piga (2011) argues that post-tender corruption is monitored less effectively by judges, authorites and media than corruption at tendering stage, since it involves long and expensive periods of monitoring and often higher expertise than what is needed for making price comparisons or unveiling blatant favoritism in the tender documents. Post-tender corruption is also monitored less by rival suppliers who cannot properly see the nature of the services delivered .

[4]For a discussion on the optimality of bundling in PPPs, see e.g. Bennett and Iossa (2006), Martimort and Pouyet (2006) and Iossa and Martimort (2008).

the contractor of its obligations, in respect of which the contractor bears the financial risk in terms of increased costs and reduced revenue but for which it is given relief from the application of penalties or from contract termination.[5] PPP contracts also provide typically for some revenue guarantees: in states in which user fee revenues are lower than some pre-specified amount, the contractor receives some subsidies from the public authority.

Like specific-circumstances clauses, guarantees are contingent contracts, which provide for changes in subsidies or other contractual conditions to be contingent on the realization of some external events.[6] This contingent nature inevitably reduces transparency in PPP contracting and creates scope for corruption at post-tender stage. Complacent public officials may indeed report states of the world that justify a contingent subsidy or a change in contractual conditions, and thus unduly improve the financial position of the firm. Hemming (2006) for example reports that many countries have poor records of the guarantees they have provided to the contractors and that little transparency exists on their extent and application.

To analyze how post-tender corruption affects the design and performance of PPP contracts, we consider a public procurement context where project revenues are affected by the contractor's operating effort and by exogenous shocks. Incentives to the contractor are provided through a payment structure that optimally allocates revenue risk between the public authority and the contractor. The contract may provide for the contractor to be compensated in states where revenues are low. A public officials may verify the realized state and be corrupted to make false reports.

We show that optimal risk sharing calls for the set up of contingent clauses where the contractor is compensated for the occurrence of events beyond its control that negatively affect its revenues. This form of insurance improves the noise-to-signal ratio and reduces the cost of providing incentives for operational effort.

However, contracts providing for a wider applications of contingent clauses are also those which create more scope for post-tender corruption and where the cost of weak institutions is greater. When monitoring can be ineffective, either because of corruption or because of weak monitoring technologies, using contingent contracts leaves scope for manipulation by public officials (through their hiding relevant information) and by the contractors (through their misreporting information). For this reason, when the country's institutions are weak, contracts should make less use of contingent clauses and leave more exogenous risk to the contractor. The cost of weak institutions is then

[5] The events include fire, explosion, lightning, storm, tempest, flood, bursting or overflowing of water, tanks, apparatus or pipes, ionizing radiation, earthquakes, riot and civil commotion.

[6] Engel, Fisher and Galetovich (2007) derived the price duration and revenue garantees in a typical concession contract where users pay. The optimal contract involves both a state-dependent subsidy in low-demand states and a state-dependent revenue cap above which the government collects all revenues. Moreover, the concession termis state contingent in high-demand states, and the concession lasts indefinitely when subsidies are paid out. Whilst we share some of their insights, we extend the analysis to consider the possibilty of corruption and adverse selection on the demand state.

an increase in the risk premium due to the contractor and a reduction in its incentives.

We also show that when uncertainty is high, state-contingent clauses that reduce the risk exposure of the contractor are most valuable. In these instances, weak institutions with little transparency at contract execution stage have more to lose from the use of rigid contracts to fight corruption. Overall the scope for using PPPs will therefore be lower when project risks are higher.

We also briefly discuss the shape of the optimal anti-corruption program. We show that corruption needs to be fought by a combination of better monitoring technologies and government policies which make public officials accountable for their actions. Accountability can be achieved by linking more explicitly the budget of the government agency in charge of monitoring, or even the salary of the individual public official, to the effectiveness of its monitoring and thus the monitoring outcome.

The paper is organized as follows. Section 2 presents our model. Section 2 discusses the case of strong institutions where productivity shocks are verified through efficient monitoring technologies and public officials behave honestly. Section 4 studies the case of weak institutions where ex post monitoring may be ineffective, because of weak technologies or procedures or of corruption. It describes the collusion technology and side-contracts between public officials and the contractor, and derives the optimal features of the anti-corruption program, and the consequences of corruption on feasible investments. Section 5 discusses the policy implications of our results and gives empirical predictions. Proofs are relegated to an Appendix.

2 The model

We consider the following public procurement context: A public authority (the principal) relies on a private contractor (the agent) to provide a public service. Examples of such delegation include of course transportation, water production and sanitation, waste disposal, clinical and educational services etc. The provision of the service requires also to build and design an infrastructure. Incentives to the contractor are provided through a payment structure which optimally allocates revenue risk between the public authority and the contractor. The contract may provide for the contractor to be compensated when negative shocks occur during the contract execution. A public officials may verify the events. We will study the consequence of corruption of the public official on the payment structure and risk allocation provided by the optimal contract, and on the size of feasible projects.

Our model builds on several ingredients that we now present in more details.

Technology. The provision of the service requires an initial investment that costs I. One can think of it as the cost of the infrastructure required to provide the service: a rail network, a bridge, a port, a water network, a hospital or a prison. For services where users pay (concession model), the revenues from the service are stochastic and defined as

$$R = \theta + e + \zeta.$$

- First, e is the operating effort. The effect of e on R captures for example the higher demand from users of transport services when service reliability, on-the train services, or the efficiency of the ticketing system are higher. The operating effort e improves revenues but its provision is costly for the operator. This cost can be a disutility of effort counted in monetary terms which is $\frac{e^2}{2}$ or a true production cost incurred at the operation stage in which case it is also non-verifiable. The non-verifiability of costs is a key feature of complex projects like PPPs. This is especially true in developing countries as noticed by Laffont (2005) and Estache and Wren-Lewis (2009).

- Second, θ and ζ represent revenue shocks. The random variable ζ represents a demand or productivity shock that occurs before the operational stage and whose occurrence has an element of verifiability. During the design stage for example the legal standards of service may change due to a new legislation, or the innovations in the procedure and service provision may result in unexpected cost saving or increases. In transport concessions, building excavation may reveal archeological sites delaying construction, oil prices may vary, macroeconomic conditions may change affecting future demand, and so on. The random variable ζ represents a demand or productivity shock that occurs during the operational stage and whose occurrence is not verifiable. In transport concessions, demand can be affected unpredictably by competition from other modes or facilities, from the conditions affecting the wider network, such as economic activity levels or tourism demand, and from the price of inputs (e.g. fuels), and it is difficult to disentangle the effect of each of these factors. For simplicity, we assume that θ has zero mean but can only take two values $\bar{\theta} = (1 - \nu)\Delta\theta > 0$ and $\underline{\theta} = -\nu\Delta\theta < 0$ with respective probabilities ν and $1 - \nu$. Let $E_\theta(\cdot)$ be the expectation operator with respect to θ and $\Theta = \{\underline{\theta}, \bar{\theta}\}$ be the set of possible demand shocks. We further assume that ζ is normally distributed with zero mean and variance σ^2.

To simplify exposition, we shall use R interchangeably to denote also the benefit from the service, for those services where users do not pay (PFI model). Here, e captures for example the operational efficiency of hospitals, the attitude of prisons staff towards inmates, or the quality of education and management in schools, whilst ζ captures the uncertainty affecting the social benefits derived from the service, such as changes in users' needs due to new legislations introducing tighter standards, or to the availability of alternative services.

Information. Our model entails both elements of adverse selection and moral hazard.

- First, the parameter θ is unknown to all parties at the time a PPP contract is signed even though it will be later known by the contractor. This setting reflects the procurement of complex projects which require technically demanding and specialist skills, which make past information within the public sector of little use to assess current risks. It is then reasonable to expect that as events unfold, there arises an informational advantage of the operator on the productivity shocks that affect the building stage.

- This signal is a piece of *soft information* that can be manipulated by the contractor. This creates an adverse selection problem ex post and contracts will have to be designed to screen that parameter.

- Second, a public official (or public official) can be used to generate a binary signal $\sigma \in \Sigma = \{\sigma_1, \sigma_2\}$ on the contractor's productivity shocks in order to bridge the informational gap with the public authority. If $\sigma = \sigma_1 =$ "θ", the public official already knows at the time of contract signing that he will have all expertise to precisely assess those returns later on. Note that this does not mean that the public official knows yet what these returns will be; *"he just knows that he will know".* This assumption is consistent with the idea that the PPP project may be largely uncertain from an ex ante point of view but that public officials may view that kind of projects with more or less ambiguity.

  If instead $\sigma = \sigma_2 = \emptyset$, the public official knows, at the time the contract is designed, that he will be unable to evaluate whether the project generate highs or low returns when those shocks realize.

  Following Tirole (1986) and Laffont and Tirole (1993, Chapter 13), this signal is a piece of *hard information.* The evidence "θ" can be hidden by the public official who could claim having observed $\emptyset$. On the contrary, the public official cannot forge evidence and report "θ" when he knows $\sigma = \emptyset$.

  For simplicity, we assume that σ and θ are independently distributed and that the probability of $\sigma =$ "θ" (resp. $\sigma = \emptyset$) is ϵ (resp. $1 - \epsilon$). The parameter ϵ thus captures the effectiveness of the monitoring technology.

- Third, the contractor's effort e is non-verifiable. The operator chooses the effort e *ex post*, i.e., once he already knows θ. This simple formulation allows us to capture how the contractor can adapt its second-stage efforts to productivity shocks in the environment.

Contracts. The revenue R is verifiable and can thus be contracted upon even though the principal cannot disentangle the respective impacts of effort e, and revenue shocks θ and ζ. In transport projects, for example, revenues can be verified through electronic ticket systems, whilst in energy projects they can be specified through computerized billing systems, and revenue sharing agreements between the public authority and the contractor are widely employed. Following Holmström and Milgrom (1987, 1991), we assume for simplicity that those contracts are linear in revenues.

Contracts between the public authority and the contractor are also designed ex ante, i.e., before revenue shocks realize. In full generality, contracts must be flexible enough to accommodate the different information structures. Such contracts are designed with the dual objective of providing insurance to the operator against shocks but also inducing operational effort. Those contracts, even though they are designed ex ante, are thus contingent on the reports made on both the public official's information and the contractor's future knowledge of the productivity shocks that will realize ex post. The largest class of such contracts stipulates a menu of linear revenues sharing schemes that depend on the contractor's report $\hat{\theta}$ on the shock parameter and on the public official's report $\hat{\sigma}$. These schemes write as:

$$t(R, \hat{\theta}, \hat{\sigma}) = \alpha(\hat{\theta}, \hat{\sigma}) + \beta(\hat{\theta}, \hat{\sigma})R.$$

For further references, we denote such mechanism as the collection $\{(\alpha(\hat{\theta}, \hat{\sigma}), \beta(\hat{\theta}, \hat{\sigma}))\}_{(\hat{\theta}, \hat{\sigma}) \in \Theta \times \Sigma}$. From the Revelation Principle,[7] those menus of contracts are incentive compatible and both the contractor and the public official report truthfully their information at equilibrium.

Finally, the public official also agrees ex ante on a wage schedule $\{s(\hat{\sigma})\}_{\hat{\sigma} \in \Sigma}$ that stipulates payments for each possible reports he may make.[8] For simplicity, we denote also $s_i = s(\sigma_i)$.

Objectives. Let us describe the three players' objective functions in details.

- The public authority is risk-neutral and maximizes the share of revenues it gets net of the costs of paying for the services and the infrastructure and net of the wages left to the public official. The assumption of risk-neutrality for the public authority may be questioned in the case of small local authorities whose PPP projects may represent a significant share of their overall budget. For a large country, the existing deadweight loss in the cost of taxation may as well introduce a behavior towards risk, if the PPP project were to represent a large share of the budget. We make this assumption as it gives a simple benchmark: in the absence of moral hazard, the optimal risk allocation requires the public

[7] Myerson (1982).

[8] It is trivial to check that there is no point in making those wages depend on the firm's report and that more general contracts would not help. Beside simplicity, one possible justification for the use of wages that depend only on the supervisor's payment is that those payments may not be delayed till the firm makes his own choice within the menu when the supervisor's report is uninformative.

sector to bear all risks.[9] Formally, this objective writes as:

$$R - t(R, \hat{\theta}, \hat{\sigma}) - s(\hat{\sigma}) - I.$$

- The contractor is risk-averse with constant degree of risk-aversion $r \geq 0$, and we denote $v(x) = 1 - exp(-rx)$ its utility function. The assumption of risk-aversion captures the fact that a PPP project might represent a large share of the contractor's activities so that there is little scope for diversification. The contractor cares about the expected net return of its activities:

$$E\left(v\left(t(R, \hat{\theta}, \hat{\sigma}) - \frac{e^2}{2}\right)\right),$$

  where $E(\cdot)$ is the expectation operator with respect to (θ, σ)

  Under all circumstances below, the contractor's outside opportunity yields an exogenous payoff normalized at zero.

- The public official is also risk-averse but, for simplicity, we assume that he has an infinite risk-aversion below zero wealth or, alternatively, that he is protected by limited liability and receives only non-negative payments $s(\hat{\theta}, \hat{\sigma})$.[10] These wages should be broadly interpreted. They can stand for the share of the agency budget or resources that can be diverted for private use.[11] Alternatively, they can also be considered as proxies for career concerns.[12] The public official only enjoys a private benefit $k\tau$ when he receives a bribe $\tau \geq 0$ where $k \in [0, 1)$. Such frictions are due to the existing transaction costs of side-contracting, including possibly the cost that contractors may bear in organizing corruptible activities, the fact that side-contracts are not easily enforceable,[13] the risk of being caught for briberies, or the psychological costs that the public official may incur when being involved in some illegal activities.[14,15] We assume that k is private information for the parties involved in the corruption deal. It is drawn from the interval $[0, 1]$ according to

[9] Lewis and Sappington (1995) and Martimort and Sand-Zantman (2007) analyze the consequences of having risk-averse governments in procurement settings.

[10] It should be clear that those wages have no reason to depend on revenues.

[11] Niskanen (1971) and Laffont and Tirole (1993).

[12] If this latter perspective is taken, payments to monitors could simply be viewed as the product of the probability of getting a promotion times the private benefit associated to this new job. Whatever the interpretation behind these wages, they remain socially costly. For instance, rewarding a supervisor for a zealous behavior by moving him towards higher positions in the bureaucratic hierarchy may come at the opportunity costs of not rewarding somebody who is more talented for this job.

[13] Tirole (1992), Martimort (1999).

[14] Khalil and Lawarrée (2006).

[15] More broadly, the existence of such transaction costs is a standard assumption in the public choice and regulation literatures. See Congleton (1984), Laffont and Tirole (1993), Faure-Grimaud, Laffont and Martimort (2002) and Faure-Grimaud and Martimort (2003) among others.

the common knowledge distribution $F(\cdot)$ (with positive and atomless density $f(\cdot)$) and that distribution satisfies the monotone hazard rate property $\frac{d}{d\theta}\left(\frac{F(k)}{f(k)}\right) > 0$.

Benchmark: When effort and productivity shocks are verifiable, the contractor is fully insured against all shocks and the efficient level of effort maximizes social welfare. The efficient effort e^* is then independent of the productivity shock θ and solves:

$$e^* = \arg\max_e e - \frac{e^2}{2} \equiv 1.$$

Finally, only projects with positive value are undertaken, which imposes an upper bound I^* on the feasible investments:

$$I \leq I^* = \frac{1}{2}.$$

3 Strong institutions: The case of perfect monitoring

In this section we consider the optimal PPP contract when good monitoring technologies are in place and the public officials behave honestly maybe because a culture of benevolence has developed or maybe because institutional checks again corruption have been put in place. In particular, we assume that the country's institutions are endowed with an efficient monitoring technology $\epsilon \equiv 1$ and, of course no corruption is possible, $k \equiv 0$.

With the contract monitored during its execution, shocks that occur during the construction phase are verified and extracting the information from the contractor is useless. However, as the contractor's effort is non-verifiable, a few conditions must be satisfied to induce operational effort. Thanks to the CARA specification and the normality of shocks, we can write the contractor's moral hazard incentive constraint as:

$$e(\theta) = \arg\max_{\tilde{e}} \alpha(\theta) + \beta(\theta)(\theta + \tilde{e}) - \frac{\tilde{e}^2}{2} - \frac{r\sigma^2\beta^2}{2} \equiv \beta(\theta) \quad (1)$$

where the maximand is the certainty equivalent of the contractor's payoff when θ is observed, and where $\frac{r\sigma^2\beta^2}{2}$ is the risk premium that needs to be paid to the contractor to compensate it for bearing the risk of exogeneous shocks ζ during operations. Clearly, the risk premium raises with the degree of risk aversion of the contractor, r, with the uncertainty that characterizes the operational stage, σ^2, and with the share of revenues kept by the contractor, β.

This leads to the following expression of the contractor's certainty equivalent payoff in state θ:

$$U(\theta) = \alpha(\theta) + \beta(\theta)\theta + \left(1 - r\sigma^2\right)\frac{\beta^2}{2}. \tag{2}$$

These expressions help us to rewrite the ex ante participation constraint that must be satisfied to induce the contractor's participation when θ is observed:

$$E_\theta(v(U(\theta))) \geq 0. \tag{3}$$

In practice, only the net revenues $R' = R - \theta = e + \zeta$ matter for incentives purposes while a payment $\alpha(\theta)$ contingent on θ can provide insurance against those revenue shocks.

We are now ready to describe the optimal contract in this pure moral hazard environment.

Proposition 1 *When revenue shocks that occur during construction are verifiable, the contractor is fully insured against these revenue shocks. The contractor keeps a constant share of revenues independent of the realized shock but it receives a full monetary compensation from the public authority.*

Contracts between the public and private sectors for the provision of a service often include contingency clauses providing for monetary payments to reflect external conditions affecting the operator's profits (see e.g. HM Treasury 2007). When a productivity shock increases operating costs, for example, input prices increase, or a national strike slows down production or there is a change in legislation that increases the cost of operations, the firm receives a compensation by the authority. This also holds in our context where the contingent clauses provide for the fixed payment α (or user fees under the concession model) to reflect external conditions so as to fully insure the firm:

$$\alpha^{mh}(\underline{\theta}) - \alpha^{mh}(\bar{\theta}) = \beta^{mh}\Delta\theta > 0, \tag{4}$$

where β^{mh} is the incentives intensity, independent of θ. The fixed payment α fully compensates the operator for the lost revenues, given by $\beta^{mh}\Delta\theta$, when a negative shock hits the firm during construction. The contractor is then fully insured for exogeneous events:

$$U_1(\bar{\theta}) = U_1(\underline{\theta}).$$

As revenue shocks are exogenous and thus outside the firm's control, these contingency clauses reduce the risk premium, without weakening incentives. The noise-to-signal ratio is indeed improved.

The optimal incentives intensity β^{mh} then captures the transfer of the residual revenue risk to the operator. Whilst the contractor is fully ensured against θ, he bears revenues at operational stage because of the shock ζ. The optimal level of β then trades off incentives with risk premium. A higher risk transfer (higher β) raises the operator's incentives, but at the cost of a higher risk premium (higher $\frac{r\sigma^2\beta^2}{2}$) to compensate the operator for the operational risk he bears.

Investment. Under pure moral hazard, agency costs have some impact on the set of permissible projects. We show in the Appendix that the condition for a positive net present value project now leads to:

$$I \leq I^{mh} = \frac{1}{1 + r\sigma^2}$$

where $I^{mh} < I^*$. Note that, when the project is a larger share of the contractor's activities (r higher) or when revenue risk at operational stage is higher (σ^2 higher), providing incentives becomes more costly and the constraint on feasible investments gets tighter. The revenue shock θ instead has no implications on the feasibility of the project. With a perfect monitoring technology which allows to verify θ and fully insure the risk-averse contractor, the risk neutral public authority faces no welfare loss.

4 Weak institutions

We now consider the case of weak institutions. These are characterized by a weak monitoring technology which makes shocks θ harder to verify and corruption more difficult to detect. More precisely, we consider the setting where the monitoring technology only allows a public official to observe θ with probability $\epsilon < 1$: the public official may now have scope and incentives to manipulate his reports.

To analyze the implications on the optimal contract of weak institutions, we consider menus of revenues sharing agreements and monetary payments that depend on the monitoring report made by the public officials and the operator's announcement $\hat{\theta}$ on the realization of the shock parameter θ. We denote by $(\alpha_1(\theta), \beta_1(\theta))$ the optimal contract when σ_1 is reported by the public official, and by $(\alpha_2(\hat{\theta}), \beta_2(\hat{\theta}))$ the optimal contract when σ_2 is reported. Further we let $U_i(\theta)$ $(i = 1, 2)$ denote the contractor's interim utility obtained when adopting the optimal contract at the operational stage.

Informative monitoring. Suppose first that the public official reports truthfully an informative signal $\sigma_1 = \theta$. Then, there is no reason to distort the contract compared the case where shocks are verifiable, so everything happens as in Section 3. The contractor receives a state-contingent compensations and is fully insured against revenue shocks occurring during construction. He thus gets the same interim payoff for each realization of its revenue shocks θ, and a binding participation constraint:

$$U_1(\bar{\theta}) = U_1(\underline{\theta}) = 0 \Rightarrow E_\theta(U_1(\theta)) = 0. \quad (5)$$

Furthermore, the revenue share is unaffected

$$\beta_1^{co}(\underline{\theta}) = \beta^{mh}.$$

Uninformative monitoring. Things change dramatically if instead the public official reports $\sigma_2 = \emptyset$, as now asymmetric information between the public authority and the contractor arises. Should the public authority insists on the full insurance scheme, it would face a contractor always claiming that negative shocks hit the projects during construction. A contractor having faced a positive revenue shock will want to report a negative shock in order to receive a compensation (recall from (4) that $\alpha(\underline{\theta}) > \alpha(\bar{\theta})$). The contract designed for the case where the revenue shock θ is verifiable is not incentive compatible and a tension arises between inducing truthtelling and providing insurance against revenue shocks.

To solve the asymmetric information problem in this case, it is convenient to redefine the contractor's interim utility as:

$$U_2(\theta) = \max_{(\tilde{e},\hat{\theta})} \alpha_2(\hat{\theta}) + \beta_2(\hat{\theta})(\theta + \tilde{e}) - \frac{\tilde{e}^2}{2} - \frac{r\sigma^2\beta_2^2(\hat{\theta})}{2} = \max_{\hat{\theta}} \alpha_2(\hat{\theta}) + \beta_2(\hat{\theta})\theta + \left(1 - r\sigma^2\right)\frac{\beta_2^2(\hat{\theta})}{2}.$$

This last expression encompasses the usual incentive compatibility constraints that are both necessary and sufficient to induce truthful revelation once θ is known. Any contract satisfying the above constraint prevents an operator having faced a shock $\bar{\theta}$ to pretend having faced a more averse shock $\underline{\theta}$. It is then immediate to notice that now, even if he can still get an expected payoff $E\left(v\left(U_2(\theta)\right)\right) = 0$, the contractor must face a risky allocation of interim rents to satisfy the incentive compatibility constraint:[16]

$$U_2(\bar{\theta}) - U_2(\underline{\theta}) \geq \Delta\theta\beta_2(\underline{\theta}). \tag{6}$$

By under-reporting its productivity, the operator offers a lower estimate of revenues at operational stage and receives a greater monetary payment (or higher user fees under the concession model). With such strategy, the contractor appropriates an extra rent worth $\Delta\theta\beta_2(\underline{\theta})$. This rent is strictly positive unless $\beta_2(\underline{\theta}) = 0$. Setting $\beta_2(\underline{\theta}) = 0$ would of course remove the incentives to lie, which is good on the adverse selection side, but it would also destroy all incentives to exert effort at the operating stage following a bad revenue shock at construction stage.

To put it differently, if $\beta_2(\underline{\theta}) > 0$, the incentive compatibility constraint implies that when external events hit construction, the contractor will now have to receive only a partial compensation for the lost revenues when contracts are designed so that its expected payoff is zero; a condition that is needed to extract all the contractor's expected surplus:

$$U_2(\underline{\theta}) < 0 < U_2(\bar{\theta}).$$

The important insight here is that leaving some revenue risk to the contractor is indeed necessary to solve the asymmetric information problem on the events that occur during the building stage. This type of risk is therefore endogenous.

[16] This constraint is of course the only relevant one (binding) in our framework with two productivity shocks. See Laffont and Martimort (2002, Chapter 2) for instance.

An important consequence of this is that when $\beta_2(\underline{\theta}) > 0$ and the participation constraint (equation 3) is binding for $\sigma = \sigma_2$, Jensen's inequality implies that:

$$v(E_\theta(U_2(\theta)) > E_\theta(v(U_2(\theta))) = 0 \Rightarrow E_\theta(U_2(\theta)) > 0. \tag{7}$$

Thus, from (5) and (7), when ex-post monitoring provides no additional information and σ_2 is reported, the contractor's expected rent at interim stage must be positive. Since the contractor is risk averse, leaving endogenous risk to the contractor is costly: the contractor now needs to receive some risk premium to induce its participation. Standard computations then show that this risk premium, for any endogenous risk at interim stage $\Delta U_2 = U_2(\bar{\theta}) - U_2(\underline{\theta})$ is:

$$\varphi(\Delta U_2) = \nu \Delta U_2 + \frac{1}{r} ln\left(1 - \nu + \nu exp(-r\Delta U_2)\right),$$

where $\varphi(0) = 0$, $\varphi'(\Delta U) = \frac{\nu(1-\nu)(1-exp(-r\Delta U))}{1-\nu+\nu exp(-r\Delta U)} > 0$ and $\varphi'(0) = 0$. In particular, when the ex-post risk is just enough to satisfy the truthtelling constraint as an equality, then the risk premium is just

$$\varphi(\Delta\theta\beta_2(\underline{\theta})) > 0.$$

This risk premium was not present under perfect monitoring. It thus constitutes a cost of weak institutions. It arises because the monitoring of the contract execution process at building stage is insufficient to register all the events that may occur during this phase, which prevents the contractor from receiving a full compensation when negative revenue shocks hit it.

The stake from corruption. This additional risk premium constitutes the stake for corruption that arises under weak institutions. In exchange for a bribe, a dishonest public official may hide the informative signal $\sigma_1 =$ "θ" and collude with the contractor to share the additional risk premium. The public official's discretion precisely comes from his ability to report $\hat{\sigma} = \emptyset$ when $\sigma = \sigma_1$. Thus, the stake from corruption comes from reduced monitoring, which in turn leads to 'worse' contract design and higher risk premium for the contractor. Bribes might take the form of promises for future job opportunities in the private sector for current regulators, direct monetary bribes or campaign contributions targeted towards lawmakers and key elected officials who have influence at the various stages of the contractor's monitoring. We will be quite agnostic on the form that those illegal exchanges will take.

Consider now how the corruption deal between the contractor and the public official works. For simplicity, we assume that the public official has all bargaining power in proposing bribes to the contractor and that negotiations takes place before the realization of θ. This implies that this ex ante side-contract between the contractor and the public official is in fact a pair of side-transfers $(\tau(\underline{\theta}), \tau(\bar{\theta}))$ that solves

$$\max_{(\tau(\underline{\theta}),\tau(\bar{\theta}))} kE_\theta(\tau(\theta)) \text{ subject to } E_\theta(v(U_2(\theta)) - \tau(\theta)) \geq E_\theta(v(U_1(\theta))) = 0.$$

Such side-contract yields a zero expected payoff to the contractor in each state of nature. Since there is no asymmetric information between the public official and the contractor and the bargaining power lies all with the public official, the contractor gets full insurance. The public official extracts the whole stake from corruption, and obtains an expected benefit from corruption worth

$$k\left(E_{\theta}(U_2(\theta) - E_{\theta}(U_1(\theta))\right) = k\varphi\left(\Delta\theta\beta_2(\underline{\theta})\right). \tag{8}$$

The anti-corruption program and the optimal contract. From this it follows that to fight corruption the public authority must offer a wage schedule for the public official which induces him to report the signal $\sigma_1 = \theta$ when found, rather than hide it. Taking into account the payoff from hiding the signal, given by (8), the wage schedule for a public official of type k needs to satisfy the following collusion-proofness constraint:

$$s_1 - s_2 \geq k\varphi\left(\Delta\theta\beta_2(\underline{\theta})\right). \tag{9}$$

There is then a good reason to pay an extra wage to the public official when he reports informative news but not when his report is uninformative. Giving public officials a different wage depending on the informativeness of their report, helps to make them accountable for their actions when they act as monitors and to fight corruption. This suggests that $s_2 = 0$ and that there exists a threshold level of k, denoted by k^*, such that:

$$s_1 = k^*\varphi\left(\Delta\theta\beta_2(\underline{\theta})\right). \tag{10}$$

Then for all $k > k^*$ the public official will be corrupted in equilibrium; corruption taking place with probability $1 - F(k^*)$, whilst below that threshold, i.e., with probability $1 - F(k^*)$, corruption does not take place.

With regard to the value of s_1, the public authority faces a trade-off. On the one hand, by raising k^*, an increase in s_1 yields less corruption; on the other hand, an increase in s_1 increases the budgetary cost of the public service provision.

The next proposition summarizes the results of this section and characterizes how this trade-off shapes the optimal contract:

Proposition 2 *In the presence of weak institutions, the optimal PPP arrangement is characterized as follows: (i) Public officials are made accountable for their actions and receive a greater reward when their reports are informative. (ii) PPPs need to transfer more risk to the contractor. The contractor receives a full compensation for revenue shocks occurring during construction only if the public official is able to prove that a negative shock hit the firm. Otherwise, the contractor is only partially compensated. (iii) The revenue sharing scheme has the contractor keep a lower share of the revenues when a negative revenue shock is reported.*

Weak institutions require to create accountability for public officials, and to transfer more risk to the contractor.

As discussed earlier, with a good monitoring technology and a public official who behaves honestly, the contract replicates the same qualitative features of the optimal contract under perfect monitoring. The contractor receives a full compensation for adverse events, with $E_\theta(U_2(\theta)) = 0$, and the revenue sharing rule remains constant in θ: $\beta_1^{co} = \beta^{mh}$.

But when the public official does not provide useful information that verifies the state of the world, the contractor must receive only a partial compensation for adverse events. This can easily be seen from using the binding truthtelling and participation constraints in state σ_2 to recover the following expressions and signs for $U_2^{co}(\underline{\theta})$ and $U_2^{co}(\bar{\theta})$:

$$U_2^{co}(\underline{\theta}) = \varphi(\Delta\theta\beta_2^{co}(\underline{\theta})) - \nu\Delta\theta\beta_2^{co}(\underline{\theta}) < 0 < U_2^{co}(\bar{\theta}) = \varphi(\Delta\theta\beta_2^{co}(\underline{\theta})) + (1-\nu)\Delta\theta\beta_2^{co}(\underline{\theta})$$

where β^{co} denotes the optimal revenue share in the current setting.

Weak institutions cannot rely on contingent contracts to allocate risks efficiently as much as strong institutions can. Due to weak monitoring, insuring the contractor against adverse events beyond its control can be too costly. Verifying the state of the world is hampered by an inefficient monitoring technology and corrupted public officials. Leaving some ex post risk to the contractor then becomes optimal. This highlights the cost of weak institutions: by reducing the extent of insurance, the optimal contract increases the ex-post risk borne by the contractor, so that when a negative event hits the firm, the contractor will face a reduction in its revenues. As a consequence the risk premium increases by:

$$E_\theta(U_2^{co}(\theta)) = \varphi(\Delta\theta\beta_2^{co}(\underline{\theta})) > 0.$$

It then follows that to reduce the cost of this increased risk transfer, the public authority will want to reduce the revenue share when demand is ported low, denoted by $\beta_2^{co}(\underline{\theta})$. We indeed show in the Appendix that whilst $\beta_1^{co}(\bar{\theta}) = \beta^{mh}$, we now have: $\beta_2^{co}(\underline{\theta}) < \beta^{mh}$.This reflects a standard "no-distortion at the top" result which is familiar from the screening literature. Reducing the risk borne by the contractor when hit by a negative shock to facilitate truthtelling comes at the cost of reducing his incentives to exert effort at operational stage. The contractor is on low-powered incentives when hit by a low productivity shock.

Consider now the implications of our analysis on the design of the anti-corruption program. A critical aspect of the anti-corruption program refers to the extent by which corruption will be defeated in equilibrium. The last proposition derives the optimal level of k^* that maximizes the payoff of the public authority, and thus the likelihood with which corruption will arise in equilibrium.[17]

[17] Tirole (1992) also analyzed a model where the collusion technology k is unknown but may take

Proposition 3 *The optimal anti-corruption program does not necessarily completely defeat corruption. Corruption arises with positive probability* $\epsilon\,(1 - F(k^*))$ *where* k^**, when interior, is given by the following implicit equation:*

$$1 - k^* = \frac{F(k^*)}{f(k^*)} - \frac{\mathcal{W}(\beta^{mh}) - E_\theta(\mathcal{W}(\beta_2^{co}(\theta)))}{\varphi(\Delta\theta\beta_2^{co}(\underline{\theta}))}. \tag{11}$$

Proposition 3 shows that there is an upper bound on the likelihood of corruption. Indeed, this probability is uniformly bounded above by $\epsilon\,(1 - F(k_0))$where k_0 is defined as

$$1 - k_0 = \frac{F(k_0)}{f(k_0)}.$$

Notice that k_0 is necessarily interior to $(0, 1)$.

The optimal level of corruption reaches a trade-off between two forces. For any given monitoring technology, ϵ, fighting corruption requires to increase the threshold k^* defined in (10). This is obtained by both raising the wage s_1 if the public official makes an informative report, and by decreasing sufficiently the contractor's expected profit $E_\theta(U_2(\theta))$ if an uninformative signal is reported. These two remedies to corruption are both costly.

The first one of course increases the budgetary cost of anti-corruption policies. The second remedy has a more indirect impact. Reducing expected profit while ensuring that the contractor's participation constraint remains binding in state σ_2 can only be done by reducing the risk premium $\varphi(\Delta\theta\beta_2^{co}(\underline{\theta}))$.Of course, this calls for a reduction in the revenue share $\beta_2^{co}(\underline{\theta})$ left to the operator, compared to the case of perfect monitoring. This is costly because it reduces the contractor's effort following a negative revenue shock during the building stage.

On the other hand, fighting corruption allows to obtain an informative signal more often and thus to increase the efficacy of monitoring. When monitoring is effective, the contractor is fully insured against productivity shocks and better incentives to exert effort are provided, since (from Proposition 3):

$$\beta_1^{co}(\underline{\theta}) = \beta_2^{co}(\underline{\theta}) = \beta^{mh} \text{ but } \beta_1^{co}(\underline{\theta}) = \beta^{mh} > \beta_2^{co}(\underline{\theta}).$$

The benefits of preventing corruption is thus proportional to the efficiency loss of transferring too much risk to the contractor, namely

$$\mathcal{W}(\beta^{mh}) - E_\theta(\mathcal{W}(\beta_2^{co}(\theta))).$$

only two values. He showed that collusion may be an equilibrium phenomenon when the efficient technology of collusion is sufficiently unlikely. On this see also Kofman and Lawarrée (1996) and Lambert-Mogilianski (1998). Other models of equilibrium corruption that rely on a continuous support for the k parameter are developed in Acemoglu and Verdier (2000), Auriol (2006) and Martimort and Straub (2009). Equilibrium collusion is also found in models where the public official exerts a non-verifiable effort like Mookherjee and Png (1995) or in models with limited commitments like Strausz (1997), Olsen and Torsvick (1998) and Khalil and Lawarrée (2006).

As a result of those two forces, the threshold k^* increases and corruption is less of a concern when the ratio $\frac{\mathcal{W}(\beta^{mh})-E_\theta(\mathcal{W}(\beta_2^{co}(\theta)))}{\varphi(\Delta\theta\beta_2^{co}(\underline{\theta}))}$ is lower, which explains expression (11).

Before concluding this section, we show how basic parameters of the model affect the characteristics of the optimal PPP arrangement and the Anti-corruption program.

To get a more precise comparative statics, let us assume that $F(k) = k^{\frac{1}{\gamma}}$ for $\gamma > 0$. Note that $F(\cdot)$ is more front-loaded as γ increases, i.e., low values of k are more likely.[18] The situation of countries characterized by weaker institutions and more widespread corruption can thus be captured considering lower values of γ. Further suppose that the effectiveness of the monitoring technologies can be improved at cost for the authority $c(\epsilon)$, with $c(0) = 0$, $c'(\epsilon), c''(\epsilon) > 0$. We then obtain:

Proposition 4 *(i) In countries with weaker institutions (γ lower), the use of contingent contracts leaves more scope for manipulation by contractors and public officials, which reduces the scope for PPP. (ii) When project risks are higher ($\Delta\theta$ greater), the welfare loss from corruption under PPP is greater.*

Part (i) suggests that when monitoring has a high probability of being ineffective, either because of corruption or because of weak monitoring technologies, using contingent contracts leaves more scope for manipulation by public officials (through their hiding relevant information) and by the contractors (through their misreporting their information). Indeed, we show in appendix that when γ is lower the optimal level of monitoring technology is lower (ϵ^* lower) and the equilibrium level of corruption higher $(1 - F(k^*)$ higher; a kind of self-fulfilling prophesy. For this reason, contracts should exhibit a higher degree of rigidity. The term "rigidity" here is to mean that the contractor's payoff should be less responsive to external circumstances (ΔU smaller) and thus leave less exogenous risk to the contractor ($\beta_2^{co}(\underline{\theta})$ smaller). To the extent that PPPs are used as means to provide incentives to the contractor via risk transfer, and to the extent that efficient risk transfer requires state contingent clauses, the scope for PPPs is smaller when corruption and weak monitoring makes risk transfer more costly, that is under weak institutions.

Part (ii) is implied by the higher incentive distortion that arises under weak institutions. As the contract needs to leave risk to the contractor, when project risks are high ($\Delta\theta$ high), the risk premium that will have to be paid to the contractor will be higher ($\varphi(\Delta\theta\beta_2^{co}(\underline{\theta}))$ increases with $\Delta\theta$). This increases the cost of providing incentives, and calls for a greater reduction in $\beta_2^{co}(\underline{\theta})$, which reduces the benefit of PPPs. In other words, when uncertainty is high, the observability of events that may occur during the contract execution becomes critical to reduce the risk exposure of the contractor and the cost of providing incentives. In these cases, weaker institutions with little transparency at contract execution stage, will be more vulnerable to corruption. Making use of more rigid contracts will be necessary to fight corruption but it will also cost

[18] Observe that, in this case, $k_0 = \frac{1}{1+\gamma}$.

more in terms of risk premium. Overall the scope for using PPPs will be lower, and the more so the weaker the institutions of a country.

Investment. We show in appendix that under a positive probability of corruption at equilibrium, the condition for a positive net present value project can now be written as: (check)

$$I \leq I^{co} = I^{mh} - (1-\epsilon^* F(k^*))(1-\nu)(\mathcal{W}(\beta^{mh}) - \mathcal{W}(\beta^{co}(\underline{\theta}))) - (1-\epsilon^* F(k^*)(1-k^*))\varphi(\Delta\beta_2^{co}(\underline{\theta})).$$

This expression shows that under weak institutions, the feasibly of PPP projects is smaller. Two effects reduce the upper bound on the feasible investment. First, there is an efficiency loss when a negative shock hits operations, as captured by the term $(1-\nu)(W(\beta^{mh}) - W(\beta_2^{co}(\underline{\theta})))$. This loss arises because of the reduction in the revenue share kept by the operator when a negative shock hits operations, which weakens incentives. Second, delegation of the service provision to the contractor becomes more costly for the public authority since the additional risk premium $\varphi(\Delta\beta_2^{as}(\underline{\theta}))$ needs now to be paid to induce the contractor's participation.

5 Conclusion

Numerous regulations already exist across countries so as to limit the scope for post contractual renegotiation of concession contracts by, for example, imposing legal limits on the percentage of the contract value that can be renegotiated, or by requiring the authorization of an independent third party. These provisions were initially designed to help increase the commitment power of public authorities and thus to reduce the potential abuse of bargaining power by contractors locked in important public service contracts. These very provisions however were also clearly helpful to fight post-tender stage corruption as they increase monitoring of the contract execution stage and reduce contract flexibility. There is indeed strong evidence that corruption explained the widespread use of postcontractual renegotiations in Latin America concessions (Guasch (2004), and Guash and Straub (2009)). Guasch (2004) in particular warns that informational asymmetries on costs between the operator and the regulator provide incentives for opportunistic demands for renegotiation and increases in tariffs to restore that equilibrium.[19,20]

[19] As noted by Engel, Fisher and Galetovich (2009), existing accounting standards allow governments to renegotiate PPP contracts and elude spending limits. Here renegotiations occur to favour re-election of current governments by increasing spending in politically sensitive projects. The evidence from Chilean renegotiations of PPP contracts confirm their predictions.

[20] Bajari and Tadelis (2006) also provide insights along this line. They discuss how post-tender corruption may affect the choice of price-only versus cost-plus contractual mechanisms. Fixed price contracts awarded competitively, especially in the case of complex projects, provide an incentive to enter into a corrupt agreement where the winner will deliver at no penalty substandard quality. The

The suggestion of our paper is to make use of similar principles when dealing with contingent clauses in concession contracts. Contrary to renegotiation, contingency clauses do not need a contract redrafting or the authorization of a third party, as they are already part of the contract. They are therefore even more at risk of corruption than renegotiation clauses. Of course however this comes at the cost of distorting the risk allocation, which is key in forms of public service provision based on high risk transfer, such as PPPs. The implications of our insights on the design of procurement arrangements is then that particular care must be used with PPPs in countries with weak institutions.

Further, although we have not made an explicit distinction between the concession model and the PFI model, our analysis suggests that corruption might have higher costs on PFI models than on concession contracts. In the former, the compensation paid to the contractor takes the form of an increase in the "availability payment" (the unitary payment paid by the authority) which is financed through public funds. In the latter, which are self-financed, the compensation paid to the contractor takes the form of an increase in users' fees which is financed by users. Being the users the residual claimant of the tariff increase, the concession contracts will typically receive more ex post monitoring than the PFI model, making the deal more transparent. And since transparency helps monitoring, it is reasonable to expect that concession contracts will suffer less from post-tendering corruption than PFI contracts.

Appendix

Proof of Proposition 1. When productivity shocks are verifiable, the principal's expected payoff is

$$E_\theta \left((1-\beta(\theta))(\theta+e)-\alpha(\theta)\right) - I. \tag{A1}$$

Taking into account the expressions of the contractor's payoff from (2), we obtain the following expression of the principal's problem:

$$\max_{(U(\theta),\beta(\theta))} \quad e-\frac{e^2}{2}-\frac{r\sigma^2\beta^2}{2}-E_\theta(U(\theta))-I \text{ subject to (1) and (3).}$$

Observe that (3) is binding and that it is optimal offer full insurance, hence

$$U^{mh}(\theta)=0 \quad \forall\theta\in\Theta. \tag{A2}$$

The first-order optimality condition then yields

$$\beta^{mh}(\theta)=e^{mh}(\theta)=\frac{1}{1+r\sigma^2} \quad \forall\theta\in\Theta. \tag{A3}$$

corrupt contractor wins the tender with the lowest price offer thanks to the information advantage the briber has with respect to the other participants.

Substituting back in the maximand, we find that the project is worth undertaking if:

$$\mathcal{W}(\beta^{mh}) \equiv \frac{1}{2\left(1+r\sigma^2\right)} - I \geq 0,$$

i.e., if $I \leq \frac{1}{2(1+r\sigma^2)} \equiv I^{mh}$. ■

Proof of Proposition 2. When productivity shocks are non-verifiable, the principal maximizes

$$\max_{(k^*, U_i(\theta), \beta_i(\theta))} \quad E'_{(\theta,\sigma)}\left(e_i(\theta) - \frac{e_i^2(\theta)}{2} - \frac{r\sigma^2\beta_i^2(\theta)}{2} - U_i(\theta)\right) - I - E'_\sigma(s_i) \tag{A4}$$

$$\text{subject to:} \tag{A5}$$

$$e_i(\theta) = \arg\max_{\tilde{e}_i} \alpha_i(\theta) + \beta_i(\theta)(\theta + \tilde{e}_i) - \frac{\tilde{e}_i^2}{2} - \frac{r\sigma^2\beta_i^2}{2} \equiv \beta_i(\theta); \tag{A6}$$

$$E_\theta(v(U_i(\theta))) \geq 0 \; \forall i \in \{1, 2\}; \tag{A7}$$

$$s_2 \geq 0; (6); (9). \tag{A8}$$

where the operator $E'_\sigma(\cdot)$ represents expectation with respect to the received signal $\sigma = \sigma_1$ with probability ϵ' and $\sigma = \sigma_2$ with probability $1 - \epsilon'$, where $\epsilon' \equiv \epsilon F(k^*)$, so $(1 - F(k^*))$ is the probability of corruption. First observe that it must be $s_2 \geq 0$ and (9) binding, this yields:

$$s_1 = k(E_\theta(U_2(\theta)) - E_\theta(U_1(\theta))) \tag{A9}$$

$$s_2 = 0. \tag{A10}$$

Second, insert the expressions of the public official's transfers obtained from (A9) and (A10) into the objective function. The objective function so obtained is linear and strictly decreasing in $U_1(\theta)$ (with a coefficient $-(1-\epsilon') < 0$). From this it immediately follows that $E_\theta(U_1(\theta)) = 0$ (A7 binding for $i = 1$) and the contractor is fully insured when $\sigma = \sigma_1$:

$$U_1(\theta) = 0 \quad \forall \theta \in \Theta. \tag{A11}$$

It is easy to show that the participation constraint (A7) is binding for $i = 2$ and the truthtelling constraint (9) are both binding at the optimum. This allows us to solve explicitly this system of equations for $(U_2(\bar{\theta}), U_2(\underline{\theta}))$ thanks to the CARA specification. In particular, since:

$$\begin{aligned} E_\theta\left(v(U_2(\theta))\right) &= \nu\left[1 - \exp\left(-rU_2(\bar{\theta})\right)\right] + (1-\nu)\left[1 - \exp\left(-rU_2(\underline{\theta})\right)\right] \\ &= 1 - \exp\left(-rU_2(\underline{\theta})\right)\left[(1-\nu) + \exp\left(-r\Delta U\right)\right] \end{aligned}$$

Taking the logarithms of both sides, we obtain

$$\ln E_\theta \left(v(U_2(\theta))\right) = -\ln \exp\left(-rU_2(\underline{\theta})\right) - \ln\left[(1-\nu) + \exp\left(-r\Delta U_2\right)\right]$$

and since $\ln E_\theta \left(v(U_i(\theta))\right) = 0$ and $\Delta U = \Delta\theta\beta_2(\underline{\theta})$, we have:

$$U_2^{co}(\underline{\theta}) = \frac{1}{r} ln\left(1-\nu+\nu exp(-r\Delta\theta\beta_2(\underline{\theta}))\right).$$

and

$$U_2^{co}(\bar{\theta}) = \Delta\theta\beta_2(\underline{\theta}) + \frac{1}{r} ln\left(1-\nu+\nu exp(-r\Delta\theta\beta_2(\underline{\theta}))\right),$$

These two equations imply that the the contractor is only partially insured against productivity shocks:

$$U_2^{co}(\bar{\theta}) > 0 > U_2^{co}(\underline{\theta}),$$

and that an additional risk premium is paid:

$$E_\theta(U_2(\theta)) = \varphi(\Delta\theta\beta_2(\underline{\theta})) > 0.$$

Inserting these expressions into the maximand leads to the more compact expression of expected social welfare:

$$\max_{(k^*,\beta_1(\theta),\beta_2(\theta))} \epsilon F(k^*)\, E_\theta \mathcal{W}(\beta_1(\theta)) + (1-\epsilon F(k^*)) E_\theta\left(\mathcal{W}(\beta_2(\theta))\right) - (1-\epsilon F(k^*)(1-k^*))\varphi(\Delta\theta\beta_2(\underline{\theta})) \quad \text{(A12)}$$

where we have defined:

$$\mathcal{W}(\beta) \equiv \beta - (1+r\sigma^2)\frac{\beta^2}{2} - I$$

Optimizing with respect to $\beta_1(\theta)$ and $\beta_2(\bar{\theta})$, we find $\beta_1(\bar{\theta}) = \beta_1(\underline{\theta}) = \beta_2^{co}(\bar{\theta}) = \beta^{mh}$ (and a similar equality for the corresponding effort levels). Optimizing with respect to $\beta_2(\underline{\theta})$, we get:

$$\beta_2^{cp}(\underline{\theta}) = \Phi_\epsilon(\Delta\theta, \beta_2^{co}(\underline{\theta})) < \beta^{mh} \quad \text{(A13)}$$

where the function $\Phi_\epsilon(\Delta\theta,\beta) = \frac{1-\left(1+\frac{k\epsilon'}{1-\epsilon'}\right)\frac{\nu\Delta\theta(1-exp(-r\Delta\theta\beta))}{1-\nu+\nu exp(-r\Delta\theta\beta)}}{1+r\sigma^2}$ is strictly decreasing in β. Since we have $\Phi_\epsilon(\Delta\theta,0) > 0$ and $\Phi_\epsilon(\Delta\theta,1) < 1$, (A13) has a unique solution $\beta_2^{co}(\underline{\theta}) \in (0,\beta^{mh})$. In particular, the effort level $e_2^{co}(\underline{\theta})$ remains always positive. ■

Proof of Proposition 3. Maximizing (A12) with respect to k^*, yields the first-order condition (11). Quasi-concavity of the objective in k^* is ensured by the assumption of monotone hazard rate. ■

Proof of Proposition 4. Differentiating (A12) with respect to ϵ^*, and in the light of results in Proposition 2, we obtain

$$\epsilon F(k^*)(1-v)\left[\mathcal{W}(\beta^{mf}) - \mathcal{W}(\beta_2^{co}(\theta))\right] + F(k^*)(1-k^*))\varphi(\Delta\theta\beta_2(\underline{\theta})) = c'(\epsilon)$$

The left is increasing in γ since $F(k)$ increases in γ and $\mathcal{W}(\beta^{mf}) > \mathcal{W}(\beta_2^{co}(\theta))$. Thus ϵ^* increases in γ.

To prove the remaining statements, note that, up to terms of higher magnitude, we get the following Taylor approximations for the risk premium on the denominator:

$$\varphi(\Delta\theta\beta_2^{co}(\underline{\theta})) \approx \frac{r\nu(1-\nu)}{2}\Delta\theta^2(\beta^{mh})^2$$

$$= \frac{r\nu(1-\nu)\Delta\theta^2}{2(1+r\sigma^2)^2}.$$

Similarly, the welfare difference on the numerator can be approximated as:

$$\mathcal{W}(\beta^{mh}) - E_\theta(\mathcal{W}(\beta_2^{co}(\theta))) \approx \frac{(1-\nu)(1+r\sigma^2)}{2}(\beta^{mh} - \beta_2^{co}(\underline{\theta}))^2$$

$$= \frac{r^2\nu^2(1-\nu)\Delta\theta^4}{2(1+r\sigma^2)}\left(1 + \frac{\epsilon k_0 F(k_0)}{1-\epsilon F(k_0)}\right)^2.$$

Finally, (11) can be approximated as:

$$k^* - k_0 = \frac{(1+r\sigma^2)\Delta\theta^2}{1 + \frac{d}{dk}\left(\frac{F(k)}{f(k)}\right)|_{k=k_0}}\left(1 + \frac{\epsilon k_0 F(k_0)}{1-\epsilon F(k_0)}\right)^2.$$

which also writes as:

$$k^* - k_0 = \frac{(1+r\sigma^2)\Delta\theta^2}{1+\gamma}\left(1 + \frac{\epsilon k_0 F(k_0)}{1-\epsilon F(k_0)}\right)^2. \tag{A14}$$

The comparative statics in the proposition immediately follow. Especially, those with respect to γ uses the fact that k_0 decreases with γ. ■

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