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CORRUPTION IN PPPS, INCENTIVES AND CONTRACT INCOMPLETENESS[†]

Abstract

We analyze risk allocation and contractual choices when public procurement is plagued with moral hazard, private information on exogenous shocks, and threat of corruption. Complete contracts entail state-contingent clauses that compensate the contractor for shocks unrelated to his own effort. By improving insurance, those contracts reduce the agency cost of moral hazard. When the contractor has private information on revenues shocks, verifying messages on shocks realizations is costly. Incomplete contracts do not specify state-contingent clauses, thereby saving on verifiability costs. This makes incomplete contracts attractive even though they entail greater agency costs. Because of private information on contracting costs, a public official may have discretion to choose whether to procure under a complete or an incomplete contract. When the public official is corrupt, such delegation results in incomplete contracts being chosen too often. Empirical predictions on the use of incomplete contracts and policy implications on the benefits of standardized contracts are discussed.

JEL Classification: D23, D82, K42 and L33

Keywords: corruption, incomplete contracts, moral hazard, principal-agent-supervisor model, public-private partnerships and risk allocation

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1 Introduction

Motivation. Finding the optimal risk allocation between public and private actors is a fundamental issue for procurement contracts in complex environments.[1] Should all possible contingencies that may realize over contract duration be regulated or should some be left unspecified? To illustrate, much of the current debate on the costs and benefits of Public Private Partnerships (PPPs) both among practitioners and scholars hinges on the difficulties faced when allocating risk over long-term contracts surrounded by much uncertainty at the time of contracting.[2]

Somewhat surprisingly, real-world practices do not settle on a unified view of those issues. Depending on the institutional contexts, contracts may significantly vary both in terms of the spectrum of contingencies that end up being regulated but also in terms of the allocation of risk that those contracts induce. For example, in PPPs for highways, the World Bank recommends that traffic risk be borne entirely by the contractor.[3] In India, standardized contracts for highways are instead used and traffic risk is borne by the contractor unless the fall in traffic is caused by new macroeconomic conditions.[4] In the UK, risk allocation is typically summarized in an extensive *"risk matrix"* appended to the contract. This matrix spells out how each specific risk that may arise should be shared between contractors and public authorities (HM Treasury (2007)). Contracts are rather complete. In Italy, *"risk matrixes"* are rarely used, risk allocation is often vague and contracts remain highly incomplete.[5]

Although risk is unlikely to be eliminated once for all, risk management in public procurement and PPPs should identify the various sources of risk, and optimally allocate responsibilities between parties by crafting efficient *contingent clauses.* However, foreseeing and describing contingencies entails significant and *a priori* hard to assess contracting costs. Indeed, those costs may depend in complex ways on project characteristics, the institutional environment, the maturity of the PPP market and the degree of expertise required to craft efficient agreements.

Complete versus incomplete contracts under the threat of corruption. This paper analyzes risk allocation and the choices of contractual modes when public procurement is plagued with moral hazard, private information on exogenous shocks, and threat of corruption. We

[1] See for instance EEC (2010) for the specific case of procurement of innovation.

[2] PPPs are long-term concession contracts where the supplier takes responsibility for building and managing a public infrastructure for a duration that may be up to thirty years. PPPs are widely used across Europe, Canada, the U.S. and a number of developing countries in sectors such as transport, energy, water, IT, prisons, waste management, schools, hospitals and others. For an in depth discussion of the economics of PPP contracts, see Iossa and Martimort (2015).

[3] See Provision 5.2 in the contract model available on: http://ppp.worldbank.org/public-private-partnership/library/road-concession-toll-road-agreement-example-1

[4] http://infrastructure.gov.in/mca.htm

[5] Giorgiantonio and Parisi (2011).

argue that the degree of contract incompleteness is endogenous. It depends not only on the technological cost of verifying contingencies but also on the possibility of corrupt behavior by public officials involved in this verification process. The bulk of the argument is that leaving contracts more incomplete is a way for corrupt public officials to channel more compensation to the contractor. Corruption is thus a threat to efficient risk management. Imposing standardized forms of contracts insulates procurement from the threat of corruption although it also means opting for low-powered incentive schemes.

Model. We investigate those issues in a canonical model of the three-tier relationship made of a benevolent public authority, a corrupt public official, and a privately informed contractor. Project revenues depend on the contractor's non-verifiable effort and some extra shocks. The contractor's incentives are provided through a revenue-sharing rule that allocates revenue risk between the contractor and the public authority in a way that balances insurance concerns and moral hazard. However, part of the overall risk of the project comes from exogenous shocks that are unrelated to the contractor's effort although they remain his private information. Communication on those contingencies with the public official is thus necessary. However, those shocks can be contracted upon through contingent clauses only if the public official in charge pays contracting costs to verify communication. The public official has private information on the level of those costs.

Had exogenous shocks been common knowledge, Holmström (1979)'s *"Informational Principle"* claims that those shocks should be fully insured to reduce the cost of moral hazard since they remain outside the contractor's control. Complete contracts provide better insurance, reduce the agency cost of moral hazard and implement stronger incentives.

Yet, fully insuring against those exogenous shocks is not feasible when the contractor has private information on those exogenous shocks. The contractor may pretend being hit by an unfavorable shock to obtain greater compensations for his services. To make such manipulation less tempting, the contractor should be first somewhat punished following a bad shock and second, rewarded for truthfully communicating his information following a favorable event. To take care of this endogenous risk induced by truthtelling constraints and ensure his participation, the contractor must be paid a greater risk premium. Complete contracts certainly become less attractive than when shocks are common knowledge. Yet, an incomplete contract that would specify the same allocation for all contingencies leaves the firm exposed to even more risk, which increases the risk premium. Such arrangements thus fare even worse than complete contracts. Incomplete contracts may however be preferable if the contracting costs incurred when writing contingent clauses are too large.

The level of those contracting costs is thus key to decide whether all contingencies should be verified. Because the public official has private information on those contracting costs, delegating to this intermediate layer the decision to choose between complete and incomplete contracts has certainly some appeal. The downside of such discretion is that it can be abused. Incomplete contracts pay a higher premium to the contractor and this extra compensation can be pocketed by a corrupt public official. A corrupt official has too much incentives to opt for incomplete contracts, compared to the social optimum.

This showcases an important trade-off between two sides of the overall incentive problem that impacts the public chain of command. Reducing agency costs of service provision calls for leaving discretion to public officials but leaving them more discretion increases bureaucratic drift. To limit this drift, complete and incomplete contracts should look more alike, both ending up implementing low powered incentives. This means that, even if those clauses can be specified into a complete contract, the corresponding proviso are of limited significance, specifying minor changes with what would arise under incomplete contracting.

Comparative statics. Our model provides a number of important comparative statics. Some are related to the no-corruption version of the model; others are more specific to the possibility of corrupt behavior.

As far as the first ones are concerned, complete contracts are more attractive when uncertainty or risk aversion is greater, as then the benefit of insuring the contractor against exogenous shocks is magnified.[6] Complete contracts are also preferable when the PPP market is more mature, as then contracting costs are lower. Complex PPP projects will instead be more often left incomplete leaving ample scope for future renegotiation.

Turning now to the set of specific statics implied by the possibility of corruption, a first and seemingly obvious consequence of our results is that the cost of corruption is greater when corruption is more likely.[7] Less obviously maybe, corruption is more costly when complete contracts are more attractive, i.e., again with more uncertainty or a greater risk aversion. In both cases, not only the risk premium left to the contractor to induce his participation but also the difference in the values of this risk premium between the complete and the incomplete contracting scenarios increase. Under those circumstances, the corrupt official finds it thus more attractive to favor incomplete contracting, and the optimal institutional response exhibits a similar bias.

Organization. Section 2 discusses the related literature. Section 3 presents our model. Section 4 presents various benchmarks that are useful to understand the main trade-offs developed thereafter. Section 5 studies the case where exogenous shocks remain private information to the contractor, the public official is benevolent but contracting is now costly. Section

[6] This result echoes Crocker and Reynolds (1993)'s findings that contracts in the context of US jet engine procurement provide more flexible price adjustments as technological uncertainty increases.

[7] On this, see Jakobsen et al. (2010).

6 allows for corruption between the public official and the contractor. Section 7 concludes and draws some important policy implications of our findings. Proofs are relegated to an Appendix.

2 Related Literature

Our paper touches on several trends of the literature that are now reviewed.

Costly contracting and endogenous contract incompleteness. In the spirit of Dye (1985) and Battigalli and Maggi (2002), the implicit definition of incompleteness that is used hereafter is that contracts that are not contingent on a state of nature relevant for decision-making are incomplete.[8] Bajari and Tadelis (2001) argue that complete and high-powered contracts are more costly to renegotiate. Kvaloy and Olsen (2009) stresses a non-monotonic relationship between contracting costs and the power of incentives under limited enforcement. We depart from those justification of incompleteness in terms of renegotiation or limited enforcement to focus on risk sharing. Risk sharing was also investigated in Anderlini and Felli (1999) in an environment that differs from ours because moral hazard is ignored, making it impossible to link incompleteness and the power of incentives. Our analysis demonstrates that, when verification costs are small enough, more complete contracts are preferred and incentives are boosted as transferring risk becomes cheaper.

Corruption and contract design. The collusion literature in two-tier hierarchies (Tirole (1986), Laffont and Tirole (1993)) argues that reducing the stake of collusion between supervisors and agents calls for collusion-proof complete contracts which are less sensitive to the supervisor's information. In our context, the top principal lacks instruments to ensure that institutions are robust to the threat of corruption. (There is no incentive schemes for corrupt public officials.) Yet, standardized contracts call for reducing public officials' discretion. Also, our main focus is on the endogenous degree of contract incompleteness while the existing literature mainly derives optimal collusion-proof contracts that are by construction complete.

The possibility of collusion between contractors and public officials in the more specific context of PPPs was first investigated by Martimort and Pouyet (2008) although there collusion takes place at an earlier stage when public authorities choose between PPPs and more traditional sources of procurement. Instead, our model focuses on corruption at the implementation stage, i.e., when a PPP has already been chosen as the preferred contracting mode but the comprehensiveness of contracts has not yet been decided.

[8] Kornhauser and MacLeod (2012) discusses more broadly the possible definitions of incompleteness that have been used in the literature. Aghion and Hermalin (1990), Spier (1992) and Halonen and Hart (2013) provide explanations of contractual incompleteness that do not rely on contracting costs.

Delegation. Delegating decision rights to an agent whose objective differs from that of the principal is justified by the mere comparative advantage that public officials have in verifying contingencies; an issue that echoes the analysis of delegation as an agency problem in the theory of organizations (Holmström (1984) Melumad and Shibano (1991), Martimort and Semenov (2006), Alonso and Matoushek (2008)) and in political science (Epstein and O'Halloran (1999), Bendor and Meirowitz (2004), Huber and Shipan (2006)) although these literatures were developed in simple hierarchical environment while we embed such analysis in a more complex two-tier hierarchy. In this respect, it is important to stress is that delegation to a public official acting as an intermediate in the public chain of command would not be needed if there were no agency costs in the relationship with the contractor. Hence, the agency problem at the upper tier of the hierarchy exists only because there is an agency problem downstream. This is reminiscent of the analysis in Hiriart and Martimort (2012) who make a similar point in another two-tier model of risk regulation. Here, the flip-side of delegation is that new agency costs arise from the fact that those officials are corrupt and may thus favor contractors when choosing incomplete contracts.

3 The Model

Production technology and information. Consider a public authority (thereafter PA) who delegates the provision of a public service to a private contractor. Revenues for this service are observable and can be contracted upon.[9] Whenever the contractor is able to perfectly extract consumer's surplus (maybe by means of usage fees), these revenues can also be identified with the social benefits of the project and this is the interpretation that is adopted for the rest of the paper. The costs of providing the service is, for simplicity, normalized at zero.

Beyond a baseline level R_0, revenues are stochastic and impacted by several variables. We adopt the following additive formulation:[10]

$$R = R_0 + \theta + e + \zeta.$$

Let us explain in more details each of those components of revenues.

[9]In transport projects, for example, revenues can be verified through electronic ticketing systems, whilst in energy projects they can be specified through computerized billing systems.

[10]Following Iossa and Martimort (2015), R can be used interchangeably to denote revenues from user fees and the benefit for users for those services where users do not pay (PFI model). In this case, the contractor does not appropriate these benefits directly but it receives a payment linked to an index of R

- First, revenues increase with the contractor's effort e whose monetary cost is $\frac{e^2}{2}$. Effort is non-verifiable. Hence, the allocation of risk between the contractor and the pubic authority results from a trade-off between insurance and moral hazard.

- Second, revenues depend on a exogenous shock θ. For simplicity, this shock can only take two values $\overline{\theta} = (1-\nu)\Delta\theta > 0$ and $\underline{\theta} = -\nu\Delta\theta < 0$ with respective probabilities ν and $1-\nu$. This shock has thus zero mean and variance $\nu(1-\nu)\Delta\theta^2$. This variance will impact on the risk premium that must be paid to ensure the contractor's participation at the *ex ante* stage, i.e., before θ realizes. The realization of θ is unknown to all parties at this *ex ante* stage but θ will be learned by the contractor later on. The contractor chooses the effort e *ex post*, i.e., once he has already observed θ.

- Third, revenues are also impacted by another random shock ζ that is normally distributed with zero mean and variance σ^2. This shock is non-observable by either party. Even when θ has been learned, there remains some uncertainty on the underlying link between effort and revenues. Moral hazard remains even in contingent clauses can be written to eliminate the risk associated to θ.

Contracts and contracting technology. Following Holmström and Milgrom (1991), we restrict attention to linear revenues-sharing schemes. We also adopt the accounting convention that the government keeps all revenues R from the service and pays to the contractor:

$$t(R) = \alpha + \beta R.$$

The fixed fee α is useful to provide insurance against risk while leaving a share β of revenues to the contractor provides incentives.

We distinguish between two kinds of contracting modes that differ in how they cope with contingencies.

- With *complete contracts*, PA can offer a full menu of options $\left\{(\alpha(\hat{\theta}), \beta(\hat{\theta}))\right\}_{\hat{\theta}\in\theta}$ contingent on the report $\hat{\theta}$ made by the contractor on the realization of the productivity shock. The payment scheme then writes as:

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

  From the Revelation Principle,[11] there is of course no loss of generality in restricting the analysis to such direct and truthful mechanisms. This formulation also shows the role that the revenues-charing parameter $\beta(\hat{\theta})$ plays in screening the information learned by the contractor in the course of contracting.

[11] Myerson (1982).

- With *incomplete contracts*, PA is restricted to offer a single rigid option $(\alpha_\infty, \beta_\infty)$ that applies under all circumstances. Such incomplete contract does not rely on any communication from the contractor. The payment schemes now writes as:

$$t_\infty(R) = \alpha_\infty + \beta_\infty R.$$

State-contingent clauses can only be offered with complete contracts. As we shall see below, the value of such clauses is that they improve on both insurance and incentives. The downside of complete contracting is that writing such state-contingent clauses is costly and incomplete contracts may be preferred to save on contracting costs.

To demonstrate this point, we assume that a public official (thereafter PO) incurs an exogenous cost $z \geq 0$ of processing and understanding messages on non-verifiable contingencies. The random variable z distributed on $\mathbb{R}_+$ according to a positive density function $g(z)$ with a cumulative (atomless) distribution function $G(z)$ ($G'(z) = g(z)$) that satisfies the (strict version of the) monotone hazard rate property, i.e., $G(z)/g(z)$ is strictly increasing.

As many PPP projects are procured by local administrations, who are better informed than the central national authority about project complexity, we also assume that the realization of z is privately observed by PO. Finally, we should stress that, it is key for our modeling of contracting costs as costs of verifying messages that the exogenous shock θ remains private information for the contractor. When θ is common knowledge, no communication is needed and thus contracting costs are null; which makes the comparison between complete and incomplete contracts *de facto* irrelevant.[12]

Objective functions. We now describe the players' objective functions in more details.

- PA is risk neutral and cares about the *"value for money"* of the project. He maximizes his share of revenues net of the costs of paying the contractor and net of the contracting costs z incurred for writing complete contracts if he chooses doing so. In other words, PA cares about the "value for money" of the project.[13] Formally, with complete contracts, this objective writes as:

$$\mathbb{E}_{\theta,\zeta}\left((1 - \beta(\theta))\, R - \alpha(\theta)\right) - z.$$

  Instead, with an incomplete contract, PA can save on contracting costs and his objective becomes:

$$\mathbb{E}_{\theta,\zeta}\left((1 - \beta_\infty)\, R - \alpha_\infty\right).$$

[12]Contracting costs may also be viewed as proxies for the complexity of the project and as such interpreted as cognitive costs in the lines of Bolton and Faure-Grimaud (2009) and Tirole (2009).

[13]Remember that we also view revenues as reflecting consumers' surplus and thus the principal's objective is akin to maximizing consumer's surplus minus any payments left to the firm. Our approach could easily be extended to study the case where PA gives a weight (less than one) to the firm's profit in his objective.

- The contractor has constant absolute risk aversion $r \geq 0$. We denote by $v(x) = 1 - exp(-rx)$ his utility function defined over monetary payments x. Depending on whether contracts are complete or incomplete respectively, the contractor accepts the contract at the *ex ante* stage (i.e. before knowing θ and before ζ realizes) whenever

$$v(\mathcal{V}) = \mathbb{E}_{\theta,\zeta}\left(v\left(\alpha(\theta) + \beta(\theta)R - \frac{e^2}{2}\right)\right) \geq 0 \text{ or } v(\mathcal{V}_\infty) = \mathbb{E}_{\theta,\zeta}\left(v\left(\alpha_\infty + \beta_\infty R - \frac{e^2}{2}\right)\right) \geq 0.$$ [14]

  Assuming that the contractor is risk averse[15] and cares about the certainty equivalent of his payoff captures the idea that a PPP project might represent a large share of his activities so that there is little scope for diversification. Assuming on top that PA remains risk neutral is consistent with recent works in the Theory of the Firm (Holmström and Milgrom (1991), Tirole (2010)) and the most recent vintage of the moral hazard literature (Jewitt (1988), Jewit et al. (2008)). With this simple benchmark, the public sector should bear all the risk in the absence of moral hazard.[16]

- A benevolent PO has preferences aligned with those of PA. Instead, a corrupt PO also cares about the monetary benefits he withdraws from being in charge. We postpone to Section 6 the detailed formulation of these objectives. For the time being, we content ourselves with observing that, in practice, the planning and design stages of most PPP contracts often involve two different layers of the governmental hierarchy: the central government (for example the national Department of Transport) and the local government (a local authority). The former typically coordinates the national PPP program and provides guidelines for contracts and tenders; the latter implements and monitors local projects.

Justifying our modeling assumptions: a first pass. Our model may look complex. We now argue that it is actually parsimonious and that all ingredients are necessary. That there is moral hazard downstream and that this problem remains whether complete or incomplete contracts are chosen is key to understand how different levels of comprehensiveness in the contract impact on incentives. It is well-known that, if the contractor were risk neutral, he could be made residual claimant so as to bear all risks and provide efficient effort under all circumstances. PA could just ask *ex ante* the contractor for a fee equal to the expected

[14] $\mathbb{E}_x(\cdot)$ denotes the expectation operator with respect to any random variable x.

[15] Imperfect diversification can be justified also as a consequence of an costly access to the financial market like in Leland and Pyle (1977).

[16] Had the principal been also risk averse (as in Lewis and Sappington (1995) and Martimort and Sand-Zantman (2006) for instance), the optimal allocation of risk would have each party taking a share of risk according to risk tolerances. Starting from this more complicated benchmark, introducing asymmetric information and contract incompleteness would nevertheless move results in the same directions as those highlighted below.

revenues of the services and let the contractor chooses the first-best level of effort according to the realized shock. In such contexts, private information on the shock θ would be of no value for the contractor and there would be no reason to call PO to verify the contractor's communication. Therefore, there would be no scope for corruption whatsoever.

With risk aversion, we will demonstrate below that the contractor's compensation has to depend on the shock θ. That the contractor has private information on this parameter opens the door to strategic manipulation to inflate compensation. This layer of asymmetric information thus justifies the mere presence of PO endowed with a monitoring technology to verify the contractor's communication on the realizations those shocks. Such verification is necessary to write contingent clauses. Third, that PO gets private information on those contracting costs and may be biased towards the contractor then creates an agency problem upstream in his relationship with PA. In other words, agency problems trickles up the hierarchy. This upstream agency problem is a necessary ingredient to understand the optimal institutional response to the threat of corruption and, in particular, how standardized procedures may be imposed by the top layer.

4 Benchmarks

In this section, we analyze various special benchmarks that are relevant for the more complete characterization undertaken in Sections 5 and 6. We proceed by making the contracting environment more complex step by step.

4.1 Verifiable Effort, Verifiable Shock θ

As a first benchmark, let us suppose that both the contractor's effort e and the shocks θ and ζ are all verifiable. In that scenario, PA provides insurance to the risk-averse contractor against all those shocks. At the same time, the contract specifies the first-best effort target e^*:

$$e^{fb} = \arg\max_{e \geq 0} e - \frac{e^2}{2} \equiv 1.$$

Thanks to our additive formulation of revenues, the optimal level of effort is thus independent of the shock θ. Finally, the fixed fee is set so as to reap all profit from the contractor. The contractor bears no revenues risk and is just compensated for his disutility of effort:

$$\beta(\theta) = 0 \text{ and } \alpha(\theta) = \frac{(e^{fb})^2}{2} \quad \forall \theta \in \{\underline{\theta}, \overline{\theta}\}.$$

4.2 Non-Verifiable Effort, Verifiable Shock θ

To understand the value of complete contracts, we now characterize the optimal contract when productivity shocks are verifiable and thus writing complete contracts is costless. Because effort remains non-verifiable, there is a familiar trade-off between insurance and moral hazard. Our focus here is thus on the value of writing contingent clauses so as to improve insurance and provide better incentives. Those clauses specify a compensation $\alpha(\theta)$ and a revenue sharing formula $\beta(\theta)$ for each possible contingency θ.

Thanks to the CARA specification and the normality of shocks, we can write the certainty equivalent of the contractor's payoff when θ is observed as:

$$U(\theta) \equiv \max_{e} \alpha(\theta) + \beta(\theta)(R_0 + \theta + e) - \frac{e^2}{2} - \frac{r\sigma^2}{2}\beta^2(\theta). \tag{1}$$

Because effort is non-verifiable, the contractor must bear some revenue risk to exert a positive effort. The quantity $\frac{r\sigma^2}{2}\beta^2(\theta)$ is the risk premium that compensates the contractor for bearing the fraction $\beta(\theta)$ of the risk associated to ζ. This risk premium increases with the contractor's degree of risk aversion r, with the variance σ^2 of ζ, and with the share of revenues $\beta(\theta)$ kept by the contractor in state θ.

Once he has observed θ, the contractor chooses his effort optimally. This leads to the following moral hazard incentive constraint:

$$e(\theta) = \max_{e} \alpha(\theta) + \beta(\theta)(R_0 + \theta + e) - \frac{e^2}{2} - \frac{r\sigma^2}{2}\beta^2(\theta) \Leftrightarrow e(\theta) = \beta(\theta) \quad \forall\theta \in \{\underline{\theta}, \overline{\theta}\}. \tag{2}$$

Substituting for the above value of effort obtained from (2) into (1) yields:

$$U(\theta) = \alpha(\theta) + \beta(\theta)(R_0 + \theta) + (1 - r\sigma^2)\frac{\beta^2(\theta)}{2} \quad \forall\theta \in \{\underline{\theta}, \overline{\theta}\}. \tag{3}$$

This expression of the certainty equivalent of the contractor's payoff in state θ allows us to write his *ex ante* participation constraint as

$$\mathbb{E}_{\theta}\left(\upsilon(U(\theta))\right) \geq 0 \tag{4}$$

where we assume that the contractor's outside opportunities gives zero payoff.

We can now present the characteristics of the optimal contract when θ is verifiable.

Proposition 1 *Suppose that effort is non-verifiable but θ remains verifiable. The optimal complete contract under pure moral hazard*[17] *has the following properties.*

1. *The contractor is fully insured against uncertainty on θ:*

$$U^{mh}(\overline{\theta}) = U^{mh}(\underline{\theta}) = 0. \tag{5}$$

2. *The contractor keeps a positive fraction of revenues $\beta^{mh} < 1$ that is independent of θ and exerts suboptimal effort:*

$$e^{mh} = \beta^{mh} \equiv \frac{1}{1 + r\sigma^2} < 1 \quad \forall\theta \in \{\underline{\theta}, \overline{\theta}\}. \tag{6}$$

[17] Indexed by a superscript mh that stands for *"moral hazard"*.

Proposition 1 confirms that contracts should include state-contingent clauses that compensate the contractor for all events that are outside his control when those events are verifiable. This is nothing else than a consequence of Holmström (1979) *"Informativeness Principle"*. The shock θ should not be used for incentives purposes since it is not informative on the contractor's effort. Contingent clauses provide insurance on shocks that are unrelated to the firm's effort and those clauses improve the trade-off between insurance and incentives.

Indeed, although fluctuations on θ are fully ensured when this shock is verifiable, there still remains some uncertainty on revenues coming from the realization of ζ. This remaining uncertainty blurs the relationship between effort and revenues. The downstream moral hazard problem with the contractor remains. For each realization of θ, the contract leaves to the contractor a share β^{mh} of revenue to incentivize the contractor. This share is independent of θ thanks again to the additive functional form chosen for revenues. To participate, the contractor must be paid a risk premium which is costly to the principal and that is reduced when the principal keeps some risk; the familiar trade-off between insurance and incentives under moral hazard. Finally, it is worth pointing out that the contractor must be compensated for the revenues losses or gains associated to the realization of θ and, as a result, optimal fixed fees now depend on θ. The choice of the fixed fees $(\alpha^{mh}(\overline{\theta}), \alpha^{mh}(\underline{\theta}))$ reflects this insurance motive:

$$\alpha^{mh}(\underline{\theta}) - \alpha^{mh}(\overline{\theta}) = \Delta\theta\beta^{mh} > 0 \Leftrightarrow U^{mh}(\underline{\theta}) = U^{mh}(\overline{\theta}). \tag{7}$$

The non-verifiability of effort is thus key to obtain state-dependent fees. This dependency is an important ingredient to understand why the contractor may want to manipulate information on θ; an issue to which we now turn.

4.3 Non-Verifiable Effort, Private Information on θ: Complete Contracting

We now consider the design of a complete contract in a context where effort remains non-verifiable but the contractor has now private information on θ. For each possible report $\hat{\theta}$ on that shock and for each corresponding option $(\alpha(\hat{\theta}), \beta(\hat{\theta}))$ within the incentive menu, the contractor must evaluate how much effort he should exert. Incentives are again entirely determined by the share of revenues kept by the contractor, and thus depend only on the contractor's announcement $\hat{\theta}$ on the realized shock:

$$e(\hat{\theta}) = \arg\max_{e} \alpha(\hat{\theta}) + \beta(\hat{\theta})(R_0 + \theta + e) - \frac{e^2}{2} - \frac{r\sigma^2\beta^2(\hat{\theta})}{2} \equiv \beta(\hat{\theta}) \quad \forall(\theta, \hat{\theta}).$$

Inserting this value of the optimal effort, we can write the contractor's truthtelling constraints in compact form in terms of the certainty equivalent of the contractor's payoff in state θ as:

$$U(\theta) = \max_{\hat{\theta}\in\{\underline{\theta},\overline{\theta}\}} \alpha(\hat{\theta}) + \beta(\hat{\theta})(R_0 + \theta) + \left(1 - r\sigma^2\right)\frac{\beta^2(\hat{\theta})}{2}.$$

As standard in screening environments in a framework with a binary shock,[18] the contractor wants to report unfavorable events when instead he is hit by a favorable shock. The relevant incentive compatibility constraint (which is binding at the optimum) is thus:

$$U(\overline{\theta}) - U(\underline{\theta}) \geq \Delta\theta\beta(\underline{\theta}). \tag{8}$$

By underreporting the value of θ, the contractor presents a lower estimate of revenues and thus receives a greater compensation (i.e., $\alpha(\underline{\theta}) > \alpha(\overline{\theta})$) to participate. With such strategic manipulation of information, the contractor appropriates an information rent worth $\Delta\theta\beta(\underline{\theta})$. Setting $\beta(\underline{\theta}) = 0$, which means offering full insurance for the contractor in case a bad shock hits, would of course remove the contractor's incentives to misrepresent a positive shock. The downside of such choice is that it also exacerbates moral hazard following a bad shock $\underline{\theta}$ since the contractor has no longer any incentives to exert effort in that state. With a less extreme risk allocation, i.e. $\beta(\underline{\theta}) > 0$, the truthtelling constraint is satisfied by having the contractor bearing an endogenous risk; the certainty equivalent of his payoff $U(\theta)$ can no longer be the same across realizations of θ. Leaving some revenues risk to the contractor is necessary to solve the asymmetric information problem without excessively exacerbating moral hazard. As the contractor is risk averse and decides on participation before θ realizes, an additional risk premium must be paid to ensure his participation. Next Lemma unveils some properties of this risk premium.

Lemma 1 *The risk premium that must be paid to the contractor for inducing truthful revelation of θ at minimal agency cost is:*

$$\varphi(\Delta\theta\beta(\underline{\theta})) = \nu\Delta\theta\beta(\underline{\theta}) + \frac{1}{r}ln\left(1 - \nu + \nu exp(-r\Delta\theta\beta(\underline{\theta}))\right), \tag{9}$$

where $\varphi(0) = \varphi'(0) = 0$ and $\varphi'(\Delta\theta\beta(\underline{\theta})) > 0$ if $\beta(\underline{\theta}) > 0$.

To guarantee that the truthtelling constraint (8) is satisfied, the contract needs to create a positive gap $U(\overline{\theta}) - U(\underline{\theta})$ between returns following good and bad realizations of θ. This gap increases with the share of additional revenues that the contractor can appropriate by underreporting the shock, $\Delta\theta\beta(\underline{\theta})$. This explains why the risk premium is increasing with $\beta(\underline{\theta})$.

Equipped with the expression of the risk premium (9), we rewrite the certainty equivalent of the firm's payoff and his participation constraint at the *ex ante* stage (i.e., before θ realizes) as:

$$\mathcal{V} = \mathbb{E}_{\theta}(U(\theta)) - \varphi(\Delta\theta\beta(\underline{\theta})) \geq 0. \tag{10}$$

Taking into account the expression of effort in terms of the share of revenues kept by the contractor, PA's expected payoff with complete contracting (net of the contracting costs that

[18] Laffont and Martimort (2002, Chapter 2).

are worth $z \geq 0$) can in turn be written as

$$\mathbb{E}_\theta\left(\beta(\theta) - \frac{(1+r\sigma^2)}{2}\beta^2(\theta) - U(\theta)\right) - z = \mathcal{W}(\beta(\overline{\theta}), \beta(\underline{\theta})) - \mathcal{V} - z$$

where we now define the expected surplus of the relationship net of the risk premium in terms of the shares of revenues $(\beta(\overline{\theta}), \beta(\underline{\theta}))$ kept by the contractor for each possible realization of the shock θ as

$$\mathcal{W}(\beta(\overline{\theta}), \beta(\underline{\theta})) = \mathbb{E}_\theta\left(\beta(\theta) - \frac{(1+r\sigma^2)}{2}\beta^2(\theta)\right) - \varphi(\Delta\theta\beta(\underline{\theta})).$$

As a benchmark for the subsequent analysis, consider now the case where it is always costless to write down a complete contract (i.e., the distribution $G(\cdot)$ has a mass point at $z = 0$). The optimal contract maximizes the expression of PA's expected payoff just found above subject to the contractor's participation constraint (10). The solution is described in the following Proposition.

Proposition 2 *Suppose that effort is non-verifiable, θ is the contractor's private information and writing a complete contract is costless. The optimal complete contract*[19] *has the following properties.*

1. *The contractor is only partially compensated for the shock θ:*

$$U^{nv}\left(\overline{\theta}\right) - U^{nv}(\underline{\theta}) = \Delta\theta\beta^{nv}(\underline{\theta}) > 0. \tag{11}$$

2. *When a negative shock hits, effort is reduced as the contractor keeps a lower share of the revenues:*

$$0 < e^{nv}(\underline{\theta}) < e^{nv}\left(\overline{\theta}\right) = e^{mh} < 1$$

where

$$e^{nv}(\underline{\theta}) \equiv \beta^{nv}(\underline{\theta}) = \left(1 - \frac{\Delta\theta}{1-\nu}\varphi'(\Delta\theta\beta^{nv}(\underline{\theta}))\right)\beta^{mh}. \tag{12}$$

Since he may underreport favorable shocks, the contractor is only partially compensated following adverse events so as to make such strategy less attractive. Leaving some risk on the realization of θ to the contractor necessitates to pay a risk premium $\varphi(\Delta\theta\beta^{nv}(\underline{\theta})) > 0$. To reduce this risk premium, PA reduces the share of revenues left to the contractor when a negative shock is reported, $\beta^{nv}(\underline{\theta}) < \beta^{mh}$. Yet, in our context which mixes elements of both adverse selection and moral hazard, reducing the share of revenues kept by the contractor following adverse events in turn dampens his incentives to exert effort. No such reduction arises when a good shock hits: a *"no distortion at the top"* result which is familiar from the screening literature.

[19] Indexed with a superscript nv that stands for "*θ non-verifiable.*

4.4 Non-Verifiable Effort, Private Information on θ: Incomplete Contracting

As a last benchmark, we now consider the case where writing a complete contract is infinitively costly and contracts are necessarily left incomplete. This is of course a special case of the complete contracting scenario with the proviso that the revenues sharing rule $(\beta_\infty, \alpha_\infty)$ is now independent of any announcement on the realized shock θ. We may again define the contractor's return in state θ as

$$U_\infty(\theta) = \alpha_\infty + \beta_\infty(R_0 + \theta) + \left(1 - r\sigma^2\right) \frac{\beta_\infty^2}{2}.$$

and notice that effort is again entirely defined by the share of revenues kept by the contractor, namely

$$e(\theta) = \beta_\infty.$$

Because payments are now independent of the realized state θ, there is no possible insurance against that shock. In that case, (8) is necessarily satisfied with an equality:

$$U_\infty(\overline{\theta}) - U_\infty(\underline{\theta}) = \Delta\theta\beta_\infty. \tag{13}$$

A rigid contract, that does not adjust to the realized value of θ, again imposes some risk on the contractor. This risk is proportional to the contractor's share of revenues β_∞ which is of course very similar to that arising in the complete contracting scenario. To compensate for this risk, a risk premium worth $\varphi(\Delta\theta\beta_\infty)$ must now be paid to the contractor.

The optimal incomplete contract is now obtained from maximizing the principal's expected payoff, namely $\mathcal{W}(\beta_\infty, \beta_\infty) - \mathcal{V}_\infty$, subject to the contractor's participation constraint that now writes as:

$$\mathcal{V}_\infty = \mathbb{E}_\theta(U_\infty(\theta)) - \varphi(\Delta\theta\beta_\infty(\underline{\theta})) \geq 0. \tag{14}$$

Next Proposition characterizes this optimal incomplete contract.

Proposition 3 *Suppose that effort is non-verifiable and that θ is the contractor's private information.The optimal incomplete contract has the following properties.*

1. *The contractor bears all the risk on θ:*

$$U_\infty^{nv}(\overline{\theta}) = U_\infty^{nv}(\underline{\theta}) + \Delta\theta\beta_\infty^{nv}. \tag{15}$$

2. *The contractor keeps a share of revenues that is independent of θ and that lies in between the shares of revenues implemented under complete contracting for the different realizations of θ:*

$$\beta^{nv}(\underline{\theta}) < \beta_\infty^{nv} < \beta^{nv}(\overline{\theta}) = \beta^{mh} < 1 \tag{16}$$

with

$$\beta_\infty^{nv} = \beta^{mh}\left(1 - \Delta\theta\varphi'(\Delta\theta\beta_\infty^{nv})\right). \tag{17}$$

3. *Effort is always suboptimal and lies in between the efforts implemented under complete contracting for the different realizations of θ:*

$$e^{nv}(\underline{\theta}) < e^{nv}_{\infty} < e^{nv}(\overline{\theta}) = e^{mh} < 1. \tag{18}$$

4. *The risk premium is greater under incomplete contracting than with complete contracting:*

$$\varphi(\Delta\theta\beta^{nv}_{\infty}) > \varphi(\Delta\theta\beta^{nv}(\underline{\theta})). \tag{19}$$

Writing an incomplete contract has two consequences. On the one hand, as the contract cannot be contingent on the realized shock θ, the contractor is necessarily forced to bear some risk related to θ. Inducing the contractor's participation thus requires that PA pays a risk premium $\varphi(\Delta\theta\beta_{\infty})$.

On the other hand, an incomplete contract leaves to the contractor a share of revenues which is constant across all possible values of θ. This constant share lies in between the shock-contingent values obtained with complete contracting. Decreasing β_{∞} to reduce the risk premium $\varphi(\Delta\theta\beta_{\infty})$ and provide more insurance against θ has now the perverse effect of also dampening effort even when a good shock $\overline{\theta}$ realizes. As a result, PA finds it less attractive to reduce β_{∞}. The contractor bears more risk under incomplete contracting:

$$\beta^{nv}_{\infty} > \beta^{nv}(\underline{\theta}).$$

It follows that the risk premium is greater under incomplete contracting than with complete contracting. As we will see below, this result if of particular importance when we consider the possibility of a corrupt PO acting on behalf of PA.

5 The Choice Between Complete and Incomplete Contracts with a Benevolent Public Official

5.1 Back to Justifying our Modeling Assumptions

Before moving further into the solution of our contracting problem, we want to stress here the importance of making the joint assumptions that θ is private information of the contractor, that there is moral hazard and that there exist contracting costs altogether if one wants to properly justify the use of incomplete contracts and view this choice as a source of corruption.

Suppose *a contrario* that the shock θ, although non-verifiable, is observed by both PA and the contractor. In the absence of contracting costs, parties could agree *ex ante* on a *revelation mechanism* à la Maskin. It is well known that such mechanism would help to implement the same outcome as if θ was verifiable simply by cross-checking the PA's and the contractor's announcements on the shock θ that they both observe.[20] Truth-telling is an equilibrium of

[20]See Maskin (1999) and Laffont and Martimort (2002, Chapter 6).

such mechanism.[21] So, we would be back to the contracting scenario depicted in Section 4.2. Now, the shock θ becomes *de facto* contractible and state-contingent clauses are always useful. In other words, the incompleteness of contracts cannot be explained in such environment.

Suppose instead that θ is a shock that remains privately observed by the contractor but that contracting costs are null. This scenario was investigated in Section 4.3. Screening considerations call for making contingent clauses explicit. A complete contract is always optimal although it fares worst than when θ is common knowledge. There is no justification for corruption in this environment.

Suppose now that moral hazard is completely absent of our analysis. This can be either because the contractor is risk neutral or because the effort is infinitely costly and revenues are only affected by the shocks θ and ζ. In the first scenario, the optimal complete and incomplete contracts are readily obtained by taking limits when r goes to zero of the existing solutions described respectively in Propositions 2 and 3. Whether a complete or an incomplete contract is chosen, the contractor always exerts the effort e^{fb}, always gets all revenues from the service (i.e., $\beta^{nv}(\theta) = \beta^{nv}_{\infty} = 1$ for all θ) and receives a fee that is independent on the realized shock (namely, $\alpha^{nv}(\theta) = \alpha^{nv}_{\infty} = -R_0 - \frac{1}{2}$). In other words, the complete and the incomplete contracts are identical. As a result, there is no reason to communicate the realization of the shock θ. No contracting costs are needed to verify this message and thus there is no scope for corruption. When effort is infinitively costly, the sole role of the parameter β is to allocate revenues but, by definition, it has no impact on the values of those revenues. In the first-best scenario, the effort e^{fb} would of course be zero under all circumstances. When θ is instead private information, PA can just keep all revenues and pay a null fee; the contractor is basically useless. Whether the contract is complete or not again does not matter and against, there is still no scope for communication, information manipulations and corruption.

To conclude, we must insists and stress that asking whether an incomplete non-contingent contracts can emerge in our contracting environment is a meaningful question only when θ is private information for the contractor, there is moral hazard and there are contracting costs of verifying the latter's messages on the realization of those costs. Since those contracting costs are a key determinant of the choices between complete and incomplete contracting, it becomes important to study the PO's incentives to make this choice when he retains private information on the value of the contracting costs. This in turn raises the issue of designing the best institutional framework that could deal with biases in the PO's objectives and decisions.

[21] It is also well-known that such mechanism can have multiple equilibria but introducing a third agent, namely the PO, also informed on this state of nature could easily guarantee uniqueness if one is concerned with unique implementation.

5.2 Characterization

Following the justifications for our modeling that were given in Section 5.1, we now characterize the optimal contracting mode when both the effort and the shock are non-verifiable but privately known by the contractor. We also assume that contracting is costly but, in a first pass, that PO shares PA's preferences. This benchmark allows us to understand how the contracting cost z affects contractual choices when there is no threat of corruption.

Under asymmetric information, a complete contract has to extract the contractor's private information on θ. This entails two different kinds of contracting costs. The first ones are screening costs whose impact is well known. Complete contracts have to satisfy a truthtelling constraint to induce the contractor to report information. As a result, the contractor should bear some endogenous risk, meaning that full insurance is no longer optimal. A costly risk premium must be paid to the contractor. To reduce this cost, the contractor's share of revenues diminishes which dampens incentives to exert effort.

Second, and this is a more novel aspect of our modeling, writing a complete contract entails a contracting cost z that is borne to verify the contractor's reports on contingencies. This cost is privately observed by PO and will be taken into account when he chooses between complete and incomplete contracting. An important question is whether delegating the task of choosing between those two contracting modes creates additional agency costs. As we shall see, there are no such costs when PO shares PA's preferences. Agency costs of delegation will instead arise when PO is corrupt.

Suppose a benevolent PO chooses when to write a complete contract. Such delegation is a priori attractive because PO has private information on the realization of the contracting costs and can tailor his decision to the value of those costs. The optimality condition identifies a cut-off value z^* such that for realizations of the contracting costs $z \leq z^*$ a complete contract contingent on θ is written, whilst for all $z > z^*$ an incomplete contract is preferred. The cut-off z^* is defined as follows:

$$z^* = \mathcal{W}(\beta(\overline{\theta}), \beta(\underline{\theta})) - \mathcal{V} - (\mathcal{W}(\beta_\infty, \beta_\infty) - \mathcal{V}_\infty) \,. \tag{20}$$

To illustrate, suppose that PA commits to offer the optimal complete and incomplete contracts described in Sections 4.3 and 4.4 respectively. We already know that those contracts extract all expected payoff from the contractor, $\mathcal{V}^{nv} = \mathcal{V}^{nv}_\infty = 0$. Because $\mathcal{W}(\beta(\overline{\theta}), \beta(\underline{\theta}))$ is maximized for $(\beta^{mh}, \beta^{nv}(\underline{\theta})$, the corresponding cut-off z^{nv} would then be strictly positive:

$$z^{nv} = \mathcal{W}(\beta^{mh}, \beta^{nv}(\underline{\theta})) - \mathcal{W}(\beta^{nv}_\infty, \beta^{nv}_\infty) > 0. \tag{21}$$

The right-hand side can be interpreted as the value of writing a complete contract when the shock is verifiable. The cut-off defined through (21) turns out to be optimal when PO is benevolent as we will see below.

Turning now to the characterization of this optimal cut-off rule, it should be rather intuitive that the solution to the contracting problem now lies somewhere in between the outcomes achieved when there are no contracting costs and when those costs are infinite. Formally, the optimal cut-off rule, the corresponding shares of revenues and the contractor's payoffs now altogether maximize PA's expected payoff:

$$(\mathcal{P}): \quad \max_{(z^*,\beta_\infty,\beta(\underline{\theta}),\beta(\overline{\theta}),\mathcal{V},\mathcal{V}_\infty)} \int_0^{z^*} \left(\mathcal{W}(\beta(\overline{\theta}),\beta(\underline{\theta}) - \mathcal{V} - z\right) dG(z) + (1-G(z^*))\left(\mathcal{W}(\beta_\infty,\beta_\infty) - \mathcal{V}_\infty\right)$$

subject to the cut-off condition (20) and the firm's participation constraints (namely (10) and (14)) that ensure a positive payoff to the contractor whether a complete or an incomplete contract is chosen.

Importantly for what follows, notice that a pointwise optimization of the maximand with respect to z^* would give us a first-order condition that is nothing else that (20). In other words, the PA would like to commit *ex ante* to a cut-off rule that is indeed *ex post* optimal when the PO in charge of this delegated choice has similar preferences. This suggests that this condition (20) is actually redundant. Yet, in view of preparing for the analysis to come when PO is corrupt, we keep this more general formulation.

The following Proposition then characterizes the optimal contracting mode.

Proposition 4 *Suppose that effort is non-verifiable, that θ is contractor's private information, and that PO shares PA's preferences.*

1. *A complete contract is chosen if and only if contracting costs are small enough:*

$$z \leq z^{nv} = \mathcal{W}(\beta^{mh},\beta^{nv}(\underline{\theta})) - \mathcal{W}(\beta^{nv}_\infty,\beta^{nv}_\infty).$$

2. *The complete (resp. incomplete) contract chosen when $z \leq z^{nv}$ (resp. $z \geq z^{nv}$) is characterized in Proposition 2 (resp. 3).*

3. *The contractor always breaks even in expectation whether a complete or an incomplete contract is chosen:*

$$\mathcal{V}^{nc} = \mathcal{V}^{nc}_\infty = 0.^{22} \tag{22}$$

The level of contractual completeness is captured by the value of the cutoff z^{nv}. Since the interests of PA and PO are aligned, there are no agency costs of delegating the contract choice to PO even when the latter has private information on contracting costs.

[22] The superscript nc stands for *"no corruption"*.

Complete contracting is more attractive when uncertainty and/or risk aversion are greater, as it increases the benefit of insuring the private contractor against exogenous shocks. To illustrate, simple Taylor expansions obtained when $\Delta\theta$ is small enough show that, up to a term of second order magnitude in $\Delta\theta$, z^{nv} increases with $\Delta\theta$ and r:

$$\frac{\partial z^{nv}}{\partial \Delta\theta} = r\nu(1-\nu)\Delta\theta\left(\beta_{\infty}^{nv} - \beta^{nv}\left(\underline{\theta}\right)\right) > 0 \text{ and } \frac{\partial z^{nv}}{\partial r} = \nu(1-\nu)\frac{(\Delta\theta)^2}{2}\left(\beta_{\infty}^{nv} - \beta^{nv}\left(\underline{\theta}\right)\right) > 0.$$

6 The Choice Between Complete and Incomplete Contracts with a Corrupt Public Official

The incidence of corruption in PPP and concession contracts has been widely recorded.[23] In Europe, those concerns have been repeatedly emphasized by public decision-makers[24] up to the point of establishing new rules on transparency of contractual clauses in public procurement contracts. Corruption may occur at different stages of the procurement process whether it is planning, tendering, contracting, or execution but its most subtle and difficult form to detect is probably as once a bad contract has been designed, since undue benefits for the contractor are difficult to challenge. PPP agreements are particularly vulnerable to such corruption because of their complexity and of the central role played by the design stage in committing parties for a long period of time. Contracts are also typically kept confidential, and little transparency exist on the contingencies that justify compensations to the contractor or even on the amounts to be paid;[25] a practice that certainly favors corruption.

To take into account the possibility of corruption in our model, we now remove the assumption that PO and PA share the same objectives. We allow for the possibility that PO may favor the contractor when negotiating contract terms. As we shall see, this discretion that is delegated to PO may create new agency costs between the two top layers of the chain of command and distort contractual arrangements.

6.1 The Stake For Corruption

The previous section has shown how, for z sufficiently large, an incomplete contract is optimal, whilst for z small enough the benefits of better insurance and higher incentives justifies complete contracts. However, when his preferences are not aligned with those of PA, PO may be bribed by the contractor in order to bias the selection process towards the contracting mode that the latter finds the most favorable. We will model such corruption with a simple reduced form, and relegate details of its microfundations to the Appendix. We assume from now on that PO gives an extra weight $\gamma \in [0, 1)$ to the expected value of the

[23] Wren-Lewis (2011) and Auriol and Straub (2011), Engel et al. (2014).
[24] European Parliament (2012).
[25] Hemming (2006).

certainty equivalent of the contractor's payoff $\mathbb{E}_\theta(U(\theta))$ in his objective function.[26] As we shall see, the implication of this formulation is that PO benefits from crafting contracts that correspond to a greater risk premium.

Formally, PO's payoff under complete contracting can be written as:

$$\mathbb{E}_{\theta,\zeta}\left((1-\beta(\theta))\,R-\alpha(\theta)\right)-z+\gamma E_\theta(U(\theta))=\mathcal{W}(\beta(\bar{\theta}),\beta(\underline{\theta}))-z-(1-\gamma)\mathcal{V}+\gamma\varphi(\Delta\theta\beta(\underline{\theta}))$$

where we have taken care of the fact that, under complete contracting,

$$\mathcal{V}=\mathbb{E}_\theta(U(\theta))-\varphi(\Delta\theta\beta(\underline{\theta})).$$

Similarly, PO's payoff under incomplete contracting becomes:

$$\mathbb{E}_{\theta,\zeta}\left((1-\beta_\infty)\,R-\alpha_\infty\right)+\gamma\mathbb{E}_\theta(U_\infty(\theta))=\mathcal{W}(\beta_\infty,\beta_\infty)-(1-\gamma)\mathcal{V}_\infty+\gamma\varphi(\Delta\theta\beta_\infty)$$

where now

$$\mathcal{V}_\infty=\mathbb{E}_\theta(U^{nv}_\infty(\theta))-\varphi(\Delta\theta\beta_\infty).$$

To evaluate PO's incentives to choose between complete and incomplete contracting, let us suppose in a first pass that the optimal contractual arrangements found in Proposition 4 are still proposed even if PO is corrupt. We are interested in finding conditions under which a corrupt PO might still choose to write a complete contract. As a preliminary step, observe that the comparison of (12) and (17)) and the fact that φ is strictly increasing on its positive domain altogether imply that $\beta^{nv}_\infty>\beta^{nv}(\underline{\theta})$. Under incomplete contracting, the risk left on the contractor is greater than under complete contracting. The risk premium needed to ensure his participation is thus also larger and thus (19) holds. PO now chooses a complete contract when:

$$\begin{aligned}z\leq z^*&=\mathcal{W}(\beta^{mh},\beta^{nv}(\underline{\theta}))-\mathcal{W}_\infty(\beta_\infty)+\gamma(\varphi(\Delta\theta\beta^{nv}(\underline{\theta}))-\varphi(\Delta\theta\beta^{nv}_\infty))\\&=z^{nv}+\gamma(\varphi(\Delta\theta\beta^{nv}(\underline{\theta}))-\varphi(\Delta\theta\beta^{nv}_\infty))<z^{nv}.\end{aligned}$$

The corrupt PO is biased towards choosing an incomplete contract too often compared to what the PA would do on his own.

We now turn to the more general scenario where the revenue sharing rules $(\beta_\infty,\beta(\underline{\theta}),\beta(\bar{\theta}))$, the corresponding risk premia $(\varphi(\Delta\theta\beta(\underline{\theta})),\varphi(\Delta\theta\beta_\infty))$ and the payoffs $(\mathcal{V},\mathcal{V}_\infty)$ that are proposed to the contractor are arbitrary. A corrupt PO chooses to implement a complete contract when $z\leq z^*$ where z^* is now defined as:

$$z^*=\mathcal{W}(\beta(\bar{\theta}),\beta(\underline{\theta}))-(1-\gamma)\mathcal{V}-(\mathcal{W}(\beta_\infty,\beta_\infty)-(1-\gamma)\mathcal{V}_\infty)+\gamma(\varphi(\Delta\theta\beta(\underline{\theta}))-\varphi(\Delta\theta\beta_\infty)).\quad(23)$$

[26]We assume that the central authority is not corrupt. In practice, corruption may indeed occur not only for public officials but also at higher levels of the chain of command. Our conclusions could easily be generalized provided that corruption is more of a concern at lower tiers of public administration.

PO chooses a complete contract if the gains in expected surplus net of contracting costs outweighs the benefits of a greater risk premium under incomplete contracting. He chooses an incomplete contract otherwise. Constraint (23) characterizes how a biased PO chooses contractual modes to respond to his private information on contracting costs and his own preferences.

A comment on communication mechanisms and optimal delegation. Our analysis focuses on the case where the choice between incomplete and complete contracting is delegated to PO. An alternative would be for PA to always choose between the two contracting modes by himself upfront even if he has no precise knowledge of contracting costs at the time of doing so. This would mean committing *ex ante* either to always implement a complete contract or to always focus on an incomplete contract irrespectively of the realized contracting costs.[27] Corollary 1 below will confirm that relying on PO's information is valuable. Beyond those polar scenarios, PA could thus also commit to a mechanism that, on top of the requested revenue sharing parameters for both complete and incomplete contracts, would also stipulate a probability $x(\hat{z})$ of implementing a complete contract as a function of PO's report $\hat{z}$ on the contracting costs z he has observed.[28] This delegation mechanism is in line with Holmström (1984)'s earlier work on and the more recent literature on delegation mechanisms in organizations (Melumad and Shibano (1991), Martimort and Semenov (2006) and Alonso and Matoushek (2008), among others). In front of the mechanisms $x(\hat{z})$, PO chooses to truthfully reveal his information on the level of contracting cost when the following incentive compatibility conditions hold:

$$z \in \arg\max_{\hat{z}\geq 0} x(\hat{z})(\mathcal{W}(\beta(\overline{\theta}), \beta(\underline{\theta})) - z - (1-\gamma)\mathcal{V} + \gamma\varphi(\Delta\theta\beta(\underline{\theta})))$$

$$+(1-x(\hat{z}))(\mathcal{W}(\beta_\infty, \beta_\infty) - (1-\gamma)\mathcal{V}_\infty + \gamma\varphi(\Delta\theta\beta_\infty)).$$

Simple revealed preferences arguments immediately show that $x(z)$ is weakly decreasing in z and thus almost everywhere differentiable. Suppose that there is a discontinuity point, say for a level z^* of the contracting costs, with x_0 and x_1 being respectively the left- and the right-limits of $x(z)$ at z^*. Those constants must satisfy the monotonicity requirement $x_0 = \lim_{z\to z^{*-}} x(z) \geq \lim_{z\to z^{*+}} x(z) = x_1$. At the same time, PO's payoff must be continuous at z^* and, thus, z^* must satisfy (23). At any point of differentiability z, i.e., on the right and the left of z^*, incentive compatibility amounts to:

$$\dot{x}(z)(\mathcal{W}(\beta(\overline{\theta}), \beta(\underline{\theta})) - z - (1-\gamma)\mathcal{V} - \mathcal{W}(\beta_\infty, \beta_\infty) + (1-\gamma)\mathcal{V}_\infty + \gamma(\varphi(\Delta\theta\beta(\underline{\theta})) - \varphi(\Delta\theta\beta_\infty))) = 0$$

$$\Leftrightarrow \dot{x}(z)(z^* - z) = 0.$$

[27] The implicit assumption here is that those costs may be *ex post* observable although not verifiable; a standard assumption in the incomplete contracts literature.

[28] It can be easily checked that there is no benefits for PA to make the revenue sharing parameters depend on PO's announcement $\hat{z}$.

From this, it immediately follows that $x(z)$ is necessarily constant on the open intervals $[0, z^*)$ and $(z^*, +\infty]$.

Finally, observe that the principal's objective being linear in the probability $x(z)$, the optimal mechanism with a non-trivial delegation (i.e., where PA does not keep full control on contractual choice) should necessarily have x_0 and x_1 being corner solutions:

$$0 = x_1 < x_0 = 1.$$

This is precisely the property that holds when the choice of the contracting mode is delegated to PO and the latter follows the cut-off rule (23). In other words, the contractual outcome achieved when PA delegates contracting rights to PO is the same as what is achieved in a more centralized organization where PA keeps those rights but requests PO to communicate on the value of contracting costs he privately knows.

6.2 Optimal Contracts under the Threat of Corruption

When the contractual choice is delegated to a corrupt PO, the contracting problem may be rewritten as:

$$(\mathcal{P}^{co}): \max_{(z^*, \beta_\infty, \beta(\underline{\theta}), \beta(\overline{\theta}), \mathcal{V}, \mathcal{V}_\infty)} \int_0^{z^*} \left(\mathcal{W}(\beta(\overline{\theta}), \beta(\underline{\theta})) - \mathcal{V} - z\right) dG(z) + (1 - G(z^*)) \left(\mathcal{W}(\beta_\infty, \beta_\infty) - \mathcal{V}_\infty\right)$$

subject to the cut-off condition (23) and the contractor's participation constraints (10) and (14) which have to hold whether contracts are complete or incomplete.

Remember that (23) defines a decision rule that is not *ex post* optimal from PA's viewpoint since it favors too much the choice of an incomplete contract. When facing such distortion, PA has two options: First, he could choose to leave different contractual options as they are, and simply accept that an incomplete contract will be selected too often. Second, he may choose to modify the shape of those options so as to affect indirectly PO's choice, making the complete contracting mode more attractive. Of course, the optimal institutional response to the risk of corruption mixes those elements. Incomplete contracts are still chosen too often but the difference between incomplete and complete contracts is reduced to limit PO's discretion.

The following Proposition derives the optimal arrangement in this environment with corruption. To get clear results and ensure quasi-concavity of the problem despite its high nonlinearity, we consider the case where the bias γ is not too large.

Proposition 5 *Assume that γ is not too large. The presence of corruption has three different effects on the optimal contractual arrangement.*

1. *Conditionally on the revenue sharing rules* $(\beta^{co}(\overline{\theta}), \beta^{co}(\underline{\theta}), \beta^{co}_{\infty})$ *offered under both contracting modes, the incomplete contract remains chosen too often, i.e., when* $z \geq z^{co}$*, where:*[29]

$$z^{co} \leq \mathcal{W}(\beta^{co}(\overline{\theta}), \beta^{co}(\underline{\theta})) - \mathcal{W}(\beta^{co}_{\infty}, \beta^{co}_{\infty}). \tag{24}$$

2. *The complete contract option is modified so that the contractor now bears more revenue risk when a negative shock hits:*

$$\beta^{nv}(\underline{\theta}) \leq \beta^{co}(\underline{\theta}) \leq \beta^{co}(\overline{\theta}) = \beta^{mh}. \tag{25}$$

3. *The incomplete contract option is also modified so that the contractor now bears less revenue risk:*

$$\beta^{nv}_{\infty} \geq \beta^{co}_{\infty} \geq \beta^{co}(\underline{\theta}).$$

The contracts designed for the case of a benevolent PO are now no longer optimal, as they would induce a corrupt PO to select an incomplete contract too often. The optimal contractual arrangement now trades off the agency costs of delegated contracting with the agency costs of delegated public service provision. The design of the complete and incomplete options reduces the distortion in the decision rule followed by PO but it is now at the cost of introducing new distortions in the contractual options offered to the contractor.

The main features of the optimal contractual arrangement that result from this trade-off can be best understood by inspecting the decision rule (23). Indeed, the excessive bias of the PO towards incomplete contracting can now be countered by making the contractor's contracts under both scenarios more similar in terms of the risk borne. This in turn is obtained by increasing the risk premium $\varphi(\Delta\theta\beta(\underline{\theta}))$ under complete contracting while also reducing its value $\varphi(\Delta\theta\beta_{\infty})$ under incomplete contracting. More risk is thus borne with a complete contract when a bad shock hits and less risk is borne with an incomplete contract.

Making the two contractual choices more alike is a way to reduce the discretion left to the PO. In this sense it provides a rationale for a widely spread practice in PPP projects, which is to provide national guidelines on contractual clauses or even, to design centrally standardized contract terms that are then implemented locally, with minor variations. We shall come back to this point in Section 7.

Yet, even when the optimal response to the threat of corruption has been taken into account, the optimal decision rule remains excessively biased towards incomplete contracting even though this bias is now mitigated. The choice between complete and incomplete contracting reflects a compromise between PA's and PO's preferences.

[29] The superscript *co* stands for *corruption*.

Comparative statics. To better understand the nature of the distortions needed under the threat of corruption, we now provide a number of instructive comparative statics. To get clear results (that might nevertheless hold under broader circumstances), we proceed in the limiting case where both γ and $\Delta\theta$ are both small enough.

Proposition 6 *Suppose that γ and $\Delta\theta$ are small enough. Up to terms of higher-order magnitude, we have the following Taylor approximation:*

$$z^{nv} - z^{co} = \frac{\gamma r^2 \nu^3 (1-\nu)}{(1+r\sigma^2)^2}\Delta\theta^4 + o(\Delta\theta^4).^{30} \tag{26}$$

The cost of corruption, in the sense of $z^{nv} - z^{co}$ being higher (i.e., a greater bias towards incomplete contracting with a corrupt PO) increases with risk aversion (r greater), uncertainty ($\Delta\theta$ greater), and the PO's bias (γ greater).

More uncertainty or a greater risk aversion are two factors which increases the risk premium left to the contractor to induce his participation. In both cases, not only the risk premium left to the contractor to induce his participation but also the difference in the values of this risk premium between the complete and the incomplete contracting scenarios increases. Under those circumstances, the corrupt official finds it thus more attractive to favor incomplete contracting, and the optimal institutional response exhibits a similar bias.

The value of delegation. We have been silent on whether delegating contracting rights to the PO (i.e., letting chooses contract terms knowing contracting costs) is actually optimal. Delegation allows to use local information on z that is not available to PA, but it comes at the risk of corruption. Centralization implies more national control but less use of local information. We can therefore think of centralization as the case where the PA chooses contract terms without information on contracting costs; he will either always use a complete contract or an incomplete contact, depending on expected payoffs. To illustrate, PA uses a complete contract if and only if:

$$\mathbb{E}_z(z) < \mathcal{W}(\beta^{nv}(\bar{\theta}), \beta^{nv}(\underline{\theta})) - \mathcal{W}(\beta^{nv}_\infty, \beta^{nv}_\infty).$$

When PO's preferences are aligned with those of PA, simple revealed preferences arguments show that delegation is preferred to centralization. Such benevolent PO will therefore condition the contract on the local information on z in an optimal way and PO follows the threshold z^{nv} to make his choice. Delegation is clearly always weakly preferred to rigid rules that would not use this information.

When the PO is corrupt, delegation comes at the cost of a bias towards too much incompleteness in the contract. We show in the Appendix however that the benefits of delegation will remain, provided risk aversion and or uncertainty are sufficiently small and PO's

[30] With $\lim_{\Delta\theta\to 0} \frac{o(\Delta\theta^4)}{\Delta\theta^4} = 0$.

and PA's preferences are close enough (γ small). In this case, the difference in cutoff rules ($z^{nv} - z^{co}$) is also small, as suggested by Proposition 6. This result revisits in our context an insight which is well-known from the political science literature, the so called *"Ally Principle"*, according to which more delegation to better informed lower tiers would occur when corruption is less of a concern.[31] We state this result formally below.

Corollary 1 *Suppose that γ and $\Delta\theta$ are small enough. Delegation is optimal when there is small uncertainty ($\Delta\theta$ small), small risk aversion (r small), and a small corruption bias (γ small).*

Whilst the central authority should reduce the discretion of the PO by designing centrally standardized contracts that follow specific guidelines, eliminating discretion altogether is suboptimal under the conditions of Corollary 1. Some discretion on contractual clauses should be left to local PO.

7 Conclusion and Implications

This paper shows how the degree of incompleteness of contracting arrangements can be linked to the degree of corruption of public officials in charge of crafting those contracts. Our paper predicts that incomplete contracts may be chosen too often when public officials in charge of designing contracts are corrupt. Fighting corruption requires to decrease the discretion of contracting authorities by making greater use of standardized contracts that are designed centrally but implemented locally.

We conclude this paper with a few implications of our findings for real-world practices.

Where should we expect incomplete contracting? In practice, we may expect to see incomplete contracts for more complex projects, because verification costs will be higher. Project complexity is more of an issue in some sectors like waste management, energy, information technologies, and for some large transport projects with volatile demand (e.g. new bridges, motorways or tunnels in areas that were not previously served). Corruption stakes may be significant in those sectors. However, as experience with PPPs matures, past cases provide useful information that reduce verification costs, and thus we should also observe more complete contracts for more mature PPP markets. The risk of corruption may also diminish there.

To the extent that small and medium size companies are less able to diversify risks than larger corporations and thus may be considered as being more risk averse, our results also suggest that incomplete contracts should prevail in sectors where contractual stakes represent a significant share of the contractor's activities.

[31]See Epstein and O'Halloran (1999), Bendor and Meirowitz (2004) and Huber and Shipan (2006) among others.

Some countries, such as the UK or India, have relied on standardized contracts designed centrally and imposed locally with minor variations, thus reducing the degree of local discretion. This practice is much in line with our results that complete and incomplete contracts tend to look alike. Coming back to our earlier motivating examples, the choice of relying on standardized contracts made in India is indeed optimal if anti-corruption measures have already been taken to keep this threat low. Instead, the World Bank may be right when recommending against contingent clauses if this recommendation applies in institutional contexts where corruption is pervasive.

Incomplete contracting, corruption and renegotiation. There exists ample evidence that corruption explains the widespread use of post-contractual renegotiations in Latin America concessions.[32] Our analysis is somewhat complementary since we demonstrated that corruption may also have a role at the *ex ante* stage when parties decide how detailed their agreements should be. Incomplete contracts are chosen in corrupt institutional environments but, because those contracts are also the most likely to be renegotiated, the impact of corruption on contract design and economic performances is likely to be even more significant than suggested by the earlier literature that focused only on its *ex post* role at the renegotiation stage.

Towards a broader view of incomplete contracting. There is no role for asset ownership in our analysis. Revenues are supposed to be verifiable and revenues-sharing rules are thus always feasible. The only source of incompleteness comes from the fact that contracts can either be contingent on productivity shocks (complete contracting) or not (incomplete contracting). This feature of our model of course echoes real-world practices where much effort is devoted to find how to share revenues of the service between public and private actors and much incompleteness there comes from the ability that parties may have in describing how the revenues-sharing rules should vary with exogenous shocks. In other words, the more familiar view of contract incompleteness often praised in the literature that consists in assuming non-verifiable revenues and investigating its consequences on ex ante investments is by and large orthogonal to the main purpose of the analysis and (probably) to the main concerns of practitioners. Nevertheless, our analysis could easily be extended (with some appeal) to account for asset ownership and its more traditional theoretical role.

To illustrate, suppose that revenues are non-verifiable. The only feasible contracts now consist in allocating ownership of the assets, giving thereby to the owner the returns stream on these assets. In practice, this form of contract incompleteness amounts to assuming that the share of revenues β can only be either 0 (public ownership) or 1 (private ownership). As reminded above, the bulk of the analysis was to investigate how this share of revenues should be contingent (complete contracting) or not (incomplete contracting) on realization

[32]Guasch and Straub (2009).

of productivity shocks. If ownership can be contingent on reports on the value of the productivity shock θ, the same lessons as in the main text applies with the proviso that β is now restricted by ownership patterns. Incomplete contracts (in the sense of being non-contingent on θ) let the firm bear more risk which is precisely what arises by leaving ownership. More complete contracts are a contrario associated with public ownership. When corruption enters the picture, biased public officials may excessively favor private ownership and incomplete contracts; a feature that is reminiscent of much casual evidence in the field.

Implications for developing countries. Following insights pushed forward by Laffont (2005) and Estache and Wren-Lewis (2009), we may assume in a first pass that the trade-offs between contracting modes are essentially the same whether countries are developing ones or not but that the magnitude of various parameters may differ, impacting then on how the trade-off is solved. For instance, we might conjecture that the absence of monitoring devices to curb collusion and the development of a culture for corruption throughout the economy may altogether increase the parameter γ making standardized contracts more attractive. Along the same token (and even though this parameter is not formally introduced into our model), we might also posit that the presence of a more significant cost of public funds in developing countries would also exacerbate the conflict of interests between PA and PO and make it more attractive for the former to impose more standardized contracts. Yet, these insights may be overly optimistic. One dimension that is left unsettled by our analysis is that PA himself may be corrupt in which case we conjecture that the disciplinary role of standardized contracts would disappear. In other words, if corruption trickles up the chain of command, incomplete contracts may be preferred and, unfortunately, little effort may be done to fight those biases.

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Appendix

Proof of Proposition 1. The principal's expected payoff can be written as:

$$\mathbb{E}_{\theta,\zeta}\left(1-\beta\left(\theta\right)\right)\left(R_0+e\left(\theta\right)+\theta+\zeta\right)-\alpha(\theta)) = \mathbb{E}_\theta\left(\beta(\theta)-\frac{(1+r\sigma^2)}{2}\beta^2(\theta)-U(\theta)\right). \quad \text{(A1)}$$

When θ is verifiable, the optimal contract maximizes the above expression subject to the contractor's participation constraint:

$$\mathbb{E}_\theta(U(\theta)) \geq 0. \quad \text{(A2)}$$

It is optimal to have full insurance and to saturate the contractor's *ex ante* participation constraint so as to get (5). The first-order optimality condition with respect to $\beta(\theta)$ then gives us (6). The fixed fees $\alpha^{mh}(\theta)$ tailored to the realization of θ are then chosen so that:

$$\alpha^{mh}(\theta)+\beta^{mh}\theta+\frac{(\beta^{mh})^2}{2}=U^{mh}(\theta)=0.$$

■

Proof of Lemma 1. The contractor's expected utility can be written as in terms of its certainty equivalent $\mathcal{V}$ as:

$$\mathbb{E}_\theta(v(U(\theta)))=v(\mathcal{V}).$$

The risk premium φ is then defined as

$$\mathcal{V} = \mathbb{E}_\theta(U(\theta)) - \varphi.$$

Using the CARA specification, we get:

$$exp(-r(\mathbb{E}_\theta(U(\theta)) - \varphi)) = \mathbb{E}_\theta(exp(-rU(\theta))).$$

Simplifying yields:

$$exp(-r(\nu\Delta U - \varphi)) = 1 - \nu + \nu \exp(-r\Delta U)$$

where $\Delta U = U(\overline{\theta}) - U(\underline{\theta})$. Taking logarithms of both sides, we obtain:

$$\varphi(\Delta U) = \nu\Delta U + \frac{1}{r} ln\left(1 - \nu + \nu \exp(-r\Delta U)\right). \tag{A3}$$

with

$$\varphi'(\Delta U) = \frac{\nu(1-\nu)(1 - exp(-r\Delta U))}{1 - \nu + \nu exp(-r\Delta U)} > 0.$$

Finally, the expression of the risk premium given in (9) follows from inserting the value of ΔU obtained when the incentive constraint (8) is binding. ■

Proof of Proposition 2. First, we write the principal's problem as:

$$\max_{(\beta(\theta), U(\theta), \mathcal{V})} \mathbb{E}_\theta\left(\beta(\theta) - \frac{(1 + r\sigma^2)}{2}\beta^2(\theta) - U(\theta)\right) \text{ subject to (8) and (10).}$$

where, using the CARA specification and following Lemma 1, we have

$$\mathcal{V} = \mathbb{E}_\theta\left(U(\theta)\right) - \varphi(\Delta U)$$

and where $\varphi(\Delta U)$ is defined as in (A3). Inserting into the maximand, we get:

$$\max_{(\beta(\theta), U(\theta), \mathcal{V})} \mathbb{E}_\theta\left(\beta(\theta) - \frac{(1 + r\sigma^2)}{2}\beta^2(\theta)\right) - \mathcal{V} - \varphi(\Delta U) \text{ subject to (8) and (10).}$$

Observing now that $\varphi' > 0$, (8) is thus necessarily binding. The principal's problem can thus be rewritten as:

$$(\mathcal{P}_0): \quad \max_{(\beta(\overline{\theta}), \beta(\underline{\theta})), \mathcal{V}} \mathcal{W}(\beta(\overline{\theta}), \beta(\underline{\theta})) - \mathcal{V} \text{ subject to (10).}$$

Maximizing (P_0) is then immediate. Of course (10) is binding at the optimum. Pointwise optimization of the strictly concave function $\mathcal{W}(\beta(\overline{\theta}), \beta(\underline{\theta}))$ with respect to each of its argument respectively gives us the first-order conditions $\beta^{nv}\left(\overline{\theta}\right) = \beta^{mh}$, and (12). Observe that the right-hand side of (12) is a decreasing function of $\beta^{nv}(\underline{\theta})$ while the right-hand side is increasing and there exists a unique solution $\beta^{nv}(\underline{\theta})$ in $[0, 1]$ to this equation. ■

Proof of Proposition 3. Following the same steps as in the previous proof, the principal's maximization problem can then be written as:

$$\max_{(\beta_\infty, U_\infty(\theta), \mathcal{V}_\infty)} \beta_\infty - \frac{(1+r\sigma^2)}{2}\beta_\infty^2 - \mathcal{V}_\infty - \varphi(\Delta U_\infty) \text{ subject to (13) and (14)}$$

which can be simplified into

$$(\mathcal{P}_\infty): \max_{\beta_\infty, \mathcal{V}_\infty} \mathcal{W}(\beta_\infty, \beta_\infty) - \mathcal{V}_\infty \text{ subject to (14).}$$

Clearly, the contractor's participation constraint (14) is binding at the optimum. The first-order optimality condition for β_∞ then yields (17). Observe that the right-hand side of (17) is a decreasing function of $\beta^{nv}(\underline{\theta})$ while the right-hand side is decreasing with a unique solution in $[0,1]$. Lastly, observe that

$$\beta_\infty^{nv} > \beta^{mh}\left(1 - \frac{\Delta\theta}{1-\nu}\varphi'(\Delta\theta\beta_\infty^{nv})\right).$$

It thus follows from the quasi-concavity of the objective function under complete contracting that

$$\beta_\infty^{nv} > \beta^{nv}(\underline{\theta})$$

so that the risk premium under incomplete contracting is greater than under complete contracting. Observe also that $\beta_\infty^{nv} < \beta^{mh}$, so that we finally obtain the comparative statics (16). ■

Proof of Proposition 4. Consider $(\mathcal{P})$ where the incentive constraint (20) has been omitted. Observe that both (10) and (14) are necessarily binding at its optimum so that

$$\mathcal{V} = \mathcal{V}_\infty = 0. \tag{A4}$$

Inserting into the maximand and optimizing with respect to z yields the condition (20) written for $\mathcal{V} = \mathcal{V}_\infty = 0$ so that the constraint (20) could indeed be omitted from the optimization. Finally, Item 2. immediately follows from pointwise optimization. ■

Micro-foundations for PO's preferences. Suppose that PO and the contractor share perfect knowledge on the realization of θ with some probability q. More precisely, with such probability PO receives at the interim stage hard evidence, σ = "θ", stipulating that he will observe the shock θ (whatever its value) when that shock will realize later on. Under those circumstances, information sharing triggers collusive behavior between the contractor and PO. With probability $1-q$, there is no such informative signal (i.e., $\sigma = \emptyset$) and there won't be any information sharing with the firm. Collusion is not possible under that scenario. If PO does not collude with the contractor, he reports to the principal the realization of the shock when it realizes.

Although the basic sharing rule agreement (say $\{(\alpha(\theta), \beta(\theta))\}_{\theta \in \{\underline{\theta}, \bar{\theta}\}}$ for a complete contract and $(\alpha_\infty, \beta_\infty)$ for an incomplete one) is not a priori contingent on σ, a system of state-dependent fees can be renegociated to provide full insurance in case PO reports $\sigma =$ "θ" at the interim stage. Those new fees are designed to extract the contractor's surplus, so that $U(\theta) = 0$, although the parameter $\beta(\theta)$ or β_∞ depending on the contracting scenario remains unchanged.

PO cares on both PA's objective and the possible gains from collusion he may pocket from adopting a collusive behavior. To illustrate, PO's payoff with a complete contract had any been signed can be expressed as:

$$\mathbb{E}_{\theta,\zeta}\left(\left(1-\beta(\theta)\right)R - \alpha(\theta)\right) - z + qk\mathbb{E}_\theta(\tau(\theta)) = \mathcal{W}(\beta(\bar{\theta}), \beta(\underline{\theta})) - z - \mathcal{V} + qk\mathbb{E}_\theta(\tau(\theta))$$

where the parameter $k < 1$ captures the cost of transferring bribes.[33] Of course, a similar expression applies with an incomplete contract.

With a complete contract, a collusive deal stipulates bribes $(\tau(\underline{\theta}), \tau(\bar{\theta}))$ which maximize PO's expected utility subject to the constraint that the contractor's expected payoff from accepting the bribes are greater than zero (we assume that the contractor cannot be rewarded for denunciating a rogue deal). PO obtains a gains from colluding when a complete contract is offered that is worth:

$$\max_{(\tau(\underline{\theta}), \tau(\bar{\theta}))} k\mathbb{E}_\theta(\tau(\theta)) \text{ subject to } \mathbb{E}_\theta(v(U(\theta)) - \tau(\theta)) \geq 0.$$

This side-contract gives full insurance to the contractor. The public official extracts the whole stake from corruption, and obtains an expected benefit from corruption worth:

$$k\mathbb{E}_\theta(U(\theta)).$$

Taking $\gamma = kq < 1$ and inserting into PO's objective, we get an overall expression of that objective as stipulated in the text. ■

Proof of Proposition 5. After integrating by parts, we may rewrite the maximand of $(\mathcal{P}^{co})$ as:

$$G(z^*)\left(\mathcal{W}(\beta(\bar{\theta}), \beta(\underline{\theta})) - \mathcal{V} - (\mathcal{W}(\beta_\infty, \beta_\infty) - \mathcal{V}_\infty) - z^*\right) + \int_0^{z^*} G(z)dz + \mathcal{W}(\beta_\infty, \beta_\infty) - \mathcal{V}_\infty.$$

Optimal degree of incompleteness. Let us first fix the revenues sharing rules $(\beta(\bar{\theta}), \beta(\underline{\theta}))$ and β_∞ under both contracting modes. The maximization problem so obtained is linear in $(\mathcal{V}, \mathcal{V}_\infty)$

[33]Those costs might include the cost that the contractor may bear in organizing corruptible activities, the fact that side-contracts are not easily enforceable (on this issue see Tirole (1992), and Martimort (1999)), the risk of being caught for briberies, or the psychological costs that PO may incur when being involved in some illegal activities as in Khalil and Lawarrée (2006).

and the maximand is strictly quasi-concave in z^* when $G(z)/g(z)$ is increasing in z. Denoting respectively by $\mu \geq 0$, $\mu_\infty \geq 0$ and λ the Lagrange multipliers for (10), (14) and (23), we write the Lagragean for this problem as:

$$\mathcal{L}(\beta(\overline{\theta}), \beta(\underline{\theta}), \beta_\infty, z^*, \mathcal{V}, \mathcal{V}_\infty, \lambda, \mu, \mu_\infty)$$

$$= G(z^*)\left(\mathcal{W}(\beta(\overline{\theta}), \beta(\underline{\theta})) - \mathcal{V} - (\mathcal{W}(\beta_\infty, \beta_\infty) - \mathcal{V}_\infty) - z^*\right) + \int_0^{z^*} G(z)dz$$

$$+\mathcal{W}(\beta_\infty, \beta_\infty) - \mathcal{V}_\infty$$

$$+\lambda\left(\mathcal{W}(\beta(\overline{\theta}), \beta(\underline{\theta})) - (1-\gamma)\mathcal{V} - (\mathcal{W}(\beta_\infty, \beta_\infty) - (1-\gamma)\mathcal{V}_\infty) + \gamma\left(\varphi(\Delta\theta\beta(\underline{\theta})) - \varphi(\Delta\theta\beta_\infty)\right) - z^*\right)$$

$$+\mu\mathcal{V} + \mu_\infty\mathcal{V}_\infty.$$

From the remarks above, this Lagrangean is quasi-concave in $(z^*, \mathcal{V}, \mathcal{V}_\infty)$. The Karush-Khun Tucker (necessary and sufficient) conditions for optimality with respect to z^*, $\mathcal{V}$, and $\mathcal{V}_\infty$ can then be written respectively as:

$$\mathcal{W}(\beta(\overline{\theta}), \beta(\underline{\theta})) - \mathcal{V} - (\mathcal{W}(\beta_\infty, \beta_\infty) - \mathcal{V}_\infty) - z^* = \frac{\lambda}{g(z^*)}, \tag{A5}$$

$$\mu = G(z^*) + \lambda(1-\gamma), \tag{A6}$$

$$\mu_\infty = 1 - G(z^*) - \lambda(1-\gamma). \tag{A7}$$

We consider (and will find conditions below such that) cases where (10) and (14) are both binding. It implies

$$\mathcal{V}^{co} = \mathcal{V}^{co}_\infty = 0. \tag{A8}$$

which gives

$$G(z^*) + \lambda(1-\gamma) \geq 0 \Leftrightarrow G(z^*) + \lambda \geq \gamma\lambda, \tag{A9}$$

and

$$1 - G(z^*) - \lambda(1-\gamma) \geq 0 \Leftrightarrow 1 - G(z^*) - \lambda \geq -\gamma\lambda. \tag{A10}$$

Inserting (A8) into (A5), using (23) and simplifying, we obtain:

$$\frac{\lambda}{g(z^*)} = \gamma\left(\varphi(\Delta\theta\beta_\infty) - \varphi(\Delta\theta\beta(\underline{\theta}))\right). \tag{A11}$$

Observe that $\lambda \geq 0$ when $\gamma \geq 0$ and

$$\beta_\infty \geq \beta(\underline{\theta}). \tag{A12}$$

We will come back on this condition below. Inserting $\lambda \geq 0$ into (A5) and again taking into account (A8) yields:

$$\mathcal{W}(\beta(\overline{\theta}), \beta(\underline{\theta})) - \mathcal{W}(\beta_\infty, \beta_\infty) \geq z^* \tag{A13}$$

which gives us (24) for the optimal sharing rules that are defined below in more details. For further references, we define $z^*(\beta(\overline{\theta}), \beta(\underline{\theta}), \beta_\infty)$ as the solution (unique from strict quasi-concavity) of the optimization problem with fixed $(\beta(\overline{\theta}), \beta(\underline{\theta}), \beta_\infty)$.

Optimal revenue sharing rules. We now turn to the analysis of these optimal sharing rules. We define the maximized value of PA's problem $\mathcal{L}^*(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty)$ as:

$$\begin{aligned}&\mathcal{L}^*(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty)\\ &= G(z^*(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty))\left(\mathcal{W}(\beta(\overline{\theta}),\beta(\underline{\theta}))-\mathcal{W}(\beta_\infty,\beta_\infty)-z^*(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty)\right)\\ &\quad+\int_0^{z^*(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty)} G(z)dz+\mathcal{W}(\beta_\infty,\beta_\infty).\end{aligned}$$

Observe that this objective is strictly quasi-concave in $(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty)$ at $\gamma=0$ and that it remains so when γ is small enough as assumed. Denoting now

$$\begin{aligned}&\lambda(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty)=\\ &g(z^*(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty))\left(\mathcal{W}(\beta(\overline{\theta}),\beta(\underline{\theta}))-\mathcal{W}(\beta_\infty,\beta_\infty)-z^*(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty)\right),\end{aligned}\tag{A14}$$

we may write the necessary conditions for optimality of $\mathcal{L}^*(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty)$ with respect to $\beta(\overline{\theta})$, $\beta(\underline{\theta})$ and β_∞, respectively as:

$$(G(z^*(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty))+\lambda(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty))\frac{\partial\mathcal{W}}{\partial\beta(\overline{\theta})}(\beta(\overline{\theta}),\beta(\underline{\theta}))=0,\tag{A15}$$

$$(G(z^*(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty))+\lambda(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty))\frac{\partial\mathcal{W}}{\partial\beta(\underline{\theta})}(\beta(\overline{\theta}),\beta(\underline{\theta}))=-\lambda(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty)\gamma\Delta\theta\varphi'(\Delta\theta\beta(\underline{\theta})),\tag{A16}$$

and

$$\begin{aligned}&(1-G(z^*(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty))+\lambda(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty))\left(\frac{\partial\mathcal{W}}{\partial\beta(\overline{\theta})}(\beta_\infty,\beta_\infty)+\frac{\partial\mathcal{W}}{\partial\beta(\underline{\theta})}(\beta_\infty,\beta_\infty)\right)\\ &\quad=\lambda(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty)\gamma\Delta\theta\varphi'(\Delta\theta\beta(\underline{\theta})).\end{aligned}\tag{A17}$$

From (A15), it immediately follows that $\beta^{co}(\overline{\theta})=\beta^{mh}$ as requested by (25).

From (A16), we also get:

$$(1-\nu)\left(1-\frac{\beta(\underline{\theta})}{\beta^{mh}}\right)-\Delta\theta\varphi'(\Delta\theta\beta(\underline{\theta}))=-\frac{\lambda(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty)\gamma\Delta\theta\varphi'(\Delta\theta\beta(\underline{\theta}))}{G(z^*(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty))+\lambda(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty)}.\tag{A18}$$

When $\lambda(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty)>0$ as requested when (A12) holds, the denominator on the right-hand side of (A19) is negative from (A9). Two implications follows. First, when evaluated at $\beta(\underline{\theta})=\beta^{mh}$ the derivative of $\mathcal{L}^*(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty)$ with respect to $\beta(\underline{\theta})$ is

$$-\frac{G(z^*(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty))+(1-\gamma)\lambda(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty)}{G(z^*(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty))+\lambda(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty)}\Delta\theta\varphi'(\Delta\theta\beta(\underline{\theta}))\leq 0\tag{A19}$$

where we have used again (A9). From the quasi-concavity of $\mathcal{L}^*(\beta(\overline{\theta}),\beta(\underline{\theta}),\beta_\infty)$, we thus deduce that $\beta^{co}(\underline{\theta})\leq\beta^{mh}$ as requested by (25). Second, we also have

$$(1-\nu)\left(1-\frac{\beta(\underline{\theta})}{\beta^{mh}}\right)-\Delta\theta\varphi'(\Delta\theta\beta(\underline{\theta}))\leq 0.$$

Using the quasi-concavity of the objective with a non-corrupt PO, it follows that $\beta^{co}(\underline{\theta}) \geq \beta^{nv}(\underline{\theta})$, again as requested by (25).

From (A17), we finally get:

$$1 - \frac{\beta_\infty}{\beta^{mh}} - \Delta\theta\varphi'(\Delta\theta\beta_\infty) = \frac{\lambda(\beta(\overline{\theta}), \beta(\underline{\theta}), \beta_\infty)\gamma\Delta\theta\varphi'(\Delta\theta\beta_\infty)}{1 - G(z^*(\beta(\overline{\theta}), \beta(\underline{\theta}), \beta_\infty)) + \lambda(\beta(\overline{\theta}), \beta(\underline{\theta}), \beta_\infty)}. \tag{A20}$$

When $\lambda(\beta(\overline{\theta}), \beta(\underline{\theta}), \beta_\infty) > 0$ as requested when (A12) holds, the denominator on the right-hand side of (A20) is positive from (A10) and thus:

$$1 - \frac{\beta_\infty}{\beta^{mh}} - \Delta\theta\varphi'(\Delta\theta\beta_\infty) \geq 0$$

Using the quasi-concavity of the objective with a non-corrupt PO, it follows that $\beta^{co}_\infty \leq \beta^{nv}_\infty$, again as requested by (25).

Condition on a non-negative multiplier. We now come back on condition (A12). Observe that, when γ is small enough, λ is close enough to zero from (A11). Then, z^{co} is close to $z^{nv} > 0$ so that conditions (A9) and (A10) both hold. $\beta^{co}(\underline{\theta})$ and β^{co}_∞ are close to $\beta^{nv}(\underline{\theta})$ and β^{nv}_∞ respectively. They thus satisfy (A12) and $\lambda \geq 0$ as requested. ■

Proof of Proposition 6. When γ is small enough, we immediately get from (A11) the following Taylor expansion for λ:

$$\lambda = \gamma g(z^{nv}) \left(\varphi(\Delta\theta\beta^{nv}_\infty) - \varphi(\Delta\theta\beta^{nv}(\underline{\theta}))\right) \varphi'(\Delta\theta\beta^{nv}(\underline{\theta})). \tag{A21}$$

Inserting into (A19) and (A20) respectively gives us the following Taylor expansions:

$$\beta^{co}(\underline{\theta}) = \beta^{nv}(\underline{\theta}) + \frac{\beta^{mh} g(z^{nv})}{(1-\nu)G(z^{nv})}\gamma^2\Delta\theta \left(\varphi(\Delta\theta\beta^{nv}_\infty) - \varphi(\Delta\theta\beta^{nv}(\underline{\theta}))\right) \varphi'(\Delta\theta\beta^{nv}(\underline{\theta})); \tag{A22}$$

$$\beta^{co}_\infty = \beta^{nv}_\infty - \frac{\beta^{mh} g(z^{nv})}{1 - G(z^{nv})}\gamma^2\Delta\theta \left(\varphi(\Delta\theta\beta^{nv}_\infty) - \varphi(\Delta\theta\beta^{nv}(\underline{\theta}))\right) \varphi'(\Delta\theta\beta^{nv}(\underline{\theta})). \tag{A23}$$

Hence, the differences $\beta^{co}(\underline{\theta}) - \beta^{nv}(\underline{\theta})$ and $\beta^{co}_\infty - \beta^{nv}_\infty$ are only of a second-order magnitude in γ. Inserting these findings into (23) gives us

$$z^{nv} - z^{co} = \gamma \left(\varphi(\Delta\theta\beta^{nv}_\infty) - \varphi(\Delta\theta\beta^{nv}(\underline{\theta}))\right). \tag{A24}$$

Consider now $\Delta\theta$ small enough so that the risk premium for some arbitrary revenue sharing parameter β can be approximated as:

$$\varphi(\Delta\theta\beta) = \frac{r\nu(1-\nu)}{2}(\Delta\theta)^2\beta^2 \tag{A25}$$

with

$$\varphi'(\Delta\theta\beta) = r\nu(1-\nu)\Delta\theta\beta. \tag{A26}$$

Using, for $\Delta\theta$ small enough, the following approximations of $\beta^{nv}(\underline{\theta})$ and β^{nv}_{∞} can be respectively obtained from (12) and (17):

$$\beta^{nv}(\underline{\theta}) = \beta^{mh}(1 - r\nu(\Delta\theta)^2\beta^{mh}) \tag{A27}$$

and

$$\beta^{nv}_{\infty} = \beta^{mh}(1 - r\nu(1-\nu)(\Delta\theta)^2\beta^{mh}). \tag{A28}$$

Using (A25), (A27) and (A28), we get the following approximation:

$$\varphi(\Delta\theta\beta^{nv}_{\infty}) - \varphi(\Delta\theta\beta^{nv}(\underline{\theta})) = r^2\nu^3(1-\nu)(\Delta\theta)^4(\beta^{mh})^2 \tag{A29}$$

Inserting into (A24), we finally obtain (26). Comparative statics immediately follow. ■

Proof of Corollary 1. Under centralization, expected welfare is given by the solution to

$$\max\left\{\mathcal{W}(\beta^{nv}(\bar{\theta}), \beta^{nv}(\underline{\theta})) - \mathbb{E}_z(z), \mathcal{W}(\beta^{nv}_{\infty}, \beta^{nv}_{\infty})\right\},$$

where $\mathbb{E}_z(z) = \int_0^1 z dG(z)$. With a corrupt$PO$ expected welfare under decentralization is:

$$EW^{co}(z^{co}, \beta^{co}(\bar{\theta}), \beta^{co}(\underline{\theta}), \beta^{co}_{\infty}) \equiv \int_0^{z^{co}} \left(\mathcal{W}(\beta^{co}(\bar{\theta}), \beta^{co}(\underline{\theta})) - z\right) dG(z) + (1 - G(z^{co}))\mathcal{W}(\beta^{co}_{\infty}, \beta^{co}_{\infty}),$$

which is greater than the expected welfare that is obtained if the optimal contracts for a benevolent PO are offered:

$$EW^{nv}(\hat{z}^{co}, \beta^{nv}(\bar{\theta}), \beta^{nv}(\underline{\theta}), \beta^{nv}_{\infty}) \equiv \int_0^{\hat{z}^{co}} \left(\mathcal{W}(\beta^{nv}(\bar{\theta}), \beta^{nv}(\underline{\theta})) - z\right) dG(z) + (1 - G(\hat{z}^{co}))\mathcal{W}(\beta^{nv}_{\infty}, \beta^{nv}_{\infty})$$

where

$$\begin{aligned}
\hat{z}^{co} &\equiv \mathcal{W}(\beta^{nv}(\bar{\theta}), \beta^{nv}(\underline{\theta})) - (\mathcal{W}(\beta^{nv}_{\infty}, \beta^{nv}_{\infty})) + \gamma(\varphi(\Delta\theta\beta^{nv}(\underline{\theta})) - \varphi(\Delta\theta\beta^{nv}_{\infty})). \\
&= z^{nv} + \gamma(\varphi(\Delta\theta\beta^{nv}(\underline{\theta})) - \varphi(\Delta\theta\beta^{nv}_{\infty})) < z^{nv}.
\end{aligned}$$

and, clearly

$$EW^{co}(z^{co}, \beta^{co}(\bar{\theta}), \beta^{co}(\underline{\theta}), \beta^{co}_{\infty}) > EW^{nv}(\hat{z}^{co}, \beta^{nv}(\bar{\theta}), \beta^{nv}(\underline{\theta}), \beta^{nv}_{\infty}).$$

A sufficient condition for decentralization to remain optimal when PO is corruptis then

$$EW^{nv}(\hat{z}^{co}, \beta^{nv}(\bar{\theta}), \beta^{nv}(\underline{\theta}), \beta^{nv}_{\infty}) \geq \max\left\{\mathcal{W}(\beta^{nv}(\bar{\theta}), \beta^{nv}(\underline{\theta})) - \mathbb{E}_z(z), \mathcal{W}(\beta^{nv}_{\infty}, \beta^{nv}_{\infty})\right\}$$

Let

$$\mathcal{W}(\beta^{nv}(\bar{\theta}), \beta^{nv}(\underline{\theta})) - Ez < \mathcal{W}(\beta^{nv}_{\infty}, \beta^{nv}_{\infty}) \tag{A30}$$

which implies that $W(\beta^{nv}_{\infty}, \beta^{nv}_{\infty})$ is the standardized contract chosen under centralization. Under (A30), a sufficient condition for decentralization to remain optimal is thus:

$$\int_0^{\hat{z}^{co}} \left(\mathcal{W}(\beta^{nv}(\bar{\theta}), \beta^{nv}(\underline{\theta})) - z\right) dG(z) + (1 - G(\hat{z}^{co}))\mathcal{W}(\beta^{nv}_{\infty}, \beta^{nv}_{\infty}) \geq \mathcal{W}(\beta^{nv}_{\infty}, \beta^{nv}_{\infty})$$

or

$$\left(\mathcal{W}(\beta^{nv}(\overline{\theta}), \beta^{nv}(\underline{\theta})) - \mathcal{W}(\beta^{nv}_{\infty}, \beta^{nv}_{\infty})\right) G(\hat{z}^{co}) \geq \int_0^{\hat{z}^{co}} z dG(z).$$

Using the definition of $\hat{z}^{co}$, we obtain:

$$z^{nv} G(\hat{z}^{co}) \geq \int_0^{\hat{z}^{co}} z dG(z)$$

or

$$\int_0^{\hat{z}^{co}} (z^{nv} - z)\, dG(z) \geq 0$$

which is satisfied since $\hat{z}^{co} < z^{nv}$.

Suppose now that (A30) does not hold and that therefore $\mathcal{W}(\beta^{nv}(\overline{\theta}), \beta^{nv}(\underline{\theta})) - \mathbb{E}_z(z)$ is the optimal standardized contract. Then a sufficient condition for decentralization to be optimal is

$$\int_0^{\hat{z}^{co}} \left(\mathcal{W}(\beta^{nv}(\overline{\theta}), \beta^{nv}(\underline{\theta})) - z\right) dG(z) + (1 - G(\hat{z}^{co}))\mathcal{W}(\beta^{nv}_{\infty}, \beta^{nv}_{\infty}) \geq \mathcal{W}(\beta^{nv}(\overline{\theta}), \beta^{nv}(\underline{\theta})) - \mathbb{E}_z(z)$$

i.e.

$$\int_{\hat{z}^{co}}^1 z dG(z) \geq (1 - G(\hat{z}^{co})) \left[\mathcal{W}(\beta^{nv}(\overline{\theta}), \beta^{nv}(\underline{\theta})) - \mathcal{W}(\beta^{nv}_{\infty}, \beta^{nv}_{\infty})\right]$$

or

$$\int_{\hat{z}^{co}}^1 z dG(z) \geq (1 - G(\hat{z}^{co}))\, z^{nv} \int_{\hat{z}^{co}}^1 (z - z^{nv})\, dG(z) \geq 0$$

which is satisfied for $z^{nv} - \hat{z}^{co}$ sufficiently low, that is for $\gamma(\varphi(\Delta\theta\beta^{nv}(\underline{\theta})) - \varphi(\Delta\theta\beta^{nv}_{\infty}))$ sufficiently low. The result then follows from Proposition 6, which suggests that for γ and $\Delta\theta$ small enough, up to terms of higher-order magnitude, we have the following approximation:

$$z^{nv} - \hat{z}^{co} \approx \frac{\gamma r^2 \nu^3 (1-\nu)}{(1 + r\sigma^2)^2} \Delta\theta^4.$$

Thus the benefit of decentralization under corruption, will remain provided, r, $\Delta\theta$ and γ are sufficiently small. ■