Accountability to Contain Corruption in Procurement Tenders*

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Abstract

This paper addresses the issue of favoritism at the design stage of a complex procurement auction. A community of citizens wants to procure a project and lacks the knowledge and the ability to translate its preferences into operational technical specifications. This task is delegated to a public officer who may collude with one of the firms at the design stage of the procurement auction in exchange of a bribe. We investigate two simple accountability mechanisms: a random challenge mechanism (RCA) and an alert-based mechanism (ABA), that require justifying one aspect of the technical decision drawn randomly (RCA) or determined by the competitors (ABA). Relying on competitors enables the community to deter favoritism significantly more easily than by relying only on random challenges and the level of penalty needed to fully deter corruption is independent of the complexity of the project and depends on the degree of differentiation within the industry. In an illustrative example, we study the patterns of favoritism when corruption occurs under ABA and compare them with the patterns in the random challenge mechanism.

Keywords: Favoritism, accountability, procurement
Journal of Economic Literature Classification Number: D73, D82, H57.

1 Introduction

In a recent book, K. Basu (2018) questions traditional Law and Economics approach: law enforcers are also (self-interested) players. "The existence of corruption is the smoking-gun evidence of the flaw underlying traditional law and economics"(p 137). Transparency International writes in its global report on the private sector (2009) that "sustainable

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progress towards a world free of corruption requires a systematic and constructive engagement with the demand for and supply of corruption and the incentive systems that shape them both." In face of the inefficiency of anti-corruption regulatory frameworks, devising ways to engage interested parties in the fight against corruption is a most challenging and promising path forward. In this paper, we investigate some properties of a mechanism that engages private firms in the fight against corruption in public procurement.

The economic significance of public procurement in Europe is considerable: in 2010 a total of 2 406 billion euros - or around 20% of EU GDP - was spent by governments, the public sector and utility service providers on public works, goods and services.[1] A recent study commissioned by the EC developed a novel methodology to identify the costs of corruption in public procurement. For practical reasons the study focused on a subset of all public procurement worth 447 billion euros (19% of the total expenditure).[2] According to its findings the social loss due to corrupt projects amounts to 29% of the project value in urban utility construction, 20% in roads and rail and 16% in water & waste[3]. The direct cost of corruption i.e., the cost that can be directly attributed to corrupt decisions, in the five sectors under study is estimated in the study to between 1.4 – 2.2 billion euros.[4] The probability of corruption is estimated between 28–43% in waste & water treatment plants and up to 37–53% of (airport) runway construction works. This study provides a forceful confirmation that even in developed economies, corruption in procurement remains a major challenge.

As known from numerous studies and analysis (see Transparency International (2010) about the water sector) corruption can occur at each of the five stages of the procurement process including: 1. Needs assessment; 2. Preparation of bidding documents including the technical specification; 3. Contractor selection; 4. Contract execution; 5. Final accounting and audit. In this paper, we focus on "fine-tailoring", which is corruption at the design stage, i.e. at the first two stages. Private sector actors and specialized anti-corruption organizations such as Transparency International are well aware that often

[1]PWC and Ecory (2013)

[2]It corresponds to the tenders published in the Official Journal and the TED-database in 2010 (Tender Electronic Daily)

[3]Such direct public losses in corrupt/grey cases are typically a result of: cost overruns, delays of implementation and/or loss of effectiveness (including inferior quality and questionable usefulness).

[4]Road/rail, Waters & waste, Urban utility/construction/ Training/ research and development/

when the tender is announced "the winner is already known ", partly because the project has been fine-tailored to one of the bidders. The associated costs both in terms of social welfare (the project does not respond to social needs) and cost overruns (the project is designed to maximize the winner's rents) can be very significant even if the rest of the procurement process is clean. Yet, the above mentioned EC study only indirectly investigates corruption in the two first stages. Out of 27 red flags used systematically in the study only two can be viewed as somehow related to stages 1 and 2: "preferred supplier indication" and "complaints from non-winning bidders". In general, fine-tailoring has received very little attention and very few policy recommendations ever address it - none in the above mentioned EC study.

A main reason for the remarkable lack of attention to corruption at the design stage is presumably the particularly difficult nature of the associated probe. In order to establish whether or not favoritism has taken place, special knowledge is required. In some cases a small detail can be sufficient to seriously reduce competition. An example of a technical specification that clearly excludes competitors is the request for a specific brand. Such a feature secures the win of the firm that owns the brand at a high cost for the public. Prohibiting the use of brand name is by now a standard provision in most Procurement Laws.[5] But besides this one gross instance of favoritism, it is very difficult *for an outsider* to detect a technical requirement aimed at unduly favoring a specific firm.

Assessing whether favoritism has taken place or not requires either that an audit or an inspection examines the specifications of the project or that the public officer justifies his choices for these specifications. External monitoring may however be very costly as it requires an outsider to acquire the necessary knowledge about the community's needs and technical specifications. The public officer, however, has presumably much information about these aspects so that letting him be accountable for his choices, i.e. provide proofs or evidence that the project is appropriate, might save a lot of time and resources. In practice, however, it is not feasible to provide justification for all aspects of a complex project nor is it feasible to process such information in limited time. Therefore the central problem becomes the selection of which aspect(s) of the technical specification to request the public officer to provide justification about. A possible mechanism consists in choosing randomly which aspect of the technical specification to invite the public officer

[5] Equivalently, procurement laws may prescribe that when a brand name is used, the use a product / process / component that is "equivalent "must be explicitly authorized.

to justify. Another possible mechanism consists in allowing competing firms to participate in a mechanism to hold the procurement agent accountable for the announced technical specifications.

More specifically we consider a situation in which a local community of citizens wants to procure a complex good or project and lacks the ability to translate its preferences for this project into operational technical specifications. This task is delegated to a public officer who has significant discretion by force of his private information. Two candidate contractors compete to realize the project. One of them has close connections with the procurement officer so that they can collude at the design stage of the procurement auction, i.e. the public officer may distort the technical specification of the project in exchange of a bribe from this firm. Assuming that it is prohibitively costly to provide a justification for the many aspects of a complex project, we investigate two simple accountability mechanisms that ask the public officer to justify *one* aspect of the project, with the threat of being punished if he fails: a *random challenge accountability* (RCA) mechanism and an *alert-based accountability* (ABA) mechanism. The principle of these mechanisms is as follows. Before the submission of offers, one aspect of the specification announced by the public officer is selected at random (RCA) or on the basis of the red flag sent by rivals. The procurement officer is then requested to justify his decision with respect to that aspect. If he fails, the tender is relaunched with new technical specifications and the agent is penalized.

Our first central result characterizes the threshold for complete corruption deterrence with alert-based accountability. We find that it depends on the industry structure as expressed by the rival's comparative advantage. This contrasts sharply with the corresponding threshold that prevails under random challenge accountability, which is a function of the complexity of the project (dimensionality of the technical specification) and is therefore generally significantly larger. So, for instance, corruption never occurs with ABA (even with zero penalty) if the rival has no comparative advantage independently of the project's complexity while it is systematic with RCA when the penalty is low relative to complexity. In our second result, we establish that these thresholds (under RCA and under ABA) are tight i.e., below these thresholds any equilibrium is characterized by corruption with positive probability. We find that with RCA, the risk of corruption is most severe when the firm would lose the contract altogether in the absence of corruption. In contrast with ABA, corruption may occur with some positive probability in states where the firm earns significant positive rents.

The general setting does not allow us to reach a more advanced characterization of the patterns of corruption below the threshold under ABA. In order to go further, we fix an industry structure in an example which enables us to illustrate additional features. We show that the patterns of equilibrium behavior under ABA are quite different from the patterns of behavior under RCA. We exhibit multiple equilibria where the corrupt firm plays a mixed strategy so that favoritism occurs with a probability less than one and yields no expected gains. We also find that under ABA corruption may not always lead to maximal distortion; ABA may generate partial corruption. And in this case, it may lead to a project that can be more or less sophisticated than the socially preferable project.

So, our analysis supports the idea that engaging interested parties in accountability procedures can be beneficial. In our context, engaging the competing firm in the ABA mechanism induces significant improvement in terms of corruption containment, be it total or partial.

The issue of accountability has been addressed in the political science and political economy literature (e.g., Persson et al. (1997), Joshi-Houtzager (2012), Lambert-Mogiliansky (2015), Lupia-McCubbins (1994) and Malena et al (2004), UNDP (2013)) with emphasis on election rules and organizational structure. Our approach shares common features with the literature on optimal monitoring with ex-post verification (cf Townsend (1979) and Gale and Hellwig (1985)). In contrast with Townsend, we are interested in a mechanism with ex-ante commitment and we do not consider an explicit cost of verification. Most importantly, we are interested in the participation of competing firms. Our paper shares some features with the literature on inspection games (for a survey, see e.g. Avenhaus, Von Stengel and Zamir (2002)). Indeed a main issue is to investigate how the inspected responds to the inspector's verification strategy. However and in contrast with that literature, we are not concerned with statistical analysis and the structure of our inspection problem does not lend itself to the type of approach developed for inspection games. Another strand of literature is relevant to the issue of accountability, persuasion games (cf. Glazer and Rubinstein (2004) and (2006), Forges and Koessler (2007)). Although our concern is with the monitoring properties of the investigated mechanisms, “alert based accountability ”is a specific persuasion game and its analysis is the core of our contribution. From an applied point of view, our contribution is to demonstrate how a simple and rather cheap mechanism may allow stake-holders to hold procurement agents accountable and thereby contain corruption.

The paper is organized as follows. In section 2, we discuss the relationship of our approach with existing institutional framework and practice in procurement. In section 3 we present the basic model. Section 4 focuses on Random Challenge Accountability and formulate some baseline results while Section 5 presents our main results on Alert Based Accountability, which are extended in a few directions in Section 6. In section 7 we investigate an example to illustrate the equilibrium strategies that can emerge and the multiplicity issue. The last section discusses our modeling options and concludes.

2 Confronting existing practice

As explained in the Introduction, corruption at the design stage in procurement has received only scarce attention in the literature and there does not exist effective legal or procedural responses to it. Our model has therefore clearly a normative dimension: it proposes a mechanism to **reduce** corruption and favoritism at the design stage of procurement processes.

Normative analysis in public procurement often raises the concern that it relies on demanding informational and commitment assumptions. By contrast a critical argument in favor of the alert-based accountability mechanism that we describe is that it does not rely on rather unrealistic assumptions about the citizens' ability to access and process information, or to commit to a sophisticated and potentially difficult-to-enforce mechanism. Moreover, as alerts and justification take place before firms prepare their offers on the first announced project specification, ABA does not imply additional costs for honest firms and minimally burdens the procurement process.

The alert-based mechanism builds on existing institutional arrangements that can be viewed as first steps toward the full development and implementation of our ABA mechanism, as we now want to argue.

Among the institutional arrangements that try to address this corruption risk, let us first mention the so-called Integrity Pact, a framework developed by Transparency International to fight corruption in procurement.[6] The Integrity Pact relies on the idea that different stake-holders can provide valuable contributions at all stages of procurement, in particular at the design stage.[7] Within an Integrity Pact, civil society and potential bidders are invited to participate to social hearings and to request justification at various stages. Our ABA procedure is inspired by this framework and adds an enforcement mechanism by ways of sanctions so as to strengthen incentives.

The possibility of sanctioning favoritism in design is quite limited. According to e.g., the French legislation Art. 432-14, the act of providing an unjustified advantage is punished by 2 years of imprisonment and 200.000 euros of penalty. The only few cases that have been brought to Court concern the use of brand name in the technical specifications. So, it appears that the current legal arsenal against favoritism is quite exclusively focused on formal irregularities and bribery, and our enforcement mechanism is an elaboration compared to the actual use of sanctions in public procurement.

Another institutional framework on which our mechanism can be built appears in the World Bank's Procurement Guidelines (2017).[8] First, the Guidelines allow firms to request clarifications and file complaints. According to article 5.31, "Potential applicants/Bidders/Proposers/Consultants may request, in writing, clarifications of Procurement Documents issued by the Borrower."Among the bidding documents are the technical specifications. Admittedly, however, when he responds to these requests, the procurement officer is supposed to clear possible misinterpretations, not explicitly to provide justification in term of the specifications' responsiveness to social needs. Yet, this provision could be a channel for developing a procedure that allows challenging specifications. Second, the provisions in article 3.1.A and 3.6 state: "Complaints challenging the terms of pre-qualification / initial selection documents: request for proposal documents, and any other Borrower document requesting Bids, Proposals or Applications should be submitted to the Borrower ... " "In resolving a Complaint ....The Borrower shall provide sufficient information in its response to the complainant. "[9] We note in particular that the obligation to resolve a complaint with sufficient information looks very much like

[6]See McGee and Gaventa (2011).

[7]An Integrity Pact is a complex arrangement involving a commitment from the government agency and the firm, an agreement on how to uphold and monitor the commitment with the participation of all stake-holders including civil society.

[8]These Guidelines are of special interest given the World Bank's well-developed anti-corruption policy. They are widely used as a model for national and other international organizations' own guidelines.

[9]The Borrower is the official managing the procurement process.

our request to justify a specification in our mechanism. A complaint may lead to an amendment i.e., a modification of the specification, but no sanction follows neither for the firm that is being favored nor against the procurement officer. Third, there exists a set of rules related to fraud and corruption that include sanctions (Annexes IV in the Guidelines). What is sanctioned is not the incapacity to justify a decision in the sense of our mechanism but the proven occurrence of abuse aimed at obtaining financial or other benefits.

Nevertheless, the combination of these elements shows that an alert-based accountability procedure does not seem unrealistic given the existing regulatory framework in e.g., the World Bank's Procurement Guidelines. We see the proposed alert-based mechanism as a way to bridge the "soft accountability "in the provisions about clarifications and complaints with the often very demanding approach (with respect to evidence) when dealing with corruption and fraud and implementing sanctions. The alert-based accountability procedure brings in sanctions into the clause of the procurement officer's mandate. In this respect our approach to accountability is comparable to contractual arrangements that condition an agent's continuation in office on positive evaluation.

Finally, we wish to stress that our mechanism is not a judicial procedure. While this makes it "less secure", it is also less of a burden to the public official, which also limits the risks of abuse in harassment. We view the justification procedure as something similar to a social audit that always follows the announcement of the technical specification. The citizens informed by the competing firms hold a justification audience to make up their mind without additional, auditing and detailed monitoring, elements. The principle is that sanctioning requires that the citizens are strongly convinced of malfeasance. In practice we expect that actual distortion is not always identified but that sanctioning by error is nearly excluded. The main analysis assumes no error. We address the robustness of our results to errors in section 6.1.

So we would like to argue that the mechanism we investigate constitutes a reasonable extension of existing practice, one step towards improving the anti-corruption framework.

3 The Setting

We start with a complete presentation of the basic model and timing. We then discuss some seemingly restrictive assumptions of the framework.

Projects. A community, identified with a representative citizen (she), has decided to realize a complex project, e.g. a major construction work aimed at fulfilling specific social economic objectives. The citizen has no prior knowledge nor expertise to formulate the technical specifications corresponding to those objectives. She cannot design the project, choose among various versions or even identify the various relevant aspects of the project. The complexity of the project is captured by its multi-dimensionality: a project corresponds to a n-dimensional vector of specifications, $\mathbf{q} = (q_1, ..., q_n) \in \{0,1\}^n$, where n is exogenously determined by the technical properties of the project.

The citizen delegates to a public officer (a civil servant, he) the task of translating the community's preferences into the technical specifications of the project and of running a procurement auction to allocate the project to a private contractor. The public officer has specific and technical knowledge that enables him to fulfill these tasks. In particular, he has private information about $\overline{\mathbf{q}}$, the project the citizen would opt for if she were able to figure out the various technical aspects and the costs and benefits associated to them. The public officer uses his knowledge of $\overline{\mathbf{q}}$ to choose the final project $\widehat{\mathbf{q}}$, possibly different from $\overline{\mathbf{q}}$, to be allocated to a private contractor.

The nature of the community's needs is supposed to be the outcome of a random process: the random variables $\bar{q}_i$, for $i = 1, .., n$, are assumed to be independently distributed with $\bar{q}_i = 1$ with probability ε_i and 0 with probability $1 - \varepsilon_i$. We interpret $\bar{q}_i = 0$ as a standard specification and $\bar{q}_i = 1$ as a sophisticated specification; standard specifications are assumed to be more likely than sophisticated ones: $\varepsilon_i < 1/2$.

Private contractors. Several firms compete to win the procurement auction and become the unique contractor in charge of realizing the project $\widehat{\mathbf{q}}$. Each firm is characterized by its technological know-how, its experience, its formal intellectual property, the talent and ability of its employees; we capture these characteristics through a (multi-dimensional) type $\theta \in \{0,1\}^n$. We assume that the cost of realizing a project with specifications $\mathbf{q}$ for a firm of type θ is given by:

$$C(\mathbf{q}, \theta) = c \cdot \#\{i; q_i = 1, \theta_i = 0\},$$

that is, we assume that the only cost a firm incurs is when it produces a sophisticated specification while it does not have the technology for it.

We consider two firms, firm α and firm β characterized respectively by θ^α and θ^β and the profile of firms' types is called the *industry structure*. The multi-dimensionality assumption implies that, if neither $\theta^\alpha \geq \theta^\beta$ nor $\theta^\alpha \leq \theta^\beta$, each firm has a comparative advantage in realizing some projects. Most importantly, we assume that the industry structure is common knowledge for the firms in the industry, so that each firm not only knows its own type but also its opponent's type: firms are supposed to be long-term participants in similar markets and have acquired a good knowledge about each other's relative strengths and weaknesses.

The procurement process. The procurement process includes two stages. First, the public officer designs and announces a technical description $\widehat{\mathbf{q}}$ of the project to be procured. Then, the project $\widehat{\mathbf{q}}$ is allocated to one of the (two) private contractors through a (non-discriminatory) procurement auction. Given the assumption that the firms will play the auction game under complete information about each other, the choice of a specific auction format, e.g. first-price sealed-bid, or second-price sealed-bid, or ascending ... is largely inconsequential. Ruling out reservation prices or entry fees and assuming ties are broken by a 50%-50% random draw, the procurement auction will allocate the project to the contractor with the lowest cost and this contractor will earn a rent equal to the difference between the losing firm's cost and the winning firm's cost. If $C(\widehat{\mathbf{q}}, \theta^i) < C(\widehat{\mathbf{q}}, \theta^j)$ (respectively $=$) for $(i, j) = (\alpha, \beta)$ or (β, α), i wins the auction (respectively with probability 1/2), the price paid by the community corresponds to the cost of the losing firm, i.e. to $C(\widehat{\mathbf{q}}, \theta^j)$, and the winner's profit is equal to $C(\widehat{\mathbf{q}}, \theta^j) - C(\widehat{\mathbf{q}}, \theta^i)$.

Corruption. We focus on corruption at the design stage i.e., the risk of favoritism in the choice of the technical specifications of the project. We assume that only one pre-determined firm, firm α, has close connections with the public officer and that the public officer is corruptible i.e., willing to distort the project to favor firm α in exchange of a bribe. In the basic model, we assume that the identity of firm α is common knowledge from the start, because firm α is well-known to the public officer and has a long history of interaction with him. Finally, we are not concerned with the allocation of rents between the public officer and firm α i.e., by the magnitude of the bribe. Firm α and the public officer get together before the public announcement of the tender, share the information about the socially preferable project $\overline{\mathbf{q}}$ and jointly decide upon the project technical specification $\widehat{\mathbf{q}}$ to be tendered so as to maximize their aggregate expected surplus (under full information).

Accountability. The public officer is paid a fixed salary, normalized to 0, that cannot be made contingent on the specifications of the final project nor based on a revelation mechanism, because of the inability of the citizen to describe ex ante what a project is. But the public officer is accountable towards the community: he has to justify his decisions if they are challenged and he has to suffer punishment in case he cannot provide such a justification. In the basic model, we assume perfect justification capabilities: the public officer is capable of justifying an honest decision with respect to any dimension and he cannot justify any distortion in the project design. So the failure to provide a justification is the proof of misconduct in the basic model. Let L denote the monetary value of the punishment when no justification can be provided. L captures e.g. the officer's dis-utility of demotion or of being fired. Finally, when no justification can be provided, the procurement auction is canceled, a new tender is launched and firm α is excluded from it.[10]

Accountability is constrained by the fact that giving account and justifying all dimensions of a project is prohibitively costly for complex projects. To capture this feature, we assume that only one specification of the project can be challenged and justified at finite cost, normalized to zero. So, the public officer is challenged on one specification i of the announced project $\widehat{\mathbf{q}}$ and he has to justify it by providing adequate evidence that $\bar{q}_i = \widehat{q}_i$. In the basic model, if the announced project differs from the corresponding specification in the socially preferable project, i.e. if $\bar{q}_i \neq \widehat{q}_i$, there is proof of his misconduct while if $\bar{q}_i = \widehat{q}_i$, no such proof is established even though he may have distorted other specifications in the final project.

Absent any guidance, the citizen cannot distinguish among the various characteristics

[10] We do not specify the new tender, we only need to assume that firm β expects positive profits from the new tender procedure if firm α is excluded.

of a project nor describe them, so that she can only challenge one randomly drawn specification of the project, what we call *accountability based on random challenge* (abbreviated as RCA).

We investigate another procedure based on the possibility of letting the rival firm choose the specification of the project to be challenged. The idea is that since firms know each others' types, firm α's opponent knows which vector of specifications benefits firm α and therefore could be the outcome of corruption. Then, after the project $\widehat{\mathbf{q}}$ has been made public, firm β can provide guidance as to which specification of the project raises more suspicion than others with regards to the likelihood of corruption by firm α. Our *alert-based accountability* (hereafter ABA) procedure therefore relies on firm β recommending one specification of the project to be challenged after $\widehat{\mathbf{q}}$ is announced but before the procurement auction takes place.

Summary. At this point, it is worth summarizing the information and game structure.

1. The public officer learns $\overline{\mathbf{q}}$ privately. Firms in the industry learn the industry structure, i.e. $(\theta^\alpha, \theta^\beta)$.
2. The citizen commits publicly to an accountability procedure.
3. The public officer and firm α jointly design the project $\widehat{\mathbf{q}}$ that is announced under full information about $\overline{\mathbf{q}}$ and θ^α.
4. The announced accountability procedure is implemented.
5. If an adequate justification is provided, the tender proceeds with the announced project specification $\widehat{\mathbf{q}}$. Otherwise, a new tender is organized without firm α and the public officer is punished with a penalty L.

We close this section by discussing some of our assumptions. First, we focus on the formalization of projects as vectors of $\{0, 1\}^n$. n may naturally correspond to the dimension of the space of characteristics in a Lancaster (1966) approach. More precisely, we define a "unit" specification in relation with the justification process and we view it as a bunch of characteristics that are technically related and are justified jointly at no additional cost. With this perspective, n is exogenous and we rule out the possibility of manipulation of n by e.g. the public officer, a possibility that might be a concern in the RCA procedure in which the specification to be justified is drawn randomly with probability $1/n$. The discrete, and binary, characterization of each specification aims at capturing the coarseness of judgment by the citizen of the public officer's justification. Either the chosen specification passes the test of compatibility with the true one, i.e. it is close enough, and then the public officer can argue convincingly about it, or it does not, i.e. it is too different from the true one, and the public officer cannot justify it satisfactorily. We also assume that standard specifications are more likely than sophisticated ones, although it will become clear that we do not use this assumption in the core of the analysis.[11] Yet, it is a common practice to favor standardized solutions rather than sophisticated ones in public procurement under the presumption that it helps contain favoritism. In our analysis, this motive is absent because there is no way for the citizen to distinguish whether a specification is standard or sophisticated if the public officer does not provide a justification for it. And the accountability procedures we analyze are more powerful than a simple ban on sophisticated specifications, checked randomly. Favoring standardized solutions is also sometimes justified by a concern to promote competition to keep down public expenditure, as more firms might be able to achieve a more standard project. Here, we assume the set of competing contractors is fixed *a priori* so this issue does not appear.

Second, we emphasized that the basic model presented above relies on an assumption of perfect justification. This case is clearly extreme. We relax the assumption of perfect justification in section 6.1 where we consider the possibility of errors in the justification process. More precisely, we will consider that false positive and false negative are possible and we will look at the robustness of our results when the probability of false positive (i.e. signal mistakenly taken as a proof of misconduct) vanishes. So, when $\widehat{q}_i = \bar{q}_i$, we will assume that there is a probability ζ that the public officer is unable to prove that his choice was correct and when $\widehat{q}_i \neq \bar{q}_i$, there is a probability η that the public officer succeeds in convincing the citizen that his choice was correct. And we will let ζ go to 0.

Third, the ABA procedure, as described above, assumes that the citizen can identify firm α ex ante.[12] This is a simplifying assumption that enables us to present our results

[11] We do not even use the ε_i in the main analysis; they would play a role only in the quantitative characterization of the equilibrium strategies when corruption occurs.

[12] If the procedure is implemented after the tender has taken place, firm α can be identified as the winning firm. But this is not the most interesting case. Indeed, the ABA (and RCA) procedure should

more transparently. We show that our results are robust by relaxing this assumption in section 6.2, where we assume that it is common knowledge that one firm has connections with the public officer but the citizen cannot identify this firm ex ante. We therefore modify the ABA procedure by assuming that both firms send alerts and the citizen randomly chooses among these two alert signals which one to follow and therefore which specification to challenge.

4 Simple accountability procedures

This section introduces some technical notation and characterizes two benchmark cases namely, the no accountability and accountability based on random challenge.

Fix an industry structure $(\theta^\alpha, \theta^\beta)$. Given a project $\mathbf{q}$, firm α's profit in the auction is equal to $\sup\{\pi(\mathbf{q}), 0\}$ with $\pi(\mathbf{q}) \equiv C(\mathbf{q}, \theta^\beta) - C(\mathbf{q}, \theta^\alpha)$. It is immediate to see that $\max_{\mathbf{q}\in Q} \pi(\mathbf{q}) = \pi(\theta^\alpha)$.[13] If $\pi(\bar{\mathbf{q}})$ is maximal, i.e. equal to $\pi(\theta^\alpha)$, firm α has nothing to gain from engaging in corruption. Moreover, given the risk of punishment, there is no point in engaging in corruption if it leads to zero profits. So, when corruption occurs changing $\bar{\mathbf{q}}$ into $\widehat{\mathbf{q}}$, it must necessarily be the case that $\pi(\widehat{\mathbf{q}}) > 0$. Consequently, if firm α has no comparative advantage, i.e. if $\pi(\theta^\alpha) \leq 0$, there cannot be any corruption in equilibrium. So, from now on, we assume that the industry structure is such that $\pi(\theta^\alpha) > 0$.

For a given socially preferable project $\bar{\mathbf{q}}$, corruption by firm α may take the form of upgrades of some specifications i, so that $\bar{q}_i = 0$ and $\widehat{q}_i = 1$, or/and downgrades of some other specifications i, so that $\bar{q}_i = 1$ and $\widehat{q}_i = 0$. Given the risk of being caught, firm α engages in corruption to upgrade specification i only if this is strictly profitable i.e., only if $\theta_i^\alpha = 1$ and $\theta_i^\beta = 0$. For any project $\mathbf{q}$, let

$$S_u(\mathbf{q}) \equiv \left\{ j; q_j = \theta_j^\alpha = 1, \theta_j^\beta = 0 \right\}$$

denote the set of specifications that could be the outcome of an upgrade in the profile $\mathbf{q}$, and $s_u(\mathbf{q})$ its cardinal, given the industry structure. Similarly, firm α would engage in a

take place before the actual submission of bids, as this avoids the costly preparation of bids on a project that can be challenged.

[13]Note that any $\mathbf{q}$ that differs from θ^α on any characteristics i such that $\theta_i^\alpha = \theta_i^\beta$ also reaches this maximum.

downgrade of specification i only if $\theta_j^\alpha = 0$ and $\theta_j^\beta = 1$, and for any project $\mathbf{q}$, let

$$S_d(\mathbf{q}) \equiv \left\{ j; q_j = \theta_j^\alpha = 0, \theta_j^\beta = 1 \right\}$$

denote the set of specifications that could be the outcome of a downgrade in the profile $\mathbf{q}$, with cardinal $s_d(\mathbf{q})$, given an industry structure.

So, given an industry structure, the set of specifications that raise suspicion ex post in a project $\widehat{\mathbf{q}}$ is given by $S(\widehat{\mathbf{q}}) \equiv S_u(\widehat{\mathbf{q}}) \cup S_d(\widehat{\mathbf{q}})$, with cardinal $s(\widehat{\mathbf{q}}) \equiv s_u(\widehat{\mathbf{q}}) + s_d(\widehat{\mathbf{q}})$. Let $s_u^{max} = s_u(\theta^\alpha) = \max_{\mathbf{q}} s_u(\mathbf{q})$ and $s_d^{max} = s_d(\theta^\alpha) = \max_{\mathbf{q}} s_d(\mathbf{q})$.

Straightforward algebra yields the following result:

Lemma 1 *: For any* $\mathbf{q}$*, the following holds:* $\pi(\mathbf{q}) = c\left(s(\mathbf{q}) - s_d^{max}\right)$.

A given accountability procedure generates a probability of punishment and cancellation $P(\widehat{\mathbf{q}}, \bar{\mathbf{q}})$ when the socially preferable project is $\bar{\mathbf{q}}$ and the announced project is $\widehat{\mathbf{q}}$, with $P(\bar{\mathbf{q}}, \bar{\mathbf{q}}) = \mathbf{0}$ by definition. Firm α and the public officer design the final project $\widehat{\mathbf{q}}$ that maximizes their expected joint surplus taking into account this probability of being caught:

$$\pi(\widehat{\mathbf{q}})(1 - P(\widehat{\mathbf{q}}, \bar{\mathbf{q}})) - P(\widehat{\mathbf{q}}, \bar{\mathbf{q}})L. \tag{1}$$

In the no-accountability situation, corruption is never detected nor punished, $P(\widehat{\mathbf{q}}, \bar{\mathbf{q}}) = 0$, and in equilibrium the procurement auction bears on a project that best fits firm α's capacities, i.e. a project that maximizes $\pi(\widehat{\mathbf{q}})$ within the set of possible distortions. This immediately leads to the following Lemma:

Lemma 2 *(No accountability): In the absence of accountability procedure, there is corruption with probability* 1 *for all* $\bar{\mathbf{q}}$ *such that* $\pi(\bar{\mathbf{q}}) < \pi(\theta^\alpha)$*, all specifications* i *such that* $\bar{q}_i = \theta_i^\beta \neq \theta_i^\alpha$ *are distorted and the final project is always such that* $\pi(\widehat{\mathbf{q}}) = \pi(\theta^\alpha)$.

The lemma simply confirms that, absent accountability, corruption arises whenever it generates a strict gain in the procurement auction for firm α.

Let us now investigate the RCA procedure, i.e. the procedure that is based on the challenge of a specification randomly drawn within $\{1, 2, ..., n\}$ with probability $\frac{1}{n}$. Then, we obtain the following proposition.[14]

[14] Proofs are relegated in the Appendix.

Proposition 1 *(RCA): (a) Under RCA, if $L > (n-1)c$, there is no distortion in equilibrium, whatever the socially preferable specification $\bar{\mathbf{q}}$;*

(b) If $L < (n-1)c$, there exists some $\bar{\mathbf{q}}$ that is distorted with probability 1 in equilibrium;

(c) Moreover, in this last case, suppose $\bar{\mathbf{q}}_1$ and $\bar{\mathbf{q}}_2$ are such that $S(\bar{\mathbf{q}}_1) \subset S(\bar{\mathbf{q}}_2)$ strictly, then:

- *if $\pi(\bar{\mathbf{q}}_2) > \pi(\bar{\mathbf{q}}_1) \geq 0$ and there is corruption at $\bar{\mathbf{q}}_2$, then there is also corruption at $\bar{\mathbf{q}}_1$ in equilibrium*
- *and if $\pi(\bar{\mathbf{q}}_1) < \pi(\bar{\mathbf{q}}_2) \leq 0$ and there is corruption at $\bar{\mathbf{q}}_1$, then there is also corruption at $\bar{\mathbf{q}}_2$ in equilibrium.*

This proposition shows first that when $L > (n-1)c$ there is no corruption at all in equilibrium whatever the socially preferable project. Conversely, there always are states of nature, i.e. values of socially preferable project $\bar{\mathbf{q}}$, for which corruption occurs with probability 1 when $L < (n-1)c$. So, the threshold $L \lesseqgtr (n-1)c$ that determines whether there is corruption or not, depending on the industry structure, is tight. The key message here is obviously not that corruption does not occur for large punishments and occurs for low punishments, this is rather immediate; it is rather that the critical level of punishment is potentially large, of the same order as the complexity (dimensionality) of projects.[15]

The second and less intuitive message from the proposition is that, when $L < (n-1)c$, corruption is more prone to occur in situations in which firm α does not hold too strong an advantage in supplying the socially preferable project so that it would tie with firm β in the procurement auction without corruption. The intuition for this result runs as follows. Corruption induces a potential gain but it also induces a risk of losing the punishment plus the profit that would have been obtained without engaging in corruption. This no-corruption profit is measured by $\sup\{\pi(\bar{\mathbf{q}}); 0\}$. Therefore, whenever firm α holds a net technological advantage over its rival in supplying the socially preferable project, i.e. whenever $\pi(\bar{\mathbf{q}}) \geq 0$, the higher this technological advantage, the larger the loss from

[15] The tightness result depends on the specific cost structure in our model. Generalizing our model to allow for a cost $c_i^+ > 0$ to produce specification $q_i = 1$ when $\theta_i = 0$ and for a cost $c_i^- > 0$ to produce specification $q_i = 0$ when $\theta_i = 1$, there is in general no specification profile $\mathbf{q}$ such that $\pi(\mathbf{q}) = 0$. So, the result generalizes so that there exists L_c and L_d, with $L_c \leq L_d$, such that corruption is deterred in all equilibria whenever $L > L_d$ and there is corruption in all equilibria whenever $L < L_c$. L_c and L_d are of the order of magnitude of $(n-1)\max_{i \in S(\theta^\alpha)} c_i$ and the difference between L_c and L_d is of the order of magnitude of the highest possible value of $\pi(\bar{\mathbf{q}}_2) - \pi(\bar{\mathbf{q}}_1)$ when $\pi(\bar{\mathbf{q}}_1) \leq 0 \leq \pi(\bar{\mathbf{q}}_2)$ and $S(\bar{\mathbf{q}}_1) \subset S(\bar{\mathbf{q}}_2)$.

being caught in the corruption stage and therefore the less likely corruption. So, when L falls slightly below $(n-1)c$, corruption appears first for some states of nature such that $\pi(\bar{\mathbf{q}}) \leq 0$.

What if, absent corruption, firm α would lose the auction, i.e. if $\pi(\bar{\mathbf{q}}) < 0$? Engaging in corruption from a state of nature $\bar{\mathbf{q}}_1$, with $\pi(\bar{\mathbf{q}}_1) < 0$, so as to induce a strictly profitable profile $\widehat{\mathbf{q}}$ requires more distortions than at $\bar{\mathbf{q}}_2$ such that $S(\bar{\mathbf{q}}_1) \subset S(\bar{\mathbf{q}}_2) \subset S(\widehat{\mathbf{q}})$ and $\pi(\bar{\mathbf{q}}_2) = 0$, hence a higher probability of getting caught, while the default option, i.e. no corruption, yields the same null expected profit. Therefore, if corruption is prevented for any $\bar{\mathbf{q}}_2$ such that $\pi(\bar{\mathbf{q}}_2) = 0$, then it should also be prevented for any $\bar{\mathbf{q}}_1$ such that $\pi(\bar{\mathbf{q}}_1) < 0$ and conversely, if corruption occurs for some $\bar{\mathbf{q}}_1$ such that $\pi(\bar{\mathbf{q}}_1) < 0$, it should also occur for some $\bar{\mathbf{q}}_2$ such that $\pi(\bar{\mathbf{q}}_2) = 0$.

So, the states of nature in which firm α is the most likely to engage in corruption correspond to situations in which firm α has no net advantage over firm β and firm α would tie with firm β in the procurement auction. In other words, corruption is most difficult to fight when it involves distorting the project so as to make firm α win the procurement auction instead of tying, rather than when the issue is to increase its (already positive) winner's profit.

5 Alert-based accountability in the basic model

Given an industry structure $(\theta^\alpha, \theta^\beta)$ that is common knowledge among the two firms, the ABA procedure determines a Bayesian game to be played between them. Firm α privately knows the state of nature characterized by $\bar{\mathbf{q}}$ and its strategy maps any socially preferable project, $\bar{\mathbf{q}}$ into an announced project $\widehat{\mathbf{q}}$; it can either engage in corruption by upgrading some specifications and downgrading some others, or refrain from engaging in corruption. Firm β observes the announced project $\widehat{\mathbf{q}}$, forms posterior beliefs about $\bar{\mathbf{q}}$ given $\widehat{\mathbf{q}}$, and its strategy maps any announced project into a specification i to be flagged, i.e. which the public officer should justify.

It is intuitive that whenever corruption takes place, firm β has to play mixed strategies. If it were to select always one deterministic specification for any announced project $\widehat{\mathbf{q}}$, firm α would never engage in corruption by distorting this specification and firm β would be worse off than under a uniform random alert strategy, with which it would always have a positive probability of canceling the tender.

Consequently, we consider mixed (behavioral) strategies: let $\rho_i(\widehat{\mathbf{q}})$, for any $i \in S(\widehat{\mathbf{q}})$, denote the probability that firm β flags specification i when the final project is $\widehat{\mathbf{q}}$, with $\rho_i(\widehat{\mathbf{q}}) \geq 0$ and $\sum_{i \in S(\widehat{\mathbf{q}})} \rho_i(\widehat{\mathbf{q}}) = 1$ and let $p_i(\bar{\mathbf{q}})$, for any $i \in S(\theta^\alpha) \backslash S(\bar{\mathbf{q}})$, denote the probability that firm α chooses to engage in corruption and distort specification i, with $p_i(\bar{\mathbf{q}}) \geq 0$ so that $1 - \sum_{i \in S(\theta^\alpha) \backslash S(\bar{\mathbf{q}})} p_i(\bar{\mathbf{q}}) \geq 0$ is equal to the probability that firm α does not engage in corruption at $\bar{\mathbf{q}}$.

As can be expected, corruption is deterred under ABA whenever the penalty for being caught is large enough. The more interesting question is to characterize what "large enough "means and how it compares with the corresponding threshold under RCA.

Theorem 1 *(Complete deterrence under ABA): Assume $L > s_d^{max} c$; the equilibrium outcome under alert-based accountability is unique and corresponds to the no-corruption outcome whatever the socially preferable project* $\bar{\mathbf{q}}$.

The theorem provides a threshold on the magnitude of penalties that deter corruption in any state of nature: more precisely, for any penalty such that $L > s_d^{max} c$, there does not exist another equilibrium outcome than the no corruption outcome.

The threshold depends on the industry structure $(\theta^\alpha, \theta^\beta)$ through the number of specifications on which firm β has a competitive advantage over firm α. Note also that $s_d^{max} c = C(\theta^\beta, \theta^\alpha)$; that is, the corruption deterrence threshold corresponds to a value of the punishment that is equal to firm α's cost in realizing the project that best fits with firm β's technological capacities.[16] The smaller the number of specifications for which firm β has a competitive advantage over firm α, the easier it is to prevent corruption under ABA.

The extreme case corresponds to the situation in which firm α unambiguously dominates firm β is terms of technological advantages, so that $s_d^{max} = 0$; in this case, we have the following remarkable corollary.

Corollary 1 *(No corruption by a superior firm): When firm α is more technologically efficient that firm β, i.e. when $s_d^{max} = 0$, firm α never engages in corruption under ABA.*

[16] Generalizing our model to allow for a cost $c_i^+ > 0$ to produce specification $q_i = 1$ when $\theta_i = 0$ and for a cost $c_i^- > 0$ to produce specification $q_i = 0$ when $\theta_i = 1$, as has been discussed in footnote 15, the theorem extends with $C(\theta^\beta, \theta^\alpha)$ as the appropriate expression for the threshold for the corruption-deterring penalty.

To understand this result, consider a socially preferable project characterized by $s_u(\bar{\mathbf{q}}) \geq 0$. Firm α would earn $\pi(\bar{\mathbf{q}}) = s_u(\bar{\mathbf{q}})c$ if it does not try to manipulate the final project. If instead it distorts (upgrades) $k \geq 1$ specifications so as to increase its rival's cost by kc, it would generate a probability $\frac{k}{s_u(\bar{\mathbf{q}})+k}$ of being caught and would thus earn an expected payoff equal to:

$$(s_u(\bar{\mathbf{q}}) + k)c \times \{1 - \frac{k}{s_u(\bar{\mathbf{q}}) + k}\} - L \times \frac{k}{s_u(\bar{\mathbf{q}}) + k} = s_u(\bar{\mathbf{q}})c - \frac{kL}{s_u(\bar{\mathbf{q}}) + k},$$

which is smaller than the no-corruption payoff for any L and k. In other words, there is room for corruption under alert-based accountability only when firm α can dilute firm β's suspicion over both types of manipulations, i.e. upgrades and downgrades, i.e. both inducing sophisticated specifications that are favorable to firm α and avoiding sophisticated specifications that are favorable to its rival. When dilution of distortions among possible downgrades is impossible, the gains from distortion are wiped out by the increase in the probability of being caught.

The second remark concerns the comparison with the RCA procedure. The critical level of punishment that deters entirely corruption under ABA is lower than the corresponding level of punishment under RCA: given that $s_u^{max} > 0$ by assumption and $s_u^{max} + s_d^{max} \leq n$, it follows that $s_d^{max}c \leq (n-1)c$. It is potentially much lower when there is little differentiation in the industry as captured by the proportion of specifications over which firm β has a technological advantage over firm α. When this proportion s_d^{max}/n is small, firm α has limited possibilities of dilution of the upgrades it can induce and corruption is therefore more easily deterred. A crucial determinant of the efficiency of ABA is therefore related to the extent of differentiation in the industry as captured by the strength of the competitor compared to the complexity of projects involved. The stronger the competitor the more difficult it is to fully deter favoritism in project design.

The better performance of the ABA procedure comes obviously from the ability of firm β to exploit ex-post information about the set of specifications that raise suspicion in the announced project. Challenges can be concentrated on the subset of specifications that raise suspicion *ex post*, i.e. on $S(\widehat{\mathbf{q}})$. Indeed, if the verification procedure could be ex ante specified conditional on the announced project $\widehat{\mathbf{q}}$, a (uniformly distributed) random challenge procedure over $S(\widehat{\mathbf{q}})$ conditional on $\widehat{\mathbf{q}}$ being observed would deter corruption in all states of nature. Note that the proof of the theorem precisely exhibits an equilibrium that attain the no-corruption outcome such that $\rho_i(\widehat{\mathbf{q}}) = \frac{1}{s(\widehat{\mathbf{q}})}$ for $i \in S(\widehat{\mathbf{q}})$; this is precisely what an ex-ante specified random challenge procedure restricted on $S(\widehat{\mathbf{q}})$ would generate. So, ABA is equivalent to the possibility of committing ex ante on a contingent uniform verification procedure on $S(\widehat{\mathbf{q}})$ *as far as* we are concerned with completely wiping out the occurrence of corruption. The next result and the example section that follows show however that ABA performs differently from this contingent random verification procedure when $L < s_d^{max}c$. The critical argument in favor of ABA is that it does not rely on rather unrealistic assumptions about the citizen's ability to access and process information and her ability to commit on a sophisticated and potentially difficult-to-enforce mechanism conditional on the announced final project.

Assume now that the punishment is not large so that $L < s_d^{max}c$. We show that corruption necessarily takes place with positive probability so that the threshold $L \lesseqgtr s_d^{max}c$ that has been characterized in the previous theorem is actually "tight ". Moreover, we can characterize states of nature in which corruption occurs.

Theorem 2 *(Corruption onto firm α's preferred project under ABA): When $L < s_d^{max}c$, any announced project $\widehat{\mathbf{q}}$ such that $\pi(\widehat{\mathbf{q}}) = \pi(\theta^\alpha) = s_u^{max}c$ is the outcome of corruption with positive probability in any equilibrium under ABA.*

When penalties are not sufficient to completely wipe out corruption, Theorem 2 tells us that when the set of suspects is maximal so that $\pi(\widehat{\mathbf{q}}) = \pi(\theta^\alpha)$, there is necessarily corruption with positive probability in any equilibrium. Therefore, Theorem 2 confirms that the threshold $s_d^{max}c$ is indeed tight in the ABA procedure: when L is larger, there is no corruption in any equilibrium, while when L is smaller, there is some corruption in any equilibrium.[17]

Compared to the case of RCA, Theorem 2 also points toward a modification in the form of equilibrium strategies when there is corruption. Under ABA, as soon as $L < s_d^{max}c$, when the final project that is announced yields maximal profit to firm α, there is positive probability that there has been active corruption.[18] Therefore, corruption

[17]In the generalized setting sketched in footnote 15, the theorem extends with the threshold $C(\theta^\beta, \theta^\alpha)$ provided that $\pi(\theta^\alpha) > max_{i \in S(\theta^\alpha)} c_i$, which guarantees in the proof developed in the Appendix that $\pi(\bar{\mathbf{q}}^i) \geq 0$. If this condition is not met, the tightness property of the threshold disappears and there is a lower threshold $L_c^* < C(\theta^\beta, \theta^\alpha)$ under which corruption takes place in any equilibrium.

[18]Of course, there is a positive probability that it corresponds to the socially preferable project, in which case firm α need not engage in corruption at all.

becomes an issue under ABA not so as to enable firm α to win the tender, as opposed to a tie, but rather so as to induce a perfect fit of the final project with firm α technological abilities.

Given the complexity of the game induced by alert-based accountability in general, we are not able to characterize more precise properties of equilibrium strategies in the general setting when $L < s_d^{max} c$. So, in section 7, we develop an example with a specific industry structure and we characterize several types of corruption equilibria in this simplified setting.

6 Extensions

6.1 Almost perfect justification

We first investigate the robustness of our results with respect to the assumption that the public officer can perfectly justify his choice of project. So, in this subsection only, we assume that:

- when the specification i has not been distorted, i.e. $\widehat{q}_i = \bar{q}_i$, and the public officer is required to justify specification i, he can do so successfully with probability $1 - \zeta$ and he fails to do so with probability ζ; false positive signals of misconduct may exist.

- And when the specification i has been distorted, i.e. $\widehat{q}_i \neq \bar{q}_i$, and the public officer is required to justify specification i, he fails to do so with probability $1 - \eta$ but he succeeds in convincing the citizen that his choice was correct with probability η; false negative signals, i.e. the absence of a proof of misconduct, can also occur.

In this framework, under either RCA or ABA, the public officer may not be able to justify convincingly specification i while in fact corruption did not take place. Canceling the initial auction, and organizing a new auction after excluding firm α may then be a mistake from the citizen's point of view. Yet, if the probability of mistakes is small enough, it seems reasonable to stick to this rule absent any additional information. This is the approach that we follow in this section: we will investigate situations in which false negatives may happen with non-negligeable probability while the probability of false positives tends to 0 (ζ goes to 0).[19] Then, it is immediate to compute the expected profit of firm α when it engages in corruption under each accountability procedure.

Under the RCA procedure, consider a distortion from $\bar{\mathbf{q}}$ to $\widehat{\mathbf{q}}$ that consists in s specifications being modified. The expected value of this distortion is given by

$$(1-\phi(\frac{s}{n}))\pi(\widehat{\mathbf{q}})-\phi(\frac{s}{n})L,$$

where, for any integer s between 1 and n, $\phi(\frac{s}{n}) \equiv (1-\frac{s}{n})\zeta + \frac{s}{n}(1-\eta)$ and $\phi(\frac{s}{n})$ tends to $\frac{s}{n}(1-\eta)$ when ζ goes to 0. With this modification, it is immediate to adapt the proof of Proposition 1 and to obtain the following extension of this proposition:[20]

Proposition 2 *(RCA with almost perfect justification): Under RCA, if* $L > (\frac{n}{1-\eta}-1)c$, *there is no distortion in equilibrium whatever the socially preferable specification* $\bar{\mathbf{q}}$ *when* ζ *is small enough; and if* $L < (\frac{n}{1-\eta}-1)c$ *and for* ζ *small enough, there exists some* $\bar{\mathbf{q}}$ *that is distorted with probability* 1 *in equilibrium.*

Similarly, under the ABA procedure, the expected value of a distortion from $\bar{\mathbf{q}}$ to $\widehat{\mathbf{q}}$ is given by:

$$\left(1-\psi\left(\sum\nolimits_{i\in S(\widehat{\mathbf{q}})\backslash S(\bar{\mathbf{q}})}\rho_i\right)\right)\pi(\widehat{\mathbf{q}})-\psi\left(\sum\nolimits_{i\in S(\widehat{\mathbf{q}})\backslash S(\bar{\mathbf{q}})}\rho_i\right)L, \tag{2}$$

where for any $\rho \in [0,1]$, $\psi(\rho) \equiv [\zeta + (1-\zeta-\eta)\rho]$ tends to $(1-\eta)\rho$ when ζ goes to 0. Again, using this modification, one can adapt the proofs of Theorem 1 and Theorem 2 and obtain the following extension of these results:[21]

Theorem 3 *(ABA with almost perfect justification): Under ABA, if* $L > \frac{s_d^{max}+\eta s_u^{max}}{1-\eta}c$, *the unique equilibrium outcome is the no corruption outcome whatever the socially preferable specification* $\bar{\mathbf{q}}$ *when* ζ *is small enough; and if* $L < \frac{s_d^{max}+\eta s_u^{max}}{1-\eta}c$ *and for* ζ *small enough,*

[19]**See section 2 for a justification of this asymmetry.**

[20]The proof is a replication of the proof of Proposition 1 using the fact that there is a finite number of possible project profiles and the expected value of the distortion from $\bar{\mathbf{q}}$ to $\widehat{\mathbf{q}}$ can be written alternatively as: $\pi(\bar{\mathbf{q}})+\phi(\frac{s}{n})\left[\left(\frac{s}{\phi(\frac{s}{n})}-s\right)c-(\pi(\bar{\mathbf{q}})+L)\right]$.

[21]The proof is a replication of the proofs of both theorems using the fact that there is a finite number of possible project profiles and using $\psi\left(\sum_{i\in S(\widehat{\mathbf{q}})\backslash S(\bar{\mathbf{q}})}\rho_i\right)$ instead of $\sum_{i\in S(\widehat{\mathbf{q}})\backslash S(\bar{\mathbf{q}})}\rho_i$ in the various proofs, as suggested in (2). Note, in particular, that for the uniform alert strategy over $S(\widehat{\mathbf{q}})$, i.e. $\rho_i(\widehat{\mathbf{q}}) = \frac{1}{s(\widehat{\mathbf{q}})}$ (cf the proof of Theorem 1), the expected value of the distortion from $\bar{\mathbf{q}}$ to $\widehat{\mathbf{q}}$ can be written alternatively as: $\pi(\bar{\mathbf{q}})+(\frac{s(\widehat{\mathbf{q}})-s(\bar{\mathbf{q}})}{s(\widehat{\mathbf{q}})})s(\widehat{\mathbf{q}})c-\psi\left(\frac{s(\widehat{\mathbf{q}})-s(\bar{\mathbf{q}})}{s(\widehat{\mathbf{q}})}\right))(\pi(\widehat{\mathbf{q}})+L)$.

any announced project $\widehat{\mathbf{q}}$ *such that* $\pi(\widehat{\mathbf{q}}) = s_u^{max}c$ *is the outcome of corruption with positive probability in equilibrium.*

These results show that our characterization of the thresholds for corruption deterrence under both accountability procedures and of their relative properties is qualitatively robust to the introduction of some imperfection in the way the public officer is able to justify his choices. The critical level of punishment under the RCA procedure is again of the same order as n, the complexity measure of the projects, while the critical level of punishment under the ABA procedure is related to the industry structure, as captured by s_d^{max} and, here, s_u^{max}.[22] The level of punishment necessary to deter corruption may then be much lower with the ABA procedure.

6.2 Ex ante symmetric contractors

In the basic model, we have assumed that, because of the history in the industry, the identity of the potentially bribing firm, firm α, is common knowledge. In this subsection, we instead assume that firm α (the firm with appropriate connections with the public officer that enable it to engage in corruption with the public officer) cannot be identified ex-ante by the citizen. The citizen knows that one firm has connections with the public officer but both private contractors are perfectly symmetric ex ante for the design of the accountability procedure.

The consequence of this symmetry is that accountability procedures have to be modified so that they do not rely on information about who firm α is. The RCA procedure is inherently symmetric in the determination of the specification that is challenged, but the basic model assumes that firm α is excluded if corruption is detected, which is not implementable with symmetric and non-distinguishable firms. So, we need to specify more precisely what occurs after corruption is detected. An appropriate mechanism design approach would have to rely on an explicit formalization of social welfare objectives, which is not the route we have followed. So, we stick with our approach of investigating the corruption deterrence performances of a given procedure.

Suppose that if corruption is detected because a socially preferable project is $\bar{\mathbf{q}}$ has been distorted into an announced project $\widehat{\mathbf{q}}$ (with s specification distortions), the contin-

[22] s_d^{max} and s_u^{max} are defined on p.15. They are the maximum (over projects) sets of specifications that raise suspicion of downgrades respectively upgrades.

uation scenario is such that firm α has an expected profit equal to $u(\bar{\mathbf{q}}, \widehat{\mathbf{q}})$. Then, when considering whether to engage in corruption, firm α compares the following expected profit :

$$(1 - \frac{s}{n})\pi(\widehat{\mathbf{q}}) + \frac{s}{n}(u(\bar{\mathbf{q}}, \widehat{\mathbf{q}}) - L),$$

with $\pi(\bar{\mathbf{q}})$, the profit from refraining from doing so. On top of this penalty L, the most stringent punishment for corruption consists in canceling the whole procurement altogether: in this case, firm α would face the same incentives as in the basic model, since then $u(\bar{\mathbf{q}}, \widehat{\mathbf{q}}) = 0$ for any $\bar{\mathbf{q}}$ and $\widehat{\mathbf{q}}$, and Proposition 1 remains valid.[23]

Admittedly, a complete cancellation of procurement is extreme. With no outside sources, the social cost may be very large if the project is highly socially valuable. Considering less extreme forms of punishment following corruption the expression above shows that: the milder the punishment (i.e. the higher $u(\bar{\mathbf{q}}, \widehat{\mathbf{q}})$), the weaker firm α's incentives to refrain from corruption for a given penalty L. A very mild procedure would be to rerun the auction with the same two contractors for a project $\widehat{\mathbf{q}}'$ that differs from $\widehat{\mathbf{q}}$ by simply correcting the specification that has been found distorted in $\widehat{\mathbf{q}}$. Deterring completely corruption would then require a very large penalty L. An intermediate procedure would randomize, with equal probability, the choice of one of the firm to be excluded and then rerun the auction. These scenarios would necessitate a precise description of the continuation mechanism and in the end, they would deliver a threshold for complete corruption deterrence that would be larger than the one that can be characterized with complete canceling of procurement. We have decided not to follow this route: since our objective is mostly to analyze ABA and RCA simply constitutes a benchmark, we consider the procedure that, under random challenges, has the highest possible power for firm α, i.e. the complete cancellation procedure after corruption has been detected.

The problem is different with adapting the ABA procedure. ABA is asymmetric in its design in the basic model, as it relies on an alert sent by firm β. We modify the procedure by allowing both firms to send alerts after $\widehat{\mathbf{q}}$ is announced, and the citizen randomizes equally between the two firms' challenges when choosing whose alert to follow. If, following the alert sent by firm i, corruption is detected, then the auction is canceled, firm $j \neq i$ is excluded and the auction is rerun with only firm i. The randomization

[23]Note that in this scenario, firm β would face only weak incentives to send a appropriate flag as it would get zero profit anyway.

then bears on whose alert to follow, which implicitly determines which firm's potential misbehavior is checked; this avoids drawing randomly which firm to exclude or completely canceling procurement, as in the modified RCA procedure.[24]

With the modified ABA procedure, the expected value of a distortion from $\bar{\mathbf{q}}$ to $\widehat{\mathbf{q}}$ is given by:

$$\left(1 - \frac{1}{2}\sum\nolimits_{i \in S(\widehat{\mathbf{q}}) \setminus S(\bar{\mathbf{q}})} \rho_i\right) \pi(\widehat{\mathbf{q}}) - \frac{1}{2}\left(\sum\nolimits_{i \in S(\widehat{\mathbf{q}}) \setminus S(\bar{\mathbf{q}})} \rho_i\right) L. \quad (3)$$

Then, we obtain easily the following generalization of Theorem 1 and Theorem 2:

Theorem 4 *(ABA with ex ante symmetric firms): If* $L > (s_u^{\max} + 2s_d^{max})\, c$*, the equilibrium outcome under alert-based accountability played with ex-ante symmetric firms is unique and corresponds to the no-corruption outcome whatever the socially preferable project* $\bar{\mathbf{q}}$*; and if* $L < (s_u^{\max} + 2s_d^{max})\, c$*, any announced project* $\widehat{\mathbf{q}}$ *such that* $\pi(\widehat{\mathbf{q}}) = s_u^{max} c$ *is the outcome of corruption with positive probability in any equilibrium under ABA.*

Unsurprisingly, we find that the minimal punishment is larger when firm α cannot be identified compared to the results in the previous sections. This is because firm α only gets caught with half of the probability compared to the situation addressed in Theorem 1. More interestingly, the determinant of the punishment that fully deters corruption depends only on the market structure as before and remains disconnected from the complexity (dimensionality) of the project. A difference, however, is that firm α's comparative advantage also matters. As a consequence and in contrast with the previous results, we can have corruption even when firm β has no comparative advantage. The randomization between alerts lowers the detection risk and breaks the symmetry between expected gains and expected losses of a marginal distortion. This explains why corruption can be worthwhile even when firm α cannot dilute the risk of detection over the two types of distortions. As a consequence, the threshold value for L is a function of $s_u^{\max}$ as well.

6.3 Alternative market structures

In this subsection, we will briefly and informally discuss two other possible extensions of the basic model, that we have not developed so far.

The first extension to be discussed is a natural continuation of the previous subsection. Suppose that both firms are ex ante symmetric and both have a long history of interaction

[24] Note that here, firm β's incentives are strict.

with the public officer so that both contractors would be able to engage in corruption. In other words, our model so far has focused on a monopolistic access to the public officer at the corruption stage and it would then be natural to analyze a model of (duopolistic) competition in corruption.

Even a simple model of this situation would require many more details than our basic model so far: the split of the corruption rent between the public officer and the bribing firm would have to be made explicit in order to determine which firm wins the race for corruption, the scenario after corruption with one contractor is detected would have to be made more explicit so as to avoid new issues of corruption at the rerun stage, the information structure along with the competition game (or the negotiation game) should be made explicit as well.[25] Fighting corruption when there is competition in bribery in complex procurement auctions is then left for future work.

The second extension concerns the number of (non-connected) firms in the basic model. It would be natural to assume that there are say p contractors, say β_1, β_2, ..., β_p, that are not connected with the public officer and that would compete in the procurement auction with firm α. Describing the extended game raises no difficulty but analyzing it is difficult because Lemma 1 ceases to be true. The reason is that several competitors to firm α may determine the second lowest cost of implementing a project because of different comparative advantages on different specifications. Therefore, distorting a specification that increases the cost of one of these immediate rivals may not be sufficient to increase firm α's profit in the auction, as another immediate rival may share the same ability as firm α on this dimension.[26] It follows also from this remark that there is a structure on the set of possible equilibrium distortions, which therefore impacts the equilibrium flagging strategies. We have not been able to solve these difficulties so as to extend our model in this direction.

7 An illustrative example

Given the complexity of the game induced by alert-based accountability in general, we develop in this section a simple example in which it is possible to characterize several

[25] See Compte - Lambert-Mogiliansky - Verdier (2005) for a model of competition in corruption.

[26] As an example, suppose $\theta^{\alpha} = (1,1), \theta^{\beta_1} = (1,0)$ and $\theta^{\beta_2} = (0,1)$. If $\bar{\mathbf{q}} = (0,0)$, there is no way for firm α to earn an expected positive profit from distorting one specification only; the only type of corruption that is worth considering is to distort both specifications.

types of corruption equilibria and associated strategies.

The specific setting. Let us normalize $c = 1$ and assume that the project under consideration has many dimensions, $n > 3$, but the firms differ in their technological ability only with respect to 3 specifications, say $i = 1, 2, 3$; so, when describing a project, we will only write down the first 3 specifications. Assume also that $\varepsilon_i = \varepsilon$ for all i. We shall focus on the following industrial structure: $\theta^{\alpha} = (1, 1, 0, ...)$ and $\theta^{\beta} = (0, 0, 1, ...)$, so that firm α's highest possible gain from winning the project is $\pi(\theta^{\alpha}) = 2$ which obtains when its specification mirrors firm α's technology (at least on the 3 first dimensions). Finally, it is common knowledge that firm α has connections with the public officer that enable it to engage in corruption.

Random challenge accountability. With RCA, Proposition 1 shows that if $L > n-1$, there cannot be any corruption in equilibrium, while if $L < n-1$, there is a strict expected gain in engaging in corruption for firm α in at least one state of nature $\bar{\mathbf{q}}$ and the largest risk of corruption is found in states $\bar{\mathbf{q}}$ such that $\pi(\bar{\mathbf{q}}) = 0$. More precisely, the following claim holds:

Claim 1 : *For L such that $n-1 > L > \sup\{n-2; \frac{2n}{3}-2\}$ corruption occurs in equilibrium for states of nature $\bar{\mathbf{q}}$ such that $\pi(\bar{\mathbf{q}}) = 0$ but not for $\bar{\mathbf{q}}$ such that $\pi(\bar{\mathbf{q}}) \in \{-1, 1\}$*

When $\pi(\bar{q}) = 0$, firm α has an incentive to distort one specification to its advantage so that $\pi(\widehat{\mathbf{q}}) = 1$. This shows that with RCA the most severe risk of corruption arises when firm α would tie with its rival in the procurement auction and thus earn zero profit. Corruption, in that interval of values for L, amounts to securing a win while incurring the smallest risk of detection. This means that with RCA the most serious risk of favoritism arises when the allocation outcome, i.e. which firm wins, is at stake rather than when favoritism brings about larger profit.

Alert based accountability. First, note that firm β will concentrate its alert strategy on possible suspects $i \in \{1, 2, 3\}$. Given the symmetric structure of the model, we will w.l.o.g. focus on an alert strategy for firm β that is symmetric *within* the set of suspect upgrades, i.e. between $i = 1$ and $i = 2$ when there are both suspects, and that is symmetric among all non-suspect specifications. As a consequence, a strategy for firm β is fully described by $\rho(\widehat{\mathbf{q}})$, the probability for flagging the set of suspect upgrades $\{1, 2\}$, the complementary probability applies to the only suspect downgrade $\{3\}$.

As an illustration of Theorem 1 and 2, whenever $L > 1$ there is no corruption in equilibrium, because here $s_d^{max} = 1$ (and $s_u^{max} = 2$) while whenever $L < 1$, there is corruption in any equilibrium. The critical value $L^* = 1$ for corruption deterrence is tight: it is smallest penalty that ensures a corruption-free environment. This threshold is much lower than in the case of RCA, in particular when the dimensionality of projects is high.

We now go a bit further than the general analysis of the previous sections by showing first that when $L < 1$, corruption exhibits an interesting pattern.

Claim 2 *: When $L < 1$, the following constitutes an equilibrium under ABA. Let $k = \frac{\varepsilon^2}{(1-\varepsilon)^2}$;*

- *firm α acts as follows:*
  - *if $\bar{\mathbf{q}} = (1, 1, 1, ...)$ or $\bar{\mathbf{q}} = (1, 0, 1, ...)$ or $\bar{\mathbf{q}} = (0, 1, 1, ...)$, it engages in corruption with $\widehat{\mathbf{q}} = \theta^\alpha$; (To be precise, $\widehat{\mathbf{q}}$ may differ from θ^α in all other dimensions but the 3 first ones; we neglect this to simplify the writing.)*
  - *if $\bar{\mathbf{q}} = (1, 0, 1, ...)$ or $\bar{\mathbf{q}} = (0, 1, 1, ...)$ or $\bar{\mathbf{q}} = (0, 0, 0, ...)$, it engages in corruption with probability k to $\widehat{\mathbf{q}} = \theta^\alpha$, and refrains from corruption, so that $\widehat{\mathbf{q}} = \bar{\mathbf{q}}$, with probability $1 - k$;*
  - *it refrains from corruption in other states of nature.*
- *Firm β follows an alert strategy with $\rho_1 = \frac{1}{1+L}$ and $\rho_2 = \frac{2}{2+L}$ (beliefs are specified in the proof).*

Compared to RCA, ABA does not only lower the critical penalty that ensures a corruption-free environment, it also changes the nature of corruption whenever it occurs, i.e. when L is small. Under ABA, when L is slightly below the critical level, corruption may take place in various states of nature, some of them such that firm α already enjoys a strong advantage compared to firm β. Moreover, in such states of nature, corruption may take place with a probability strictly smaller than 1. In equilibrium the extent of favoritism reflects the asymmetry in the occurrence of $\overline{q}_i = 1$ and $\overline{q}_i = 0$. The smaller ε the smaller the extent of equilibrium corruption in those states.

Suppose that the projects are of high dimensionality, n is large, and assume that $L < 1$. Under RCA, the proof of the first claim shows that in all states of nature, corruption occurs with probability 1 resulting in a project $\widehat{\mathbf{q}}; \pi(\widehat{\mathbf{q}}) = \pi(\theta^\alpha)$. Under alert-based accountability, the proposed equilibrium shows that corruption does not occur with probability 1 for all states of nature in equilibrium. In particular, in states of nature such that $\bar{q}_3 = 0$ that require firm α to upgrade specification $i = 1$ or $i = 2$ from $\bar{q}_i = 0$ to $\widehat{q}_i = 1$, or both. The reason is that observing some $\widehat{q}_i = 1$, for $i = 1$ or 2, raises suspicion much more strongly than observing $\widehat{q}_3 = 0$ for firm β as sophisticated specifications are less likely than standard ones in the socially preferable project. Therefore, such $\widehat{q}_i = 1$ is flagged more often than $\widehat{q}_3 = 0$, to the point that firm α is indifferent between inducing these upgrades or not. Of course, by the same token, firm α always downgrades specification $i = 3$ with probability 1 whenever this is relevant. This finding suggests that under alert-based accountability, downgrades are more likely to occur than upgrades. This reflects our assumption about social preferences: standardized specifications are more likely than sophisticated ones in the socially preferable projects.

The previous equilibrium is by no means unique. Indeed, the game played under ABA is complex and multiple equilibria exist in general. To illustrate, in the following claim, we exhibit *partial corruption* equilibria, where corruption does not lead to maximal profit, i.e. does not lead to $\widehat{\mathbf{q}}; \pi(\widehat{\mathbf{q}}) = \pi(\theta^\alpha)$.

Claim 3 : *The alert strategy for firm β characterized in the previous claim and the following class of corruption strategies for firm α constitute equilibria under alert-based accountability:*

- *if $\bar{\mathbf{q}} = (1, 1, 1, ...)$, engage in corruption with $\widehat{\mathbf{q}} = \theta^\alpha$;*
- *if $\bar{\mathbf{q}} = (1, 0, 0, ...)$ or $\bar{\mathbf{q}} = (0, 1, 0, ...)$, engage in corruption with probability $r \in [0, 1]$ to $\widehat{\mathbf{q}} = \theta^\alpha$, and refrain from corruption, so that $\widehat{\mathbf{q}} = \bar{\mathbf{q}}$, with probability $1 - r$;*
- *if $\bar{\mathbf{q}} = (1, 0, 1, ...)$, engage in corruption with probability $v \in [0, 1]$ to $\widehat{\mathbf{q}} = (1, 0, 0, ...)$ and with probability $1 - v$ to $\widehat{\mathbf{q}} = \theta^\alpha$; similarly for $\bar{\mathbf{q}} = (0, 1, 1, ...)$, $\widehat{\mathbf{q}} = (0, 1, 0, ...)$ with probability v and $\widehat{\mathbf{q}} = \theta^\alpha$ with probability $1 - v$;*
- *if $\bar{\mathbf{q}} = (0, 0, 0, ...)$, engage in corruption to $\widehat{\mathbf{q}} = \theta^\alpha$ with probability $s \geq 0$, to $\widehat{\mathbf{q}} = (1, 0, 0, ...)$ with probability $t \geq 0$, to $\widehat{\mathbf{q}} = (0, 1, 0, ...)$ with probability t and refrain from corruption with probability $1 - s - 2t \geq 0$.*

In this more general class of equilibria,[27] corruption does not necessarily mean maximal corruption, i.e. corruption so as to induce $\widehat{\mathbf{q}} = (1, 1, 0, ...)$. Corruption may also induce $\widehat{\mathbf{q}} = (1, 0, 0, ...)$ or $\widehat{\mathbf{q}} = (0, 1, 0, ...)$ with positive probability, i.e. as partial corruption. So, this is another way by which alert-based accountability helps curb corruption problems: it may reduce the scope of corruption. Note also that in these cases of partial corruption, the announced project may be less sophisticated than the socially preferable project, which goes a bit against arguments that can be heard in the public debate about the fact that favoritism implies inflated sophistication and a good way to curb favoritism is to prohibit sophistication as much as possible.

8 Conclusion

The model we have investigated is characterized by central and, we have argued, most relevant features of procurement situations:

- citizens cannot easily design complex projects or mechanisms ex ante, they are unable to assess the relevance of the specifications of a project and they have limited resources in checking them out ex post;
- public officers have some technical knowledge and expertise about the community's needs. They work under administrative rules with limited monetary incentives so that they are not incentivized to use their knowledge and expertise in the socially preferable manner;
- through their use of the technology and their market interactions, firms know each others much better than public authorities do.

Given these key ingredients and several restrictive assumptions that we have discussed, we analyze the corruption deterrence properties of accountability procedures that require justifying either one randomly drawn specification of the project (under the random challenge procedure) or one specification on which the non-corrupt firm has sent a red flag (under the alert-based procedure). Our results strongly underline the value of relying on all competing firms in accountability procedures in the context of a complex procurement auction. Because the competitor has incentives to challenge a procurement decision that

[27] The equilibrium that we discussed extensively above is such that $s = r = k^2$ and $t = v = 0$.

leaves him aside and because he has better information than the citizens, he can more efficiently target the request for justification than the citizen. As a consequence full corruption deterrence becomes feasible under alert-based accountability at a level of penalty which is much lower than under random challenges and unrelated to the complexity of the project. Instead, it depends on the industry profile. When firms are close competitors so they differ over a small number of dimensions full deterrence is achieved at minimal cost. And if the competitor has no comparative advantage, corruption is deterred by the mere prospect of losing the auction if detected, no penalty is needed.

The analysis also shows that when corruption does occur under alert based accountability (because the penalty is too small), patterns of equilibrium behavior emerge that are quite different from the ones induced by accountability based on random challenges. First while the risk of corruption is most severe when the allocation of the project is at stake under random challenge, with an alert-based mechanism there is a risk even when the firm already has a solid advantage. Second, while corruption is a 0/1 phenomenon (for each state of nature) under random challenges, it may occur with a probability that is positive but less than one under the alert-based mechanism; therefore, corruption yields no expected gain for the bribing firm given that the rival's equilibrium behavior. More generally, favoritism under the alert-based mechanism does not always lead to maximal profit for the corrupt firm. The specific patterns of corruption under the alert-based mechanism are closely related to the asymmetry between standard and sophisticated specifications. Finally, multiple equilibria emerge naturally when accountability is based on alerts by the competitor.

We have discussed a few critical assumptions on which our results rely. Arguably, our model of the corruption stage is quite special. First, competition may unravel to the corruption stage and there could be some competitive corruption game among firms to become the bribing firm. Although the point is valid, we think it is appropriate to work out the case of monopoly in corruption as a first step. Second, it may be more relevant to suppose that negotiations between the public officer and the bribing firm take place under bilateral asymmetric information, the firm not knowing the socially preferable set of specifications and the public officer not knowing the firm's technological advantages. This information structure plus the fact that these negotiations must be secret and that monetary transfers may be largely hindered should lead to an inefficient outcome for the two parties. Our choice of a game that leads to an efficient agreement for the colluding parties aims at giving the best chances to favoritism, thereby providing a "conservative "picture of what can be achieved in terms of corruption deterrence by the alert-based accountability procedure. Third, the challenge technology and the costs attached to it ultimately imply that the problem boils down to the choice of one characteristics to verify and there are no errors in the verification process. The possibility of verifying a larger, but fixed-size sample of characteristics is not critical. The possibility of errors weakens the deterrence power of the studied accountability procedures. However, our results are robust to the introduction of some imperfection in the verification technology. Finally, a distinguishing feature of the proposed mechanism is that its cost is low, to the public official in particular, compared with a judicial procedure and therefore less prone to abuse to harass the public official.

To conclude, we have analyzed the properties of new accountability procedures that build on existing practice and complement them with enforcement means. Even though these procedures rely on strong modeling assumptions, they exploit the knowledge of industry participants and this is a feature that seems worth developing and that is already present in existing institutional frameworks.

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Appendix

Proof of Proposition 1

(a) If $\bar{\mathbf{q}}$ is distorted into $\widehat{\mathbf{q}}$, there exists $S \subseteq S(\widehat{\mathbf{q}})$ non empty, with cardinal $s \geq 1$, such that $S(\widehat{\mathbf{q}}) = S \cup S(\bar{\mathbf{q}})$, that corresponds to the set of all specifications that are distorted. The expected value of distorting $\bar{\mathbf{q}}$ into $\widehat{\mathbf{q}}$ is thus equal to: $\pi(\widehat{\mathbf{q}})\left[1-\frac{s}{n}\right]-\frac{s}{n}L$. Using the fact that $\pi(\widehat{\mathbf{q}}) = \pi(\bar{\mathbf{q}}) + (s(\widehat{\mathbf{q}}) - s(\bar{\mathbf{q}}))c$, this expected value can be written as:

$$\pi(\bar{\mathbf{q}}) + sc - \frac{s}{n}\left[\pi(\bar{\mathbf{q}}) + sc + L\right] = \pi(\bar{\mathbf{q}}) + \frac{s}{n}\left[(n-s)c - (\pi(\bar{\mathbf{q}}) + L)\right]. \tag{4}$$

If $L > (n-1)c$, then for any $\bar{\mathbf{q}}$ such that $\pi(\bar{\mathbf{q}}) \geq 0$ and any $s \geq 1$,

$$\pi(\bar{\mathbf{q}}) + L > (n-1)c \geq (n-s)c.$$

It follows that the expected value of the distortion from $\bar{\mathbf{q}}$ to $\widehat{\mathbf{q}}$ is smaller than $\pi(\bar{\mathbf{q}})$, the value of not engaging in distortion, and firm α prefers not to engage in corruption.

Rewrite the expected value of distorting $\bar{\mathbf{q}}$ into $\widehat{\mathbf{q}}$ in (4) as: $(1-\frac{s}{n})\pi(\bar{\mathbf{q}})+\frac{s}{n}\left[(n-s)c - L\right]$. Then, if $L > (n-1)c$, *a fortiori* $L > (n-s)c$ for any $s \geq 1$ and then, for any $\bar{\mathbf{q}}$ such that $\pi(\bar{\mathbf{q}}) < 0$, the expected value of the distortion from $\bar{\mathbf{q}}$ to $\widehat{\mathbf{q}}$ is negative and, again, firm α prefers not to engage in corruption.

So, if $L > (n-1)c$, there cannot be any corruption in equilibrium.

(b) Suppose now that $L < (n-1)c$ and consider a socially preferable project $\bar{\mathbf{q}}$ such that $\pi(\bar{\mathbf{q}}) = 0$. Using (4), it comes that at such a profile, firm α is strictly better off making one distortion within $S(\theta^\alpha)\backslash S(\bar{\mathbf{q}})$ than refraining from engaging in corruption. Therefore, there is necessarily corruption in equilibrium at such socially preferable project.

(c) Assume here that: $L < (n-1)c$. Consider $\bar{\mathbf{q}}_1$ and $\bar{\mathbf{q}}_2$ such that $S(\bar{\mathbf{q}}_1) \subset S(\bar{\mathbf{q}}_2)$ strictly. Suppose first that there is corruption in equilibrium at $\bar{\mathbf{q}}_2$ and $0 \leq \pi(\bar{\mathbf{q}}_1) < \pi(\bar{\mathbf{q}}_2)$. Then, there exists some $\widehat{\mathbf{q}}$ such that

$$\pi(\widehat{\mathbf{q}}) - \frac{(s(\widehat{\mathbf{q}}) - s(\bar{\mathbf{q}}_2))}{s(\widehat{\mathbf{q}})}\left[\pi(\widehat{\mathbf{q}}) + L\right] \geq \pi(\bar{\mathbf{q}}_2),$$

that is, using (4): $(n - s(\bar{\mathbf{q}}_2))c \geq (\pi(s(\bar{\mathbf{q}}_2)) + L)$. Since $s(\bar{\mathbf{q}}_2) > s(\bar{\mathbf{q}}_1)$ and $\pi(\bar{\mathbf{q}}_1) < \pi(\bar{\mathbf{q}}_2)$, it follows that: $(n - s(\bar{\mathbf{q}}_1))c > (\pi(s(\bar{\mathbf{q}}_1)) + L)$. So, there must be corruption at $\bar{\mathbf{q}}_1$.

Suppose then that there is corruption in equilibrium at $\bar{\mathbf{q}}_1$ and $\pi(\bar{\mathbf{q}}_1) < \pi(\bar{\mathbf{q}}_2) \leq 0$. Then, there exists some $\widehat{\mathbf{q}}$ such that

$$\pi(\widehat{\mathbf{q}}) - \frac{(s(\widehat{\mathbf{q}}) - s(\bar{\mathbf{q}}_1))}{s(\widehat{\mathbf{q}})}[\pi(\widehat{\mathbf{q}}) + L] \geq 0,$$

and since $s(\bar{\mathbf{q}}_2) > s(\bar{\mathbf{q}}_1)$, this holds true at $\bar{\mathbf{q}}_2$ as well. So, there must be corruption at $\bar{\mathbf{q}}_2$.

Proof of Theorem 1

1. **Existence of a no-corruption equilibrium**. Consider the following alert strategy for firm β: for any $\widehat{\mathbf{q}}$, flag any specification $i \in S(\widehat{\mathbf{q}})$ with probability $\frac{1}{s(\widehat{\mathbf{q}})}$. We next show that this alert strategy induces firm α never to engage in corruption, whatever the state of nature. If this holds, then it is easy to construct beliefs so that this alert strategy is sequentially rational firm β at any $\widehat{\mathbf{q}}$ since there is no corruption on the equilibrium path.

The expected profit of engaging in corruption in state of nature $\bar{\mathbf{q}}$ so as to induce $\widehat{\mathbf{q}}$ is given by:

$$\pi(\widehat{\mathbf{q}}) - \left(\frac{s(\widehat{\mathbf{q}}) - s(\bar{\mathbf{q}})}{s(\widehat{\mathbf{q}})}\right)(\pi(\widehat{\mathbf{q}}) + L) = \pi(\bar{\mathbf{q}}) - \left(\frac{s(\widehat{\mathbf{q}}) - s(\bar{\mathbf{q}})}{s(\widehat{\mathbf{q}})}\right)(L - s_d^{max} c),$$

since $\pi(\widehat{\mathbf{q}}) = \pi(\bar{\mathbf{q}}) + (s(\widehat{\mathbf{q}}) - s(\bar{\mathbf{q}}))\, c = (s(\widehat{\mathbf{q}}) - s_d^{\max})\, c$. Then, if $L > s_d^{max} c$, engaging in corruption to $\widehat{\mathbf{q}}$ yields an expected profit smaller than $\pi(\bar{\mathbf{q}})$, hence smaller than $\max\{\pi(\bar{\mathbf{q}}); 0\}$. It is therefore dominated by no corruption at $\bar{\mathbf{q}}$ whenever $\pi(\bar{\mathbf{q}}) \geq 0$ or $\pi(\bar{\mathbf{q}}) < 0$. So, there exists a no-corruption equilibrium.

2. **Non-existence of an outcome with corruption**. Suppose there is one. Take $\widehat{\mathbf{q}}$ that is outcome of corruption in this equilibrium and order the $\rho_i(\widehat{\mathbf{q}})$ according to $i = 1, ...s(\widehat{\mathbf{q}})$ at this profile from smallest to highest (with possible ties) and let ρ denote the corresponding column $s(\widehat{\mathbf{q}})-$dimensional vector. There are a finite number of socially preferable projects $\bar{\mathbf{q}}_{\mathbf{t}}$, for $t = 1, ...T(\widehat{\mathbf{q}})$ for which there is corruption with positive probability in equilibrium leading to $\widehat{\mathbf{q}}$.

For any t, one has:

$$s(\widehat{\mathbf{q}})c - \{\sum_{i \in S(\widehat{\mathbf{q}}) \setminus S(\bar{\mathbf{q}}_{\mathbf{t}})} \rho_i\}(\pi(\widehat{\mathbf{q}}) + L) \geq s(\bar{\mathbf{q}}_{\mathbf{t}})c$$

that is,

$$\sum_{i \in S(\widehat{\mathbf{q}}) \setminus S(\bar{\mathbf{q}}_{\mathbf{t}})} \rho_i \leq \frac{c(s(\widehat{\mathbf{q}}) - s(\bar{\mathbf{q}}_{\mathbf{t}}))}{\pi(\widehat{\mathbf{q}}) + L}. \tag{5}$$

Moreover, for any specification $i \in S(\widehat{\mathbf{q}})$ such that $\rho_i(\widehat{\mathbf{q}}) > 0$, there exists some socially preferable project that indexed by t such that $i \in S(\widehat{\mathbf{q}}) \setminus S(\bar{\mathbf{q}}_{\mathbf{t}})$, that is i is one of the distorted specifications in the corruption outcome starting from $\bar{\mathbf{q}}_{\mathbf{t}}$.

Let $\epsilon_{\mathbf{t}}$ denote the row $s(\widehat{\mathbf{q}})-$dimensional vector consisting in 0 or 1 such that $\epsilon_{\mathbf{t}i} = 1$ if and only if $i \in S(\widehat{\mathbf{q}}) \setminus S(\bar{\mathbf{q}}_{\mathbf{t}})$. (5) can be written as:

$$\epsilon_{\mathbf{t}}.\rho \leq \frac{c}{\pi(\widehat{\mathbf{q}}) + L} \epsilon_{\mathbf{t}}.\mathbf{1}$$

with $\mathbf{1}$ denoting the $s(\widehat{\mathbf{q}})-$dimensional column vector consisting of 1 at each line.

Notice that (5) can be written as an upper bound on an average value of the ρ_i over the set of distortions:

$$\frac{1}{(s(\widehat{\mathbf{q}}) - s(\bar{\mathbf{q}}_{\mathbf{t}}))} \sum_{i \in S(\widehat{\mathbf{q}}) \setminus S(\bar{\mathbf{q}}_{\mathbf{t}})} \rho_i \leq \frac{c}{\pi(\widehat{\mathbf{q}}) + L}.$$

So, given that the ρ_i are ordered, the above inequality implies that for any $j \in S(\widehat{\mathbf{q}}) \setminus S(\bar{\mathbf{q}}_{\mathbf{t}})$,

$$\frac{1}{\#\{i \leq j, i \in S(\widehat{\mathbf{q}}) \setminus S(\bar{\mathbf{q}}_{\mathbf{t}})\}} \sum_{i \in S(\widehat{\mathbf{q}}) \setminus S(\bar{\mathbf{q}}_{\mathbf{t}}), i \leq j} \rho_i \leq \frac{c}{\pi(\widehat{\mathbf{q}}) + L}$$

also holds. Let $\epsilon_{\mathbf{t}}^{\mathbf{j}}$ for $j \in S(\widehat{\mathbf{q}}) \setminus S(\bar{\mathbf{q}}_{\mathbf{t}})$, denote the truncation of $\epsilon_{\mathbf{t}}$ up to the j-th term, and 0 for larger entries. The last inequality writes as:

$$\epsilon_{\mathbf{t}}^{\mathbf{j}}.\rho \leq \frac{c}{\pi(\widehat{\mathbf{q}}) + L} \epsilon_{\mathbf{t}}^{\mathbf{j}}.\mathbf{1}.$$

With this construction, starting from the profiles of $\epsilon_{\mathbf{t}}$ for $t = 1, ...,$ it is then possible for any $i \in S(\widehat{\mathbf{q}})$ to construct a row vector $\epsilon^{\mathbf{i}}$ consisting of 1 and 0, such that $\epsilon_{\mathbf{j}}^{\mathbf{i}} = 0$ for $j > i$ and such that

$$\epsilon^{\mathbf{i}}.\rho \leq \frac{c}{\pi(\widehat{\mathbf{q}}) + L} \epsilon^{\mathbf{i}}.\mathbf{1}.$$

or, using the matrix $E = (e_{ij})_{ij} = (\epsilon_{\mathbf{j}}^{\mathbf{i}})_{ij}$,

$$E.\rho \leq \frac{c}{\pi(\widehat{\mathbf{q}}) + L} E.\mathbf{1}.$$

The matrix E is low-triangular with 1 on its diagonal; hence it is invertible and its determinant is equal to $s(\widehat{\mathbf{q}})$. Let us define the following row vector $m = s(\widehat{\mathbf{q}}).\mathbf{1}^t.E^{-1}$. Note first that all its entries are natural numbers (or 0). Then, left-multiplying both sides (8) by m, one gets:

$$m.E.\rho = s(\widehat{\mathbf{q}}).\mathbf{1}^t.\rho = s(\widehat{\mathbf{q}}) \leq \frac{c}{\pi(\widehat{\mathbf{q}})+L}m.E.\mathbf{1} = \frac{c}{\pi(\widehat{\mathbf{q}})+L}s(\widehat{\mathbf{q}})\mathbf{1}^t.\mathbf{1} = \frac{c}{\pi(\widehat{\mathbf{q}})+L}s(\widehat{\mathbf{q}})^2$$

From this, it follows that $L \leq s_d^{max}c$, a contradiction.

Proof of Theorem 2

Consider $\widehat{\mathbf{q}}$ such that $\pi(\widehat{\mathbf{q}}) = \pi(\theta^\alpha)$, so that $\pi(\widehat{\mathbf{q}}) = s_u(\widehat{\mathbf{q}})c = s_u^{max}c$ and $s_d(\widehat{\mathbf{q}}) = s_d^{max}$.

For any $i \in S(\widehat{\mathbf{q}})$, consider the project $\bar{\mathbf{q}}^i$ that coincides with the final project $\widehat{\mathbf{q}}$ except for specification i for which it is less favorable to firm α, i.e. such that $\bar{\mathbf{q}}^i_j = \widehat{\mathbf{q}}_j$ for any $j \neq i$ and $\bar{\mathbf{q}}^i_i \neq \widehat{\mathbf{q}}_i$. At $\bar{\mathbf{q}}^i$, firm α has only the choice between not engaging in corruption or distorting specification i. Given that $\pi(\widehat{\mathbf{q}}) = \pi(\theta^\alpha) \geq c > 0$ and $\pi(\widehat{\mathbf{q}}) - \pi(\bar{\mathbf{q}}^i) = c$, $\pi(\bar{\mathbf{q}}^i) \geq 0$ for all $i \in S(\widehat{\mathbf{q}})$.

For $\widehat{\mathbf{q}}$ not to be the outcome of any distortion due to corruption in equilibrium, it must be that for any $i \in S(\widehat{\mathbf{q}})$, $p_i(\bar{\mathbf{q}}^i) = 0$. $p_i(\bar{\mathbf{q}}^i) = 0$ implies that firm α does not engage at all in corruption at $\bar{\mathbf{q}}^i$ and therefore that $\rho_i(\widehat{\mathbf{q}}) \geq \frac{c}{s_u^{max}c+L}$. Summing up over $i \in S(\widehat{\mathbf{q}})$, it comes:

$$\frac{\left[s_u^{max} + s_d^{max}\right]c}{s_u^{max}c + L} \leq 1,$$

which is not compatible with $L < s_d^{max}c$. So, in any equilibrium, there must be corruption leading to any such project $\widehat{\mathbf{q}}$.

Proof of Theorem 4

The proof is directly adapted from the proof of Theorem 1 and Theorem 2. The difference is that the probability of being caught while engaging in corruption is divided by 2. Therefore, for the uniform alert strategy over $S(\widehat{\mathbf{q}})$, i.e. $\rho_i(\widehat{\mathbf{q}}) = \frac{1}{s(\widehat{\mathbf{q}})}$ (cf the proof of Theorem 1), the expected profit of engaging in corruption in state of nature $\bar{\mathbf{q}}$ so as to induce $\widehat{\mathbf{q}}$ is given by:

$$\pi(\widehat{\mathbf{q}}) - \left(\frac{s(\widehat{\mathbf{q}}) - s(\bar{\mathbf{q}})}{2s(\widehat{\mathbf{q}})}\right)(\pi(\widehat{\mathbf{q}}) + L) = \pi(\bar{\mathbf{q}}) - \left(\frac{s(\widehat{\mathbf{q}}) - s(\bar{\mathbf{q}})}{2s(\widehat{\mathbf{q}})}\right)(L - (s(\widehat{\mathbf{q}}) + s_d^{max})c).$$

From this, the existence of a no-corruption equilibrium follows.

The second part of the proof of Theorem 1 and the proof of Theorem 2 can be straightforwardly adapted using (3).

Proof of Claim 1

If $\bar{\mathbf{q}}$ is such that $\pi(\bar{\mathbf{q}}) = 1$, i.e. for $(1,0,0,...)$ or $(0,1,0,...)$ or $(1,1,1,...)$, engaging in corruption to induce $\widehat{\mathbf{q}} = (1,1,0,...)$ involves one distortion and is strictly profitable (resp. dominated by no corruption) iff: $2(1-\frac{1}{n}) - \frac{L}{n} > 1$ (resp. < 1)$\Leftrightarrow L < n-2$ (resp. $L > n-2$).

If $\bar{\mathbf{q}}$ is such that $\pi(\bar{\mathbf{q}}) = 0$, i.e. for $(0,0,0,...)$ or $(0,1,1,...)$ or $(1,0,1,...)$, engaging in corruption to induce $\widehat{\mathbf{q}} = (1,1,0,...)$ involves two distortions and is strictly profitable (resp. dominated by no corruption) iff: $2(1-\frac{2}{n}) - \frac{2L}{n} > 0$ (resp. < 0)$\Leftrightarrow L < n-2$ (resp. $L > n-2$). Engaging in corruption to induce $\widehat{\mathbf{q}}$ such that $\pi(\widehat{\mathbf{q}}) = 1$ involves only one distortion and is strictly profitable (resp. dominated by no corruption) iff: $1(1-\frac{1}{n}) - \frac{L}{n} > 0$ (resp. < 0)$\Leftrightarrow L < n-1$ (resp. $L > n-1$).

If $\bar{\mathbf{q}}$ is such that $\pi(\bar{\mathbf{q}}) = -1$, i.e. for $(0,0,1,...)$, engaging in corruption to induce $\widehat{\mathbf{q}} = (1,1,0,...)$ involves three distortions and is strictly profitable (resp. dominated by no corruption) iff: $2(1-\frac{3}{n}) - \frac{3L}{n} > 0$ (resp. < 0)$\Leftrightarrow L < \frac{2n}{3} - 2$ (resp. $L > \frac{2n}{3} - 2$). Engaging in corruption to induce $\widehat{\mathbf{q}}$ such that $\pi(\widehat{\mathbf{q}}) = 1$ involves two distortions and is strictly profitable (resp. dominated by no corruption) iff: $1(1-\frac{2}{n}) - \frac{2L}{n} > 0$ (resp. < 0)$\Leftrightarrow L < \frac{n}{2} - 1$ (resp. $L > \frac{n}{2} - 1$).[28] The statement in the claim follows.

Proof of Claim 2

We use the following notation for firm β's strategy:[29]

- if $\widehat{\mathbf{q}} = (1,1,0,...)$, flag $i = 1$ with probability $\frac{\rho_2}{2}$, $i = 2$ with probability $\frac{\rho_2}{2}$ and $i = 3$ with probability $1 - \rho_2$, for some $\rho_2 \in (0,1)$;

[28]Note that for $n = 6$, $\frac{2n}{3} - 2 = \frac{n}{2} - 1$ and then for any $n > 6$, $\frac{2n}{3} - 2 > \frac{n}{2} - 1$.

[29]A subscript on ρ is used to refer to the total number of suspect upgrades in $\widehat{\mathbf{q}}$

- if $\widehat{\mathbf{q}} = (1,0,0,...)$ or $(0,1,0,...)$, flag the specification in $\{1,2\}$ that is such that $\widehat{\mathbf{q}}_i = 1$ with probability ρ_1 and $i = 3$ with probability $1-\rho_1$;
- if $\widehat{\mathbf{q}} = (1,1,1,...)$, flag specifications 1 and 2 with equal probability 1/2;
- if there is only one suspect specification, flag it with probability 1;
- for any other $\widehat{\mathbf{q}}$, flag specifications with equal probability 1/3.

The exhaustive analysis of all cases for firm α's strategy is tedious and uninformative. So, we just provide the analysis of one case. As an example, consider state $\bar{\mathbf{q}} = (0,0,0,...)$. Firm α can choose maximal corruption to induce $\widehat{\mathbf{q}} = (1,1,0,...)$, which yields an expected profit equal to $2(1-\rho_2)-\rho_2 L = 0$ given firm β's candidate strategy It can choose to refrain from corruption which yields an expected profit equal to 0. There is another possible choice that corresponds to (partial) corruption: it consists in inducing $\widehat{\mathbf{q}} = (1,0,0,...)$ (or equivalently in inducing $\widehat{\mathbf{q}} = (0,1,0,...)$), which yields an expected profit equal to $1(1-\rho_1)-\rho_1 L = 0$. Therefore, firm α's strategy is sequentially rational at $\bar{\mathbf{q}} = (0,0,0,...)$. The analysis of all other cases follows similar steps.

Let us now analyze firm β's flagging strategy. Observing $\widehat{\mathbf{q}} = (1,1,0,...)$ and given firm α's strategy, firm β conjectures that specification $i=1$ (or specification $i=2$) has been distorted with probability equal to:

$$\Pr\{\bar{\mathbf{q}} = (0,1,0,...)\}.k + \Pr\{\bar{\mathbf{q}} = (0,0,0,...)\}.k + \Pr\{\bar{\mathbf{q}} = (0,1,1,...)\}.1,$$

and that specification $i=3$ has been distorted with probability equal to:

$$\Pr\{\bar{\mathbf{q}} = (1,1,1,...)\}.1 + \Pr\{\bar{\mathbf{q}} = (0,1,1,...)\}.1 + \Pr\{\bar{\mathbf{q}} = (1,0,1,...)\}.1.$$

Given the independence of the realization of specifications in the socially preferable project, the value of k in the Claim makes these probabilities equal. This means that all three specifications $\{1,2,3\}$ are equally suspect for $\widehat{\mathbf{q}} = (1,1,0,...)$ and that firm β's flagging strategy is sequentially rational at $\widehat{\mathbf{q}} = (1,1,0,...)$. As no other profile $\widehat{\mathbf{q}}$ can be the outcome of corruption given firm α's candidate strategy, firm β is willing to randomize in any way after any other observation. This completes the characterization of the equilibrium in this example.

Proof of Claim 3

It is a simple matter a computation to show that the following conditions, on top of the conditions ensuring that probabilities are within $[0,1]$, characterizes equilibria of the game under alert-based accountability:

$$\begin{aligned} t &= k^2 v \\ s + kr &= k^2[k + (1 - v)] \end{aligned}$$

where the first condition guarantees that $i = 1$ and $i = 3$ raise equal suspicion at $\widehat{\mathbf{q}} = (1, 0, 0, ...)$ (with a similar condition at $\widehat{\mathbf{q}} = (0, 1, 0, ...)$) and the second condition guarantees that all three specifications raise equal suspicion at $\widehat{\mathbf{q}} = (1, 1, 0, ...)$.