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Competition and corruption in an agency relationship

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Abstract

The paper reconsiders the relationship between competition and corruption in a model, where corruption has solid informational foundations and where the regulatory response to the possibility of corruption is taken into account. It is shown that the effect of greater competition on corruption depends on the complementarity or substitutability of the two instruments available to decrease information rents, namely low powered incentives and greater competition. The paper concludes with a brief empirical exploration of the relationship between competitiveness and corruption on African data. © 1999 Elsevier Science B.V. All rights reserved.

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1. Introduction

> *In general, any reform that increases the competitiveness of the economy helps reduce corrupt incentives. Rose-Ackerman (1996)*

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Everybody agrees with the observation that the globalization of the world economy increases the competitiveness of the economic environment everywhere. Despite this trend, and somewhat in contradiction with Rose-Ackerman's statement above, Langseth and Bryane (1998) note: [1]

> The survey confirmed a trend demonstrated in a number of other surveys in Africa about corruption namely that corruption has increased in the last 5 years and is still increasing.

The purpose of this paper is first to review what economics has to say about the relationship between corruption and competition. One may have a normative point of view and design a framework where an optimal level of corruption occurs, assuming a benevolent government. Even though with enough money and political determination, it seems always possible to eradicate corruption, in fact all societies accept some level of corruption. [2] We can then ask what is the effect of competition on the level of ''optimal'' corruption. To do so, for consistency we must also presume that the government chooses an optimal competition policy, which together with the underlying technological, informational and behavioral characteristics of the economy generates some levels of competitive pressure. Competition is endogenous. The relevant question is more: how will changes in the pro-competition characteristics of the economy affect the actual levels of competition and corruption? Changes such as the informational effects of a more competitive environment, the greater substitutability of competitors' goods or the lower costs of these competitors are such exogenous increases in competitive pressure that can be studied. Alternatively, one may have a more positive approach and recognize that the government is captured by some interest groups, and that this entails, for example, a too laxist competition policy or too high tariffs. We can again ask how changes in the fundamentals of competitive pressure affect the equilibrium levels of corruption and competition. We can also ask how reforms in these (socially) wrong policies would affect corruption and competition, but the question of their implementability remains then open. Economists convinced of some welfare improving measures must then propose a path toward the reforms which attracts the interest of those in charge of the government. Institutions such as the World Bank, the IMF and other NGOs may condition their loans or aid on particular institutional reforms.

In Section 2, we discuss the empirical and theoretical literature bearing on the relation between competition and corruption. The only available empirical study

[1] See Section 7 for some data on the evolution of corruption in Africa and Bardhan (1997) for a recent survey on corruption and development.

[2] The literature recognizes that it is rarely optimal to eradicate corruption, see Besley and Mc Laren (1993), Mookherjee and Png (1995) and Moohkerjee (1997).

suggests a negative relationship. Our main conclusion concerning the theoretical literature will be that it has failed so far to ask the question of the relation between corruption and competition in models where equilibrium corruption has solid foundations. By taking as given the agency relationships which explain corruption, those papers have neglected the institutional response to changes in the competitiveness of the economy and at best provided a partial equilibrium analysis.

In Section 3, we construct a simple agency model with either an efficient agent or an inefficient one in which corruption may take place at equilibrium. There are two types of supervisors providing information to the principal, one being less corruptible than the other. The principal can implement a no collusion policy whereby he gives incentive payments to both types of supervisors and deters corruption (regime 1). Another policy is to save on those incentive payments and deter corruption only from the less corruptible supervisors (regime 2). In regime 2, the principal is less informed and his posterior beliefs, when the supervisor does not transmit any information, are tilted towards a higher probability of facing an efficient type (because it is in this case that there are stakes of collusion in which the supervisor hides his signal). In his rent–efficiency trade-off, the principal asks for less effort from the inefficient agent, because low powered incentives is a way to limit the information rent of the efficient type (who is more likely in this regime). So the first point is that the corruption regime uses lower powered incentives.

In Section 4, we interpret greater competition as better supervision technology. Greater competition is also a way to limit the information rent of the agent. If those two instruments — lower incentives and better supervision — are complement, it implies that greater competition is more efficient in the corruption regime where incentives are lower. Consequently, greater competition enlarges the space of parameters for which tolerating some corruption is the best strategy. Opposite results hold if the instruments are substitutes. However, we show that greater competitiveness unambiguously increases social welfare.

Next, we explore other definitions of more competition. In particular, in Section 5, we define more competition as less costly substitutes for the regulated firm. We are able to extend the above result. When the goods of the regulated firm and of the competitive sector are demand and strategic substitutes, an increase of competition decreases information rents and therefore is an instrument complement to low powered incentives. Hence, as in Section 4, more competition favors the corruption regime.

Furthermore, in Section 6, we show that if the principal himself is not benevolent, the complementarity or substitutability of better supervision and low powered incentives may vary with the level of corruption.

Section 7 is a brief empirical exploration of the relationship between competitiveness and corruption. For African data, we confirm results by Ades and di Tella (1994) according to which the most significant variable explaining improvement in the corruption record is the openness of the economy defined by imports normalized by GDP. Moreover, we show also that there is a significant interaction of this variable with the level of corruption and a sign reversal of the openness effect for low levels of corruption. Section 8 gathers concluding remarks.

2. The literature

The only empirical paper is that of Ades and di Tella (1994) which finds evidence that exogenous increases in product market competition reduce corruption in the bureaucracy. They recognize the ambiguous effect of competition in theory. Less competition means that more rents are there to be protected by corruption, but there is also a greater incentive for a regulatory response. Empirically, their most robust result is that competition expressed by the share of imports in GDP decreases significantly corruption. Also better schooling, anti-trust laws, high per capita growth rates decrease corruption but not always significantly.

We ran similar regressions for Africa and confirm that corruption is decreased by the openness of the economy expressed by the share of imports in GDP, by the growth rate and increased by aid and by the illiteracy rate (see Section 7).

In her 1978 book, Rose-Ackerman started the analysis of the effect of internal competition within the bureaucracy on corruption. A small number of honest bureaucrats can be very effective by allowing applicants to reapply for the service delivered by bureaucrats if they are asked bribes. In Rose-Ackerman (1988), she argues more generally: ''The role of competitive pressures in preventing corruption may be an important aspect of a strategy to deter bribery of low-level officials, but requires a broad based exploration of the effect of both organizational and market structures on the incentives for corruption facing both bureaucrats and their clients''.

Shleifer and Vishny (1993) consider a situation where government officials have discretion over the provision of some goods, say permits, and can collect bribes from private agents. However, they have no model of why this discretion came about. As they say ''we take the principal–agent problem as given''. Consequently, their analysis is preliminary because they cannot take into account how alternative structures of the government affect the principal–agent problem and the regulatory response of the top governmental level. They treat the set of officials providing complementary permits as sellers of complement goods who ignore the externalities they create on each other. This creates larger bribes, but smaller corruption revenues. Even though the market structure approach is part of the problem, by ignoring the foundations of the principal–agent problem, they cannot enter the specificities of corruption which are deeply connected with the information gaps of the principal and the nature of side-contracting between agents. The ''market structure'' of government officials influences the allocation of information concerning the agent but also the side-contracts being written.

Laffont and Martimort (1997) show that the inefficiency of bribe extractions by multiple bureaucrats can be exploited by the principal of the bureaucracy to construct in a less costly way collusion-proof mechanisms. In addition to the traditional yardstick competition between bureaucrats that the principal can use by exploiting the correlation of their information, it is shown that information per se often introduces increasing returns in the benefits of side-contracts, and makes desirable the separation of bureaucrats each endowed with his information technology, even when their information signals are uncorrelated.

Bliss and di Tella (1997) ask the question: Does competition kill corruption? Their model is more a model of gangster activity than corruption. Corrupt officials demand money from firms which either pay or quit. Hence, corruption affects the number of firms in a free-entry equilibrium. They make the good point that ''competition is not necessarily an exogenous parameter'' and that corruption itself affects the extent of competition. They distinguish deep competition parameters — such as transport costs, uncertainty of cost distribution, overhead cost, etc. — that they vary exogenously from the measure itself of competition which is an outcome of the economic system just as the level of corruption is. Their results both on the level of corruption and on welfare are quite ambiguous and heavily depend on the structure of the uncertainty about costs that the corrupt officials face. As the authors recognize they take as given the power enjoyed by the corrupt agents and focus on the process of bribe demands. There is no theory of why and how this power came about. This is the main weakness of this interesting paper due to the feature well recognized by the authors that they ''are not modeling agency relationship''.

To analyze the complex relationship between competition and corruption, we must have a good model of corruption, i.e., go back to the principal–agent model of corruption advocated by the pioneers (Becker and Stigler, 1974; Banfield, 1975; Rose-Ackerman, 1975, 1978; Klitgaard, 1988, 1991).

3. The model

First, we construct a hierarchical model in which optimal regulation may entail corruption. [3]

A natural monopoly can produce a public good with social value S at an observable cost:

$$C = \beta - e,$$

where β is a cost parameter which is private information of the firm, $\beta \in \{\underline{\beta}, \overline{\beta}\}$, $\Delta\beta = \overline{\beta} - \underline{\beta}$, $\Pr(\beta = \underline{\beta}) = \nu$, and e is an effort level which can decrease cost at a disutility $\psi(e)$ for the firm, with $\psi' > 0$, $\psi'' > 0$.

[3] This model builds on Tirole (1986) and Laffont and Tirole (1991).

The regulator reimburses the cost C and gives a transfer t to the firm for compensating it for its disutility of effort. The utility of the firm is then:

$$U = t - \psi(e) = t - \psi(\beta - C).$$

Consumers have a welfare:

$$V = S - (1+\lambda)(t + C),$$

where $1 + \lambda$ is the social cost of public funds strictly greater than one because of distortive taxation.

Under complete information and under the firm's participation constraint $U \geq 0$, a utilitarian regulator chooses e^*, t^* such that:

$$\psi'(e^*) = 1, \tag{1}$$

$$t = \psi(e^*), \tag{2}$$

i.e., marginal disutility of effort equates marginal social gain and the transfer equals the disutility of effort leaving the firm at its status quo level 0.

Under incomplete information, the regulator maximizes expected social welfare:

$$\nu\left[S - (1+\lambda)(\underline{t} + \underline{C}) + \underline{t} - \psi(\underline{\beta} - \underline{C})\right] + (1-\nu)$$
$$\times\left[S - (1+\lambda)(\bar{t} + \overline{C}) + \bar{t} - \psi(\overline{\beta} - \overline{C})\right]$$

under the incentive constraints:

$$\underline{t} - \psi(\underline{\beta} - \underline{C}) \geq \bar{t} - \psi(\underline{\beta} - \overline{C}) \qquad (\underline{\mathrm{IC}}),$$

$$\bar{t} - \psi(\overline{\beta} - \overline{C}) \geq \underline{t} - \psi(\overline{\beta} - \underline{C}) \qquad (\overline{\mathrm{IC}}),$$

and the participation constraints of the firm:

$$\underline{t} - \psi(\underline{\beta} - \underline{C}) \geq 0, \qquad (\underline{\mathrm{P}}),$$

$$\bar{t} - \psi(\overline{\beta} - \overline{C}) \geq 0. \qquad (\overline{\mathrm{P}}).$$

Changing notations, let:

$$\underline{U} = \underline{t} - \psi(\underline{e}),$$

$$\overline{U} = \bar{t} - \psi(\bar{e}),$$

$$\Phi(\bar{e}) = \psi(\bar{e}) - \psi(\bar{e} - \Delta\beta).$$

We know that the binding constraints are the incentive constraint of the efficient type $\underline{\beta}$, $(\underline{IC})$, and the participation constraint of the inefficient type $\bar{\beta}$, $(\bar{P})$. [4] They can be rewritten, respectively:

$$\underline{U} = \bar{U} + \Phi(\bar{e})$$

and

$$\bar{U} = 0.$$

They are binding since rents are costly to the principal. Substituting these constraints in the regulator's objective function, we have finally:

$$\nu\left[S-(1+\lambda)\left(\underline{\beta}-\underline{e}+\psi(\underline{e})\right)-\lambda\Phi(\bar{e})\right]+(1-\nu)\times\left[S-(1+\lambda)\left(\bar{\beta}-\bar{e}+\psi(\bar{e})\right)\right].$$

Maximizing with respect to the effort levels, we get:

$$\psi'(\underline{e}^*) = 1, \tag{3}$$

$$\psi'(\bar{e}^*) = 1 - \frac{\lambda}{1+\lambda}\frac{\nu}{1-\nu}\Phi'(\bar{e}^*) \tag{4}$$

and

$$\bar{U} = 0, \qquad \underline{U} = \Phi(\bar{e}^*).$$

The inefficient firm has no rent and exerts an inefficient effort level described by Eq. (4). The efficient firm has a rent and exerts an efficient effort level (see Eq. (3)). Low incentives for the inefficient type is an instrument to decrease the information rent of the efficient type.

Suppose next that the regulator can use a supervisor to partially bridge the information gap. The supervisor observes with probability ξ the value of β and obtains a verifiable signal $\sigma = \beta$ (hard information). With probability $1-\xi$, he observes nothing ($\sigma = \emptyset$). If the supervisor is benevolent or if the regulator can exert the supervision activity himself, the true signal is discovered by the regulator.

If $\sigma = \beta$, then the regulator implements the complete information regulation; Eqs. (1) and (2). If $\sigma = \emptyset$, the regulator revises his beliefs (but here the posterior probability that $\beta = \underline{\beta}$ equals the prior ν). Therefore, regulation when $\sigma = \emptyset$ is described by Eqs. (3) and (4). Thanks to the supervisor, the distortions due to asymmetric information occur only with probability $1-\xi$. In particular, supervision is another instrument to decrease the information rent of the efficient type.

Often, the supervision activity must be delegated to a third party who is not benevolent. This raises the possibility of corruption because when $\sigma = \beta$ the

[4] See Laffont and Tirole (1993), Chap. 1.

supervisor has the discretion of not showing his hard information and pretending that $\sigma = \emptyset$ by reporting $r = \emptyset$. When $\sigma = \bar{\beta}$, this serves no purpose since the $\bar{\beta}$-firm has zero rent both when $r = \emptyset$ and when $r = \bar{\beta}$ and it is not willing to pay for the message $r = \emptyset$. On the contrary, when $\sigma = \underline{\beta}$, there is a stake of collusion, $\Phi(\bar{e})$, since it has zero profit when $r = \underline{\beta}$ and a rent $\Phi(\bar{e})$ when $r = \emptyset$.

There are two types of supervisors. With probability ζ, the supervisor will not engage in collusion if, when he reveals that $\sigma = \underline{\beta}$, he is paid $\underline{s}$ greater or equal to the stake of collusion $\Phi(\bar{e})$ discounted by the transaction cost of collusion $1 + \lambda_f$, with $\lambda_f > \lambda$:

$$\underline{s} \geq \frac{\Phi(\bar{e})}{1 + \lambda_f}.$$

With probability $1 - \zeta$, the supervisor is more honest or more afraid of collusion and a lower payment $\underline{s}$ such that:

$$\underline{s} \geq \frac{\Phi(\bar{e})}{1 + \lambda_f} - k,$$

is enough to prevent collusion. [5]

Let W^* denote the first best expected welfare and let $W(\bar{e})$ be the expected welfare as a function of the level of effort of the inefficient type (given that it is always optimal to impose $\underline{e} = e^*$):

$$W(\bar{e}) = \nu\left[S - (1+\lambda)\left(\underline{\beta} - e^* + \psi(e^*)\right) - \lambda\Phi(\bar{e})\right] + (1-\nu)\left[S - (1+\lambda)\left(\bar{\beta} - \bar{e} + \psi(\bar{e})\right)\right]. \quad (5)$$

Depending on the values of the parameters, we have two possible regimes.

Regime 1: No collusion.

The payment $\underline{s}$ is chosen so that no supervisor, whatever his type, wants to engage in collusion, i.e.,

$$\underline{s} = \frac{\Phi(\bar{e})}{1 + \lambda_f}.$$

[5] Here, the logic is opposite to Besley and Mc Laren (1993) for whom low wages (capitulation wage) attract dishonest supervisors. We consider incentive payments and not flat wages.

Expected welfare which takes into account the cost of these payments is now:

$$W^{\mathrm{NC}} = \xi W^* + (1-\xi) W(\bar{e}) - \lambda\nu\xi \frac{\Phi(\bar{e})}{1+\lambda_{\mathrm{f}}},$$

hence:

$$\psi'\left(\underline{e}^{\mathrm{NC}}\right) = 1, \tag{6}$$

$$\psi'(\bar{e}^{\mathrm{NC}}) = 1 - \frac{\lambda}{1+\lambda}\frac{\nu}{1-\nu}\left(1 + \frac{\xi}{(1-\xi)(1+\lambda_{\mathrm{f}})}\right)\Phi'(\bar{e}^{\mathrm{NC}}). \tag{7}$$

If λ_{f} goes to infinity, it is as if the supervisor was benevolent. Then, the effort level of the inefficient type, when he is not identified, is the same as without supervisor. More generally, the possibility of corruption of the supervisor leads to additional costs and therefore to an even lower effort level for the inefficient type (compare Eq. (4) with Eq. (7)).

Regime 2: Collusion of a proportion ζ of supervisors.

In the previous solution, there is some waste of incentive payments due to the fact that, with probability $1-\zeta$, supervisors could be made noncorrupted with smaller payments, $\underline{s}-k$ instead of $\underline{s}$, but this type of supervisor cannot be identified. An alternative is to pay only $\underline{s}-k$ and let the supervisor be corrupted with probability ζ. There is a cost for this corruption but also a gain since with probability $1-\zeta$ corruption is prevented at a smaller cost. This alternative appears interesting if ζ is small.

Optimal regulation in this case is obtained by maximizing: [6]

$$\begin{aligned} W^{\mathrm{C}} = {} & \xi(1-\zeta)\nu\left[S - (1+\lambda)(\underline{\beta} - e^* + \psi(e^*)\right] \\ & + \xi(1-\nu)\left[S - (1+\lambda)(\bar{\beta} - e^* + \psi(e^*)\right] \\ & + \nu[1-\xi+\zeta\xi]\left[S - (1+\lambda)\left(\underline{\beta} - \underline{e} + \psi(\underline{e})\right) - \lambda\Phi(\bar{e})\right] \\ & + (1-\nu)(1-\xi)\left[S - (1+\lambda)\left(\bar{\beta} - \bar{e} + \psi(\bar{e})\right)\right] \\ & - \lambda\nu\xi(1-\zeta)\left[\frac{\Phi(\bar{e})}{1+\lambda_{\mathrm{f}}} - k\right] \end{aligned} \tag{8}$$

[6] For simplicity, we have not included the transaction costs of corruption $\lambda_{\mathrm{f}}\xi\zeta\nu(\Phi(\bar{e}))/(1+\lambda_{\mathrm{f}})$, because they may correspond to the increase of welfare of some agents. Including them would decrease the welfare and effort of the inefficient type in the corruption case without changing the main results (see proposition 2).

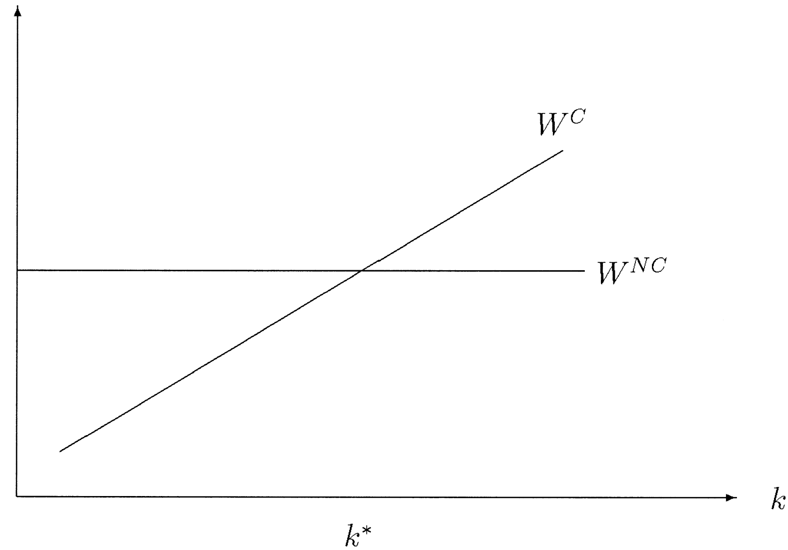

Fig. 1.

yielding

$$\psi'\left(\underline{e}^{\mathrm{C}}\right)=1, \tag{9}$$

$$\psi'(\bar{e}^{\mathrm{C}})=1-\frac{\lambda}{1+\lambda}\frac{\nu}{1-\nu}\left[1+\frac{\xi}{(1-\xi)(1+\lambda_{\mathrm{f}})}+\frac{\lambda_{\mathrm{f}}}{1+\lambda_{\mathrm{f}}}\frac{\zeta\xi}{1-\xi}\right]\times\Phi'(\bar{e}^{\mathrm{C}}). \tag{10}$$

In both regimes, we note that the effort of the inefficient type decreases with ξ. The quality of the supervisor's technology characterized by ξ and low incentives of the inefficient type are *complement* instruments to decrease the agent's information rent. Note that in the case with corruption, the effort of the inefficient type is lower than in the case without corruption. Indeed, in the former case, when the principal is uninformed, his posterior probability that he is facing an efficient agent increases [7] and therefore it is worth distorting more the effort of the inefficient type to decrease the rent of the efficient type.

It is worth understanding this result which is crucial for the analysis below. The cost of rents is higher (up to k, but this does not affect the effort levels) in the case with corruption. The rent $\Phi(\bar{e})$ is now paid more often, with probability $1-\xi+\zeta\xi$ instead of $1-\xi$, and the supervisor's payment $(\Phi(\bar{e}))/(1+\lambda_{\mathrm{f}})$ is paid less often,

[7] Indeed, it is $\hat{\nu}=\frac{(1-\xi+\xi\zeta)\nu}{(1-\nu)(1-\xi)+\nu[1-\xi+\xi\zeta]}>\nu$.

with probability $(1-\zeta)\xi$ instead of ξ. But because there exist transaction costs of collusion $(\lambda_f > 0)$, the total expected payment:

$$\Phi(\bar{e})\left(1-\xi+\zeta\xi+\frac{\xi(1-\zeta)}{1+\lambda_f}\right)=\Phi(\bar{e})\left(1-\frac{\lambda_f}{1+\lambda_f}\xi+\frac{\lambda_f\zeta\xi}{1+\lambda_f}\right),$$

is higher when $\zeta > 0$. It calls for a greater distortion of the effort level $\bar{e}$.

Since W^{NC} is independent of k and W^C is increasing in k (from the envelope theorem), we have Fig. 1.

There is a value of k^* such that for k larger than k^* it is better to let corruption happen. It is then so cheap to obtain honest behavior from a proportion $1-\zeta$ of supervisors that letting corruption happen with probability ζ dominates the costly regulation which ensures absolutely no corruption.

To explore the effect of an increase of competitiveness on corruption, we want to discover its effect on the critical value k^* to know if it enlarges or diminishes the domain of parameters for which corruption is the best strategy. We will then have an idea of how an increase of competitiveness increases the likelihood of corruption when we take into account the regulatory response of the principal.

4. Competition, information and corruption

There are many ways to model the increase of competitiveness in this environment. We first capture the information effect of competition by assuming that an increase of competition amounts to an increase of ξ, which characterizes the quality of the supervisor's technology. This may be because there are technologies similar to the one of the agent which are used in other sectors of the economy. Benchmarking and yardstick competition lead to better information. Then, we obtain:

Proposition 1 *Greater competition increases corruption in the sense that $(dk^*/d\xi) < 0$.*

Proof: By definition of k^*:

$$\begin{aligned}&\xi W^* + (1-\xi)W(\bar{e}^{NC}) - \lambda\nu\xi\frac{\Phi(\bar{e}^{NC})}{1+\lambda_f}\\&\quad=\xi W^* - \lambda\nu\zeta\xi\Phi(\bar{e}^C) + (1-\xi)W(\bar{e}^C)\\&\qquad-\lambda\nu\xi(1-\zeta)\left(\frac{\Phi(\bar{e}^C)}{1+\lambda_f}-k^*\right).\end{aligned}\tag{11}$$

Differentiating with respect to k^* and ξ we have:

$$(1-\zeta)\lambda\nu\xi \mathrm{d}k^* = \Bigg[W(\bar{e}^{\mathrm{C}}) - W(\bar{e}^{\mathrm{NC}}) - \lambda\nu\frac{\Phi(\bar{e}^{\mathrm{NC}})}{1+\lambda_{\mathrm{f}}} + \lambda\nu\left(\zeta + \frac{1-\zeta}{1+\lambda_{\mathrm{f}}}\right)\Phi(\bar{e}^{\mathrm{C}}) - (1-\zeta)\lambda\nu k^*\Bigg]\mathrm{d}\xi.$$

But from Eq. (11):

$$-\lambda\nu\frac{\Phi(\bar{e}^{\mathrm{NC}})}{1+\lambda_{\mathrm{f}}} + \lambda\nu\left(\zeta + \frac{1-\zeta}{1+\lambda_{\mathrm{f}}}\right)\Phi(\bar{e}^{\mathrm{C}}) - \lambda\nu(1-\zeta)k^* = \frac{1-\xi}{\xi}\left[W(\bar{e}^{\mathrm{C}}) - W(\bar{e}^{\mathrm{NC}})\right].$$

Hence,

$$\frac{\mathrm{d}k^*}{\mathrm{d}\xi} \propto \frac{W(\bar{e}^{\mathrm{C}}) - W(\bar{e}^{\mathrm{NC}})}{\xi}.$$

$W(\cdot)$ is a concave function which takes its maximum at $\bar{e}^*$ such that:

$$\psi'(\bar{e}^*) = 1 - \frac{\lambda}{1+\lambda}\frac{\nu}{1-\nu}\Phi'(\bar{e}^*).$$

We have:

$$\bar{e}^* > \bar{e}^{\mathrm{NC}} > \bar{e}^{\mathrm{C}}.$$

Therefore:

$$W(\bar{e}^{\mathrm{C}}) < W(\bar{e}^{\mathrm{NC}}) \text{ and } \frac{\mathrm{d}k^*}{\mathrm{d}\xi} < 0.$$

■

The intuition is as follows. An increase of information is more favorable in the corruption regime because low incentives and better information are complement instruments. We have observed above that incentives are lower in the corruption regime than in the no corruption regime. It means that the instrument, low powered incentives, is used more in the corruption regime than in the other regime. Consequently, better information, a complement instrument to low powered incentives, will be more useful in reducing information rent in the corruption regime. It follows that better information enlarges the space of parameters where it is better to let corruption happen when the principal is uninformed. Furthermore, for the parameter values k such that regime 2 is better, an increase of ξ increases the probability $\xi\zeta$ of corruption.

Note, however, that in both regimes (corruption and no corruption), the probability that the principal is uninformed decreases with ξ and we can expect welfare to increase with the quality of supervision. Indeed, we have:

Proposition 2 *Greater competition increases welfare.*

Proof: Let $W^{NC}(\bar{e})$ (respectively $W^{C}(\bar{e})$) be the regime 1 (respectively regime 2) expected social welfare as a function of the inefficient type's effort level when the level of effort for the efficient type is set at e^*. In addition, we include in $W^{C}(\bar{e})$ a portion $\delta \leq 1$ of the transaction costs of corruption $\delta\lambda_f \xi\zeta\nu(\Phi(\bar{e}))/(1+\lambda_f)$ to take into account any deadweight loss created by corruption.

Note first that $W^{NC}(\bar{e}^{NC})$ is increasing in ξ. From the envelope theorem:

$$\frac{\mathrm{d}W^{NC}}{\mathrm{d}\xi}(\bar{e}^{NC}) = \frac{\partial W^{NC}}{\partial \xi}(\bar{e}^{NC}) = W^* - W(\bar{e}^{NC}) - \lambda\nu\frac{\Phi(\bar{e}^{NC})}{1+\lambda_f},$$

$$\frac{\mathrm{d}W^{NC}}{\mathrm{d}\xi}(\bar{e}^{NC}) = \frac{\partial W^{NC}}{\partial \xi}(\bar{e}^{NC}) = \lambda\nu\frac{\lambda_f}{1+\lambda_f}\Phi(\bar{e}^{NC}) + (1-\nu) \times\left[\psi(\bar{e}^{NC}) - \bar{e}^{NC} - (\psi(e^*) - e^*)\right],$$

which is positive since e^* minimizes $\psi(e) - e$.

Now, we prove that $W^{C}(\bar{e}^{C})$ is increasing in ξ when we are in regime 2.

Note that $\Delta(\bar{e}) = W^{NC}(\bar{e}) - W^{C}(\bar{e})$ is proportional to ξ, i.e.,

$$\Delta(\bar{e}) = \nu\xi\left[\zeta\lambda_f(\delta+\lambda)\frac{\Phi(\bar{e})}{1+\lambda_f} - (1-\zeta)\lambda k\right].$$

So, if the parameters are such that we are in regime 2:

$$W^{C}(\bar{e}^{C}) > W^{NC}(\bar{e}^{NC}) > W^{NC}(\bar{e}^{C}).$$

Therefore, $\Delta(\bar{e}^{C}) < 0$ and $\partial\Delta(\bar{e}^{C})/(\partial\xi) < 0$.

Now:

$$\frac{\mathrm{d}W^{C}}{\mathrm{d}\xi}(\bar{e}^{C}) = \frac{\partial W^{NC}}{\partial \xi}(\bar{e}^{C}) - \frac{\partial \Delta}{\partial \xi}(\bar{e}^{C}) + \left(\frac{\partial W^{NC}}{\partial \bar{e}}(\bar{e}^{C}) - \frac{\partial \Delta}{\partial \bar{e}}(\bar{e}^{C})\right)\frac{\mathrm{d}\bar{e}^{C}}{\mathrm{d}\xi},$$

$$\frac{\partial W^{NC}}{\partial \xi}(\bar{e}^{C}) = \lambda\nu\frac{\lambda_f}{1+\lambda_f}\Phi(\bar{e}^{C}) + (1-\nu)\left[(\psi(\bar{e}^{C}) - \bar{e}^{C}) - (\psi(e^*) - e^*)\right] > 0,$$

$$-\frac{\partial \Delta}{\partial \xi}(\bar{e}^{C}) > 0,$$

$$\frac{\partial W^{NC}}{\partial \bar{e}}(\bar{e}^{C}) < 0 \text{ since } \bar{e}^{C} > \bar{e}^{NC} \text{ and } W^{NC}(\cdot)$$

is concave in $\bar{e}^{C}$ and maximum at $\bar{e}^{NC}$.

$$-\frac{\partial \Delta}{\partial \bar{e}}(\bar{e}^{C}) = -\nu\xi\zeta\lambda_f(\delta+\lambda)\frac{\Phi'(\bar{e}^{C})}{1+\lambda_f} < 0,$$

$$\frac{\mathrm{d}\bar{e}^{C}}{\mathrm{d}\xi} < 0$$

from the first-order condition (10).

Hence, $(\mathrm{d}W^{C}/\mathrm{d}\xi)(\bar{e}^{C}) > 0$ in regime 2.

Consequently, as ξ increases, welfare increases when the regimes are optimized by the regulator. ■

The proof is not straightforward because we have to take into account the deadweight losses of corruption which increase with ξ. However, when regime 2 is better than regime 1, this effect is dominated by the favorable effect of ξ.

To sum up, we can say that, here, increased competition implies a higher welfare but a higher probability of corruption activities. Increased competition makes corruption less costly, so much so that it makes it less worthwhile to eradicate it in more circumstances.

Remark 1: Proposition 1 relies on the fact that in our model low incentives and better supervision are complement instruments. The reverse result would hold if they were substitutes. This is obtained in the following case where better supervision improves incentives. Suppose, for example, that the supervisor observes a signal only if $\beta = \underline{\beta}$. Then after observing no signal, $\sigma = \emptyset$, the posterior belief that the firm is efficient is $(\nu(1-\xi))/(1-\nu\xi)$. This leads to the following effort levels in the cases of benevolent supervision, nonbenevolent supervision with no corruption, nonbenevolent supervision with partial corruption, respectively:

$$\psi'(\bar{e}^{**}) = 1 - \frac{\lambda}{1+\lambda}\frac{\nu(1-\xi)}{1-\nu}\Phi'(\bar{e}^{**}),$$

$$\psi'(\bar{e}^{NC}) = 1 - \frac{\lambda}{1+\lambda}\frac{\nu}{1-\nu}\left(1-\frac{\xi\lambda_f}{1+\lambda_f}\right)\Phi'(\bar{e}^{NC}),$$

$$\psi'(\bar{e}^{C}) = 1 - \frac{\lambda}{1+\lambda}\frac{\nu}{1-\nu}\left[1-\frac{\xi(1-\zeta)\lambda_f}{1+\lambda_f}\right]\Phi'(\bar{e}^{C}).$$

Hence,

$$\bar{e}^{*} < \bar{e}^{C} < \bar{e}^{NC} < \bar{e}^{**} \text{ but now } W(\bar{e}^{C}) > W(\bar{e}^{NC}) \text{ and } \frac{\mathrm{d}k^{*}}{\mathrm{d}\xi} > 0.$$

So more generally, we can expect that when competition and low incentives are complement (or substitute) instruments to decrease information rents, greater competition increases (decreases) the domain of parameters in which letting (partial) corruption happen is the best strategy of the principal.

Remark 2: So far we have taken the cost of public funds as exogenous. However, if competition affects the whole economy information rents will be lower and the budget constraint of the principal will be less tight. This decrease of the cost of public funds will increase the ability of the principal to fight corruption and this ''general equilibrium'' effect will counteract the partial equilibrium effect of proposition 1. Examples dealt with Mathematica show that this effect may or may not compensate for the effect of proposition 1.

Remark 3: We can derive another proposition from the intuition obtained above. If greater competition means less asymmetric information for the principal, [8] $\Delta\beta$ smaller, corruption decreases. Indeed if $\Delta\beta$ decreases, effort increases when the supervision technology is as in the main section. We are in the case of substitute instruments and the reverse of proposition 1 holds. On the contrary, with the technology of remark 1, instruments are complements and proposition 1 holds.

5. Product market competition and corruption

A more straightforward meaning of greater competition is that the competitive sector, which produces goods that are substitutes or complements for the regulated sector good, has become more efficient, for example, by producing at lower cost.

Let us expand the model to variable production levels of the regulated firm with a cost function:

$$C = (\beta - e)q_1,$$

where q_1 is the production level.

The competitive sector produces a quantity q_2 of a substitute or complement good at marginal cost c.

The inverse demand functions for these goods are $p_1(q_1,q_2)$ and $p_2(q_1,q_2)$. They are derived from the consumers' utility function:

$$S(q_1 + q_2) + \theta q_1 q_2,$$

where θ is a parameter of substitutability. [9]

[8] See Bliss and di Tella (1997) for such an argument.

[9] Results similar to those of this section can be obtained by defining greater competition by greater substitutability (θ smaller).

The good of the regulated firm is sold to consumers, but, if we call t the net transfer received by the firm from the regulator, its utility is still:

$$U = t - \psi(e).$$

The consumers' welfare is:

$$S(q_1 + q_2) + \theta q_1 q_2 - p_1(q_1,q_2) q_1 - c q_2$$
$$- (1 + \lambda)\big(t + (\beta - e) q_1 - p_1(q_1,q_2) q_1\big).$$

Social welfare is then:

$$S(q_1 + q_2) + \theta q_1 q_2 + \lambda p_1(q_1,q_2) q_1 - c q_2$$
$$- (1 + \lambda)\big((\beta - e) q_1 + \psi(e)\big) - \lambda U.$$

Under complete information, the regulator would require the optimal effort level of the regulated firm characterized by $\psi'(e^*) = q_1$ while operating transfers leaving no rent $\underline{U} = \overline{U} = 0$.

When β is private information of the firm and e is not observable, the regulator maximizes expected social welfare under the participation constraints and incentive constraints of the firm and taking into account that the competitive sector prices its good at marginal cost.

In Appendix A, we show that, for both $\underline{\beta}$ and $\overline{\beta}$, a reduction in the production cost c increases the production of $q_2 > 0$ and moreover that:

$$\operatorname{sign}\frac{\mathrm{d}q_1}{\mathrm{d}c} = \operatorname{sign}\frac{\mathrm{d}e}{\mathrm{d}c} = \operatorname{sign}\left[-\left(S'' + \theta + \lambda\frac{\partial^2 p_1}{\partial q_1 \partial q_2} + \frac{\partial p_1}{\partial q_2}\right)\right],$$

$$\operatorname{sign}\frac{\mathrm{d}q_1}{\mathrm{d}c} = \operatorname{sign}\frac{\mathrm{d}e}{\mathrm{d}c} = \operatorname{sign}\left[-\left(S'' + \theta + \lambda\frac{\partial \mathrm{MR}(q_1)}{\partial q_2}\right)\right],$$

$$\operatorname{sign}\frac{\mathrm{d}q_1}{\mathrm{d}c} = \operatorname{sign}\frac{\mathrm{d}e}{\mathrm{d}c} = \operatorname{sign}\left[-\left(S'' + \theta + \lambda(S''' q_1 + S'' + \theta)\right)\right].$$

If the goods are demand substitutes $(\partial p_1/\partial q_2) < 0$, then $S'' + \theta < 0$, while $S'' + \theta > 0$ if they are demand complements.

If the goods are strategic substitutes $((\partial \mathrm{MR}(q_1)/\partial q_2) < 0)$, then $S''' q_1 + S'' + \theta < 0$, while $S''' q_1 + S'' + \theta > 0$ if they are strategic complement.

Therefore, if goods are demand substitutes and strategic substitutes, then:

$$\frac{\mathrm{d}q_1}{\mathrm{d}c} > 0, \quad \frac{\mathrm{d}e}{\mathrm{d}c} > 0.$$

In particular, $\mathrm{d}\bar{e}/\mathrm{d}c > 0$ and the rent $\underline{U}$ of the efficient regulated firm is decreased when c decreases.

If goods are demand substitutes and strategic complements, then the sign of $\mathrm{d}q_1/\mathrm{d}c$ and $\mathrm{d}e/\mathrm{d}c$ can be reversed if λ is sufficiently large. In particular, $\mathrm{d}\bar{e}/\mathrm{d}c$

may become negative and the rent $\underline{U}$ of the efficient regulated firm increases when c decreases.

Proposition 3 *If the products of the regulated firm and the competitive sector are demand substitutes and strategic substitutes an increase of competition in the product market decreases the information rent.*

Let us now introduce as in Section 3 a supervisor of two types. We still denote W^* the first best expected welfare and $W(\bar{e})$ the expected welfare under incomplete information (when the efficient type has the effort level defined by $\psi'(\underline{e}) = \underline{q}_1$) as a function of the inefficient type's effort level $\bar{e}$.

In the no collusion case, expected welfare is again:

$$W^{\mathrm{NC}} = \xi W^* + (1-\xi) W(\bar{e}) - \lambda \nu \xi \frac{\Phi(\bar{e})}{1+\lambda_{\mathrm{f}}}$$

with

$$\psi'\left(\underline{e}^{\mathrm{NC}}\right) = \underline{q}_1,$$

$$\psi'(\bar{e}^{\mathrm{NC}}) = \bar{q}_1 - \frac{\lambda}{1+\lambda}\frac{\nu}{1-\nu}\left(1 + \frac{\xi}{(1-\xi)(1+\lambda_{\mathrm{f}})}\right)\Phi'(\bar{e}^{\mathrm{NC}}).$$

Similarly, in the collusion case, we obtain:

$$\psi'\left(\underline{e}^{\mathrm{C}}\right) = \underline{q}_1,$$

$$\psi'(\bar{e}^{\mathrm{C}}) = \bar{q}_1 - \frac{\lambda}{1+\lambda}\frac{\nu}{1-\nu}\left[1 + \frac{\xi}{(1-\xi)(1+\lambda_{\mathrm{f}})} + \frac{\lambda_{\mathrm{f}}}{1+\lambda_{\mathrm{f}}}\frac{\zeta\xi}{1-\xi}\right] \times \Phi'(\bar{e}^{\mathrm{C}}).$$

Because of the dichotomy property of the cost function, [10] the first-order equations concerning the production levels are unchanged. So, the only difference between the corruption case and the noncorruption case is that the coefficient of $\Phi'(\bar{e})$ in the first-order condition above is higher in the corruption case.

As before, the level k^* of k for which expected welfares are the same in both cases is defined by equating those welfares. Differentiating with respect to c and k^*, we have:

$$\frac{\mathrm{d}k^*}{\mathrm{d}c} \propto \bar{q}_2^{\mathrm{C}} - \bar{q}_2^{\mathrm{NC}} > 0.$$

In Appendix A, we show that $\bar{q}_2^{\mathrm{C}} > \bar{q}_2^{\mathrm{NC}}$ if the goods are demand substitutes and strategic substitutes.

[10] See Laffont and Tirole (1993).

Proposition 4 *If the products of the regulated firm and the competitive sector are demand substitute and strategic substitutes, an increase of competition in the product market increases corruption in the regulated sector.*

Putting together propositions 3 and 4, we see that it is exactly when low powered incentives and greater competition are complement instruments to decrease information rents, namely when goods are demand substitutes and strategic substitutes that, as in Section 4, greater competition entails more corruption. Finally, note that, here too, more competition increases social welfare. [11]

6. Nonbenevolent principal

The temptation of corruption is not limited to the bureaucracy and can be undertaken by the politicians. Rather than developing a full fledged model of political competition to explain partisan politics, we will assume that the principal is corruptible as well and maximizes a weighted average of social welfare and its private benefits b, i.e.,

$$\delta b + \mathrm{SW},$$

where δ represents its propensity to corruption.

In the no collusion case, the principal cannot reap any private benefit. In the collusion case, we assume that he can capture some of the gain of collusion $\Phi(\bar{e})$ which occurs with probability $\nu\xi\zeta$.

For simplicity again, suppose that in this case, he captures all the information rent and let us also ignore the transaction costs of collusion in the evaluation of the principal's welfare. The principal's objective function is now, as in Section 4 with the additional term:

$$\nu\xi\zeta(\delta-1)\Phi(\bar{e}),$$

which for $\delta > 1$ gives the excess valuation of the principal for its private benefits. This leads to:

$$\psi'(\bar{e}) = 1 - \frac{\lambda}{1+\lambda}\frac{\nu}{1-\nu}\left[1 + \frac{\xi(1+\lambda_{\mathrm{f}}\xi)}{(1-\xi)(1+\lambda_{\mathrm{f}})} - \frac{(\delta-1)\xi\zeta}{1-\xi}\right].$$

The corruption of the principal $(\delta > 1)$ leads to higher incentives for the inefficient type. Actually, for δ large enough, we may have incentives higher than in the first best because large information rents in the firm are the support of the principal's private benefits.

[11] Immediately by the envelope theorem.

As competition increases (ξ increases), the result of proposition 1 becomes inverted for $\delta > \delta_0$ and again restored for $\delta > \delta_1 > \delta_0$. This is because when low incentives and greater competition are complements, the result depends on the comparison of the levels of effort in both cases. This leads to a prediction of the effect of competition which changes with the level of corruption.

7. Corruption and competition in Africa

Since theory is ambiguous about the relationship between competitiveness and corruption, we explore this relationship empirically. However, because of data limitations, this section should be viewed as exploratory.

7.1. The data

The economic data we will use are taken from African Development Indicators (1997) for the following countries: Burkina-Faso, Cameroon, Congo, Cte d'Ivoire, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Madagascar, Malawi, Mali, Mozambique, Namibia, Niger, Nigeria, Senegal, Sierra-Leone, Somalia, South-Africa, Sudan, Tanzania, Togo, Uganda, Zaire, Zambia, Zimbabwe.

RGDP: Average annual percentage growth of GDP between 1990 and 1995.

AID90: Net official development assistance from all donors as share of recipient GDP in 1990.

IMPORTSGDP: Ratio of merchandise imports, f.o.b in 1995 to GDP90.

ILLITERACY: Percentage of population 15 years of age and above that is illiterate (average of 1990 and 1995).

The corruption variable in 1990 and 1995 is taken from Business International and provided by World Bank. The Business International index of corruption is based on asking businessmen in different countries, on an ordinal scale, the extent of bribery they face.

$E(t)$: Quality of the institutions from the point of view of corruption at date t (as corruption increases E decreases).

Let DELTA = $E(95) - E(90)$

	DELTA	AID90	IMPORTSGD	RGDP	ILLITERACY
Economic variables					
Mean	−0.03	17.11	0.29	1.90	50.75
Median	0.00	12.10	0.25	2.50	52.50
Maximum	2.00	69.90	0.81	6.90	81.50
Minimum	−3.00	0.00	0.10	−7.00	18.00
Std. deviation	0.92	16.98	0.17	2.81	19.53
Observations	30	29	27	28	29

Correlation matrix

DELTA	1.00	0.09	0.41	−0.06	−0.18
AID90	0.09	1.00	0.48	0.39	0.24
IMPORTSGD	0.41	0.48	1.00	0.28	−0.05
RGDP	−0.06	0.39	0.28	1.00	0.19
ILLITERACY	−0.18	0.24	−0.05	0.19	1.00

Political variables

	Mean	Median	Maximum	Minimum	Std. deviation	Observation
*E*90	2.86	3.00	5.00	0.00	1.13	30
*E*95	2.83	3.00	5.00	0.00	1.23	30

Correlation matrix

	*E*90	*E*95
*E*90	1.00	0.69
*E*95	0.69	1.00

First, we note a globally stationary situation for the evolution of the corruption variable between 1990 and 1995. Somalia deteriorates slightly the mean.

Tabulation of DELTA

Value	Count	Percent	Cumulative count	Cumulative percent
−3	1	3.33	1	3.33
−1	6	20.00	7	23.33
0	16	53.33	23	76.67
1	6	20.00	29	96.67
2	1	3.33	30	100.00
Total	30	100.00	30	100.00

Series: DELTA
Observation 30

Mean	−0.03
Median	0.00
Maximum	2.00
Minimum	−3.00
Std. deviation	0.93
Skewness	−0.72
Kurtosis	5.13

7.2. The estimation

As in the work of Ades and di Tella (1994), with a different data set, the only strongly significant variable of competitiveness that we were able to exhibit is the openness of the economy represented by the level of imports normalized by the

Table 1
Dependent variable $E95$

Cte	−0.12 (0.34)	−0.07 (0.14)	0.12 (0.28)
$E90$	0.81 (7.73)	0.74 (4.20)	0.79 (8.15)
IMPORTS/GDP	2.40 (2.45)	3.34 (2.54)	2.74 (3.43)
AID		−0.01 (−1.77)	
RDGP		0.04 (0.71)	
ILLITERACY			−0.007 (1.38)
Adjusted R^2	0.72	0.71	0.71

size of the economy (IMPORTS/GDP). To deal with the obvious endogeneity of this variable we use two stage least squares by taking various predetermined variables as instruments (see Table 1).

The growth rate decreases corruption. Aid and the illiteracy rate increase corruption but not very significantly. An increase of one standard deviation in the competitiveness expressed by the openness of the economy translates into a 40% standard deviation increase in the quality index E. A 75% increase in the openness would bring a country with average corruption to the highest quality in Africa.

Since theory suggests an ambiguous sign for this competition effect and since Section 6 with a nonbenevolent principal suggests that the effect might change with the level of corruption, we introduce an interaction between the corruption and competition variables. We obtain:

$$E95 = \underset{(-1.77)}{-1.45} + \underset{(4.34)}{1.26}E90 - \underset{(-0.50)}{0.004}\text{AID90} + \frac{\text{IMPORTS}}{\text{GDP}}\left(\underset{(2.72)}{8.12} - \underset{(1.74)}{1.85}E90 + \underset{(2.02)}{3.7 \times 10^{-7}}E90^{6}\right)$$

Adjusted $R^2 = 0.76$.

Indeed, the effect of IMPORTS/GDP does not have always the same sign. It is positive for $E90$ less than 4.3 and negative above. The interaction between IMPORTS/GDP and $E90$ is significant (Wald test of 0.035 and likelihood ratio test of 0.18).

8. Conclusion

In our model, when corruption is accepted it calls for lower powered incentives (because the likelihood of facing an efficient agent is higher in this case and the principal wishes to decrease even more rents).

Low powered incentives are an instrument to decrease information rents. Competition is also an instrument to decrease rents. When these instruments are complements, more corruption is favored (and the opposite when they are substitutes), because incentives are lower when corruption is allowed and greater competition is then more effective in this case. The principal allows corruption more often.

No hasty conclusion should be derived from the very partial analysis of this paper. In some sense, we reach conclusions similar to the ones obtained in models which show how corruption may complete missing markets. To have corruption at the equilibrium in a contracting model is related to a notion of incomplete contract, and letting corruption happen may complete in some sense the contractual framework. Further research will have to investigate more systematically in various models with incomplete contracts the effect of greater competition on the desirability of corruption to complete contracts.

Of course, we share all the traditional caveats calling for a more dynamic and comprehensive study of the effects of corruption in society. Nevertheless, we think that the literature has not taken seriously enough the empirical fact that societies let voluntarily some corruption happen and too easily conclude their analysis by saying how bad corruption is anyway.

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Appendix A

The regulator solves the program:

$$\max W = \nu\Big[S(\underline{q}_1 + \underline{q}_2) + \theta\underline{q}_1\underline{q}_2 + \lambda p_1(\underline{q}_1,\underline{q}_2)\underline{q}_1 - c\underline{q}_2 - (1+\lambda)\big((\underline{\beta} - \underline{e})\underline{q}_1 + \psi(\underline{e})\big) - \lambda\underline{U}\Big] + (1-\nu)\Big[S(\bar{q}_1 + \bar{q}_2) + \theta\bar{q}_1\bar{q}_2 + \lambda p_1(\bar{q}_1,\bar{q}_2)\bar{q}_1 - c\bar{q}_2 - (1+\lambda)\big((\bar{\beta} - \bar{e})\bar{q}_1 + \psi(\bar{e})\big) - \lambda\bar{U}\Big],$$

s.t.

$$\underline{U} \geq 0,$$

$$\bar{U} \geq 0,$$

$$\underline{U} \geq \bar{U} + \Phi(\bar{e}),$$

$$\bar{U} \geq \underline{U} - \Phi(\underline{e} + \Delta\beta).$$

We obtain:

$$\frac{\partial W}{\partial \underline{q}_1} \propto \underline{S}' + \theta \underline{q}_2 - (1+\lambda)(\underline{\beta} - \underline{e}) + \lambda\left(\frac{\partial p_1(\underline{q}_1,\underline{q}_2)}{\partial q_1}\underline{q}_1 + p_1(\underline{q}_1,\underline{q}_2)\right) = 0,$$

$$\frac{\partial W}{\partial \underline{q}_2} \propto \underline{S}' + \theta \underline{q}_1 - c + \lambda\frac{\partial p_1(\underline{q}_1,\underline{q}_2)}{\partial q_2}\underline{q}_1 = 0,$$

$$\frac{\partial W}{\partial \underline{e}} \propto -\left(\psi'(\underline{e}) - \underline{q}_1\right) = 0,$$

$$\frac{\partial W}{\partial \bar{q}_1} \propto \bar{S}' + \theta \bar{q}_2 - (1+\lambda)(\bar{\beta} - \bar{e}) + \lambda\left(\frac{\partial p_1(\bar{q}_1,\bar{q}_2)}{\partial q_1}\bar{q}_1 + p_1(\bar{q}_1,\bar{q}_2)\right) = 0,$$

$$\frac{\partial W}{\partial \bar{q}_2} \propto \bar{S}' + \theta \bar{q}_1 - c + \lambda\frac{\partial p_1}{\partial q_2}(\bar{q}_1,\bar{q}_2)\bar{q}_1 = 0,$$

$$\frac{\partial W}{\partial \bar{e}} = -\nu\lambda\Phi'(\bar{e}) - (1-\nu)(1+\lambda)\left(\psi'(\bar{e}) - \bar{q}_1\right) = 0.$$

Let us characterize the effect of $\mathrm{d}c$ on $(\underline{q}_1, \underline{q}_2, \underline{e})$. Totally differentiating the relevant system of equations, we find:

$$\begin{array}{cccc}
\mathrm{d}\underline{q}_1 & \mathrm{d}\underline{q}_2 & \mathrm{d}\underline{e} & \mathrm{d}c \\
S'' + \lambda\left[\frac{\partial^2 p_1}{\partial q_1^2} + 2\frac{\partial p_1}{\partial q_1}\right] & S'' + \theta + \lambda\left[\frac{\partial^2 p_1}{\partial q_1 \partial q_2}q_1 + \frac{\partial p_1}{\partial q_2}\right] & 1+\lambda & 0 \\
S'' + \theta + \lambda\left[\frac{\partial^2 p_1}{\partial q_1 \partial q_2}q_1 + \frac{\partial p_1}{\partial q_2}\right] & S'' + \lambda\left[\frac{\partial^2 p_1}{\partial q_2^2}q_1\right] & 0 & 1 \\
1 & 0 & -\psi'' & 0
\end{array}$$

and therefore [with $D < 0$ being the determinant of the above system]:

$$\frac{\mathrm{d}\underline{q}_1}{\mathrm{d}c} = \frac{1}{D}\left[\psi''\left(S'' + \theta + \lambda\left[\frac{\partial^2 p_1}{\partial q_1 q_2}q_1 + \frac{\partial p_1}{\partial q_2}\right]\right)\right],$$

$$\frac{\partial \underline{q}_2}{\partial c} = \frac{1}{D}\left[-\psi''\left[S'' + \lambda\left(\frac{\partial^2 p_1}{\partial q_1^2} + 2\frac{\partial p_1}{\partial q_1}\right)\right] - (1+\lambda)\right],$$

$$\frac{\partial \underline{e}}{\partial c} = +\frac{1}{D}\left[S'' + \theta + \lambda\left(\frac{\partial^2 p_1}{\partial q_1 q_2}q_1 + \frac{\partial p_1}{\partial q_2}\right)\right].$$

Hence, from concavity:

$$\frac{\mathrm{d}\underline{q}_2}{\mathrm{d}c} < 0,$$

and, furthermore:

$$\operatorname{sign}\left(\frac{\mathrm{d}\underline{q}_1}{\mathrm{d}c}\right)=\operatorname{sign}\left(\frac{\mathrm{d}\underline{e}}{\mathrm{d}c}\right)=\operatorname{sign}\left[-\left[S''+\theta+\lambda\left(\frac{\partial^2 p_1}{\partial q_1 q_2}q_1+\frac{\partial p_1}{\partial q_2}\right)\right]\right].$$

Let us now characterize the effect of $\mathrm{d}c$ on $(\bar{q}_1, \bar{q}_2, \bar{e})$. Totally differentiating the relevant system of equations, we find:

$$\begin{array}{cccc}
\mathrm{d}\bar{q}_1 & \mathrm{d}\bar{q}_2 & \mathrm{d}\bar{e} & \mathrm{d}c \\
S''+\lambda\left[\dfrac{\partial^2 p_1}{\partial q_1^2}+2\dfrac{\partial p_1}{\partial q_1}\right] & S''+\theta+\lambda\left[\dfrac{\partial^2 p_1}{\partial q_1\partial q_2}q_1+\dfrac{\partial p_1}{\partial q_2}\right] & 1+\lambda & 0 \\
S''+\theta+\lambda\left[\dfrac{\partial^2 p_1}{\partial q_1\partial q_2}q_1+\dfrac{\partial p_1}{\partial q_2}\right] & S''+\lambda\left[\dfrac{\partial^2 p_1}{\partial q_2^2}q_1\right] & 0 & 1 \\
1 & 0 & -\psi''-\dfrac{\lambda}{1+\lambda}\dfrac{\nu}{1+\nu}\Phi'' & 0
\end{array}$$

and therefore [with $D<0$ being the determinant of the above system]:

$$\frac{\mathrm{d}\bar{q}_1}{\mathrm{d}c}=-\frac{1}{D}\left[\left[-\psi''-\frac{\lambda}{1+\lambda}\frac{\nu}{1+\nu}\Phi''\right]\left[S''+\theta+\lambda\left(\frac{\partial^2 p_1}{\partial q_1 q_2}q_1+\frac{\partial p_1}{\partial q_2}\right)\right]\right],$$

$$\frac{\partial\bar{q}_2}{\partial c}=\frac{1}{D}\left[\left[-\psi''-\frac{\lambda}{1+\lambda}\frac{\nu}{1+\nu}\Phi''\right]\right.$$

$$\left.\times\left[S''+\lambda\left(\frac{\partial^2 p_1}{\partial q_1^2}+2\frac{\partial p_1}{\partial q_1}\right)\right]-(1+\lambda)\right],$$

$$\frac{\partial\bar{e}}{\partial c}=\frac{1}{D}\left[S''+\theta+\lambda\left(\frac{\partial^2 p_1}{\partial q_1 q_2}q_1+\frac{\partial p_1}{\partial q_2}\right)\right].$$

Similarly,

$$\frac{\mathrm{d}\bar{q}_2}{\mathrm{d}c}<0,$$

and:

$$\operatorname{sign}\frac{\mathrm{d}\bar{q}_1}{\mathrm{d}c}=\operatorname{sign}\left(\frac{\mathrm{d}\bar{e}}{\mathrm{d}c}\right)=\operatorname{sign}\left[-\left[S''+\theta+\lambda\left(\frac{\partial^2 p_1}{\partial q_1 q_2}q_1+\frac{\partial p_1}{\partial q_2}\right)\right]\right].$$

Let us call α the coefficient of $\Phi'(\bar{e})$ in the first-order condition with respect to $\bar{e}$. Differentiating as above with respect to $\bar{q}_1$, $\bar{q}_2$, $\bar{e}$ and α, we have:

$$\frac{\mathrm{d}\bar{q}_2}{\mathrm{d}\alpha}\propto-\frac{1}{D}\left[S''+\theta+\lambda\left(\frac{\partial^2 p_1}{\partial q_1\partial q_2}q_1+\frac{\partial p_1}{\partial q_2}\right)\right]>0$$

if goods are demand substitutes and strategic substitutes. Then:

$$\bar{q}_2^{C} > \bar{q}_2^{NC}.$$

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