ILLEGAL WASTE DISPOSAL, CORRUPTION AND ENFORCEMENT

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Illegal Waste Disposal, Corruption and Enforcement*

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Abstract

We focus on the role played by waste policy in determining waste related corruption. We first develop a simple model where an economic agent chooses the level of illegal disposal of its production-related waste. The polluting agent can be detected and punished by a local public authority, in charge of monitoring illegal waste. In the event of illegal waste being discovered, the bureaucrat may decide either to report the firm's illegal disposal or to hide the polluting firm by receiving a bribe in exchange. The bureaucrat is itself subject to (exogenous) enforcement by a central government. Our results suggest that several interesting trade-offs may emerge between the goals of reducing corruption, financing legal disposal costs and contrasting illegal dumping. Such trade offs are then tested using an empirical model where several proxies for corruption related to waste management are tested. Though our theoretical results are confirmed with respect to policy variables, enforcement seems not to be significant in affecting corruption.

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1 Introduction

Corruption seriously affects the effectiveness of economic policies in several areas. This is indeed the case with respect to waste management, as the recent crisis in outhern Italian regions testifies (D'Alisa et al. [3]). There is now increasing evidence suggesting that in several countries illegal disposal is made possible by conniving local authorities, receiving bribes in exchange of a weaker attention towards illegal dumping by individuals or criminal organizations. Among others, Liddick [5] argues about the role of "corrupt public officials" in illegal waste traffic and management.

Despite such evidence, the role played by corruptible bureaucrats in controlling and fighting illegal waste disposal and its implications on waste policy effectiveness have been quite unexplored yet. The aim of this paper is to provide some insights into the complex relationships among illegal disposal, waste policy, corruption and public enforcement. We first develop a simple theoretical model where an economic agent (a firm) chooses the level of illegal disposal of waste related to its production process, by taking into account that legal disposal requires the payment of a waste tax. Illegal waste can be detected by a local public authority (the "bureaucrat" in the following) exerting enforcement efforts to capture and punish the polluting firm. In the event of illegal waste being discovered, the bureaucrat may decide either to report the firm's illegal disposal to a higher level regulator (if she is "honest") or to hide the polluting firm by receiving a bribe in exchange (if she is "corrupt"). The choice of being corrupted is clearly affected by the bribe as well as the probability of being detected and punished by the State regulator, which in turn exerts enforcement to capture corrupt officials.

Quite interestingly, we find that the waste policy (i.e. an increase in the legal disposal charge) can increase the probability of corruption, leading to a larger illegal disposal and a higher bribe. This means that a trade-off can arise between reducing corruption and financing legal disposal costs. Moreover, whilst under corruption (ex post) enforcement negatively affects illegal disposal and the probability of corruption (as expected), the firm-related enforcement when the bureaucrat is honest ex post can increase illegal waste and the probability of corruption. In other words, the State's goal of balancing the budget for waste management may contrast with the fight against the firm's illegal dumping.

As a second step, we empirically test some of the findings from the theoretical model, by using a balanced panel data set for Italy covering the period 1999-2007. Specifically, we estimate a panel probit model, where the probability of corruption in the waste management is modeled by adopting alternatively two original proxies at regional level. Theoretical results seem to be confirmed when discussing the role played by waste related taxation in determining corruption, but enforcement does not show a significant role under any of our possible empirical specifications.

Our paper rests on the theoretical literature on waste policy in the presence of illegal dumping. Specifically, we move from Sullivan [8] and Fullerton and Kinnaman [4], where different waste policy options are compared in the presence of illegal waste disposal. Fullerton and Kinnaman (1995), in particular, analyze the optimal waste policy in a general equilibrium setting, under the assumption that illicit burning or dumping cannot be taxed directly and conclude that first best can be achieved even in the presence of illegal disposal. The authors conclude that the optimal fee structure is a deposit-refund system: a tax on all output plus a rebate on proper disposal through either recycling or garbage collection. Choe and Fraser [2] explicitly introduce monitoring cost into their model and identify the second-best optimal policy, whereas Shinkuma [7] also accounts for transaction costs in determining second best optimal instrument.

Our modeling strategy follows also the literature on officers' corruption in order to evade regulation, starting from the article by Becker and Stigler [1]. Specifically, our work is based on the idea developed in Mookherjee and Png [6], where a regulator delegates enforcement to an inspector in charge of monitoring pollution emitted by a firm. This provides scope for corruption, as the firm can bribe the inspector to under-report its pollution level. They conclude that large increases in penalties are required to reduce corruption, whilst smaller increases may actually raise bribery. We depart from Mookherjee and Png [6], as the probability of corruption in our model depends on the level of illegal disposal as well as, indirectly, on the waste tax. Such a modeling allows us to better analyze the complex trade-offs between waste management policies and incentives to corruption. The paper is organized as follows: Section 2 introduces the features of the theoretical model whilst Section 3 derives the results of the interaction between the polluting firm and the bureaucrat. Section 4 describes the details of our empirical model while Section 5 discusses the resultsand provides some final remarks.

2 The Theoretical Model

We model a "representative" agent (for example a firm or a consumer), performing an economic activity (consumption or production), that generates waste. The total amount of such activity is assumed to be exogenous and is denoted as y. A local public authority (a bureaucrat) is charged by a higher level authority with enforcing waste related regulation. The latter is shaped as a unit tax on legal disposal, that we label as t; real life examples of the latter might be a landfill tax or a waste charge. Also, the regulated agent has to bear strictly convex costs for legal disposal. On the other hand, by illegally dumping its waste, the agent can avoid legal disposal costs. The amount of illegal disposal is labelled as b, so that, given the overall level of economic activity, the amount of legal disposal is given by $y - b$. Convex legal disposal costs by the regualted agent are therefore given by $\frac{\mu(y-b)^2}{2}$, where $\mu > 0$.

We model enforcement in a very simple way, to be able to single out the impact of changes in enforcement effort levels on the likelihood corruption takes place and on the amount of waste illegally disposed of. Namely, we assume that the bureaucrat observes b with probability $\gamma \in (0,1)$, which is determined by the monitoring effort of a local public police force and is expected to depend on available budget, number of employees etc.[1] If b is observed, the bureaucrat might indeed be willing to hide illegal disposal to the central government, by accepting a bribe (labelled as m) from the agent. This latter choice depends on the bureaucrat choice of being corrupt or not. The bureaucrat itself communicates b to the government if it is not corrupt, while it communicates 0 if it is corrupt[2].

The bureaucrat itself is subject to enforcement by a national authority. The probability that corruption is discovered (when it does take place), depends on the enforcement effort exerted by the national government, summed up by a parameter $v \in (0,1)$. If corruption is discovered, then the national authority also discovers b and both the firm and the bureaucrat pay a unit fine equal to F. If the bureaucrat is honest, on the other hand, the firm pays a fine that might vary or not with the amount of unit fine X on each unit of illegal disposal[3].

The timing of the game is as follows: in the last stage, given the overall level of economic activity, the regulated agent chooses the level of illegal disposal and the bribe in order to minimize its expected costs, given the probability of the bureaucrat being corrupt. Then, the bureaucrat observes b with probability γ; in the latter case, corruption occurs if the related expected net benefits are larger than those from being honest. The corruption choice is described in the following section.

[1] The assumption that γ is exogenous implies the assumption that the bureaucrat cannot manipulate γ in order to increase expected benefits from bribery. This will be the subject of future refinements of our work.

[2] Though we model the consequences of corruption decisions in a clear cut way, the qualitative features are not expected to be affected much by such assumptions.

[3] A necessary condition for corruption to take place requires that $vF < X$, that is, the expected fine under corruption must be lower than the one in the absence of corruption.

2.1 The Corruption Choice

We assume that the bureaucrat's honesty can be summed up *ex ante* by a "honesty random variable", which is uniformy distributed, i.e. $h \sim U(0, H)$. H might be intended as the maximum opportunity cost of not being honest, and can depend on the personal features of people involved in the local bureaucracy and/or by the social capital embedded in the local community. An alternative interpretation of the random variable H is in terms of the number of honest employees in the local bureaucracy, so that the random variable h could be interpreted as the probability that one of these employees is indeed in charge of the related illegal waste disposal monitoring procedure[4].

We also normalize the bureaucrat's salary to 0[5]. As a result of our assumptions, the bureaucrat will choose of being corrupt if:

$$(1 - v)m - vFb \geq h$$

where the left hand side is the expected value of the bribe taking into account the possibility that the bribe itself is sequestered if corruption is discovered (with probability $(1 - v)$), and the expected fine if the latter event takes place.

As a result, the *ex ante* probability for the bureaucrat of being corrupt is as follows[6]:

$$F\left((1 - v)m - vFb\right) = \frac{(1 - v)m - vFb}{H}$$

This is the probability that is accounted for in the regulated agent's choice in the assessment of the costs related to illegal disposal.

2.2 The problem of the regulated agent

Given the probability of the bureaucrat of being honest, the regulated agent chooses the level of illegal disposal and the bribe to be offered to the bureaucrat

[4] Under this latter interpretation, we should make the additional assumption $H \in (0, 1]$.

[5] Other papers, such as Mookherjee and Png [6] explicitly address the impact of changes in the salary on the likelihood of corruption. We abstract from such analysis.

[6] Of course, we assume parameter values guarantee $F\left((1 - vb)m - vFb\right) \in (0, 1)$.

in order to minimize its expected costs, given by:

$$\min_{m,b} \frac{\mu \left(y-b\right)^2}{2} + t(y-b) + \\ +\gamma \left(\left(1 - \frac{(1-v)m - vFb}{H} \right) Xb + \frac{(1-v)m - vFb}{H} \left(m + vFb\right) \right) \quad (1)$$

The first order conditions imply the following equilibrium values for the level of illegal disposal (b_n) and for the bribe offered by the regulated agent (m_n)[7]:

$$b_n = \frac{2H\left(1-v\right)\left(t - X\gamma + y\mu\right)}{2\mu\left(1-v\right)H - \gamma\left(X(1-v) + Fv\left(v-2\right)\right)^2} \quad (2)$$

$$m_n = \frac{\left(X\left(1-v\right) + Fv^2\right)\left(t - X\gamma + y\mu\right)H}{2\mu\left(1-v\right)H - \gamma\left(X(1-v) + Fv\left(v-2\right)\right)^2} \quad (3)$$

3 Comparative statics/testable implications

A first interesting insight comes from the impact of a change in the tax rate on illegal behaviour and corruption[8].

Proposition 1 *An increase in the tax rate on legal disposal implies an increase in illegal disposal, in the bribe and, as a result, in the corruption probability.*

This is plausible, and suggests the existence of a trade off between waste disposal policy on one hand and illegal behaviour and corruption on the other hand. The intuition for the above result is straightforward: an increase in t leads to an increase in b and, at the margin, to an increase in the willingness to pay by the regulated agent to face a corrupt bureaucrat; as a result, the bribe m increases, together with the probability of corruption.

Results become a little more straightforward if we focus on enforcement by the national authority on the bureaucrat. Indeed,

[7] Strictly positive values for equilibrium bribe and illegal disposal require the additional assumption that $t > X\gamma - y\mu$, i.e. a sufficiently high tax on legal disposal and/or a sufficiently low fine on illegal disposal when the bureaucrat turns out to be honest *ex post*.

[8] All the details of the comparative statics are in the Appendix.

Proposition 2 *An increase in enforcement effort on the bureaucrat (as measured by v) or in the corresponding unit fine (as measured by F) implies a decrease in illegal disposal and corruption.*

The comparative statics signs are summed up in the following table.

$\frac{\partial b_n}{\partial v} < 0$	$\frac{\partial b_n}{\partial F} < 0$
$\frac{\partial \frac{(1-v)m_n - vFb_n}{H}}{\partial v} < 0$	$\frac{\partial \frac{(1-v)m_n - vFb_n}{H}}{\partial F} < 0$

The intuition is clear as well: increasing v leads to a decrease in b_n. Such a decrease always dominates (in equilibrium) the change in m_n in terms of the effects on probability of corruption, as an increase in v makes corruption more costly both for the regulated agent and for the bureaucrat.

We can now turn to the local police effort (γ) devoted to the regulated agent and to the impact of the unit fine (X) when the bureaucrat chooses not to be corrupt (and communicates therefore the true value of b to the national government). The following proposition can be stated:

Proposition 3 *An increase in enforcement devoted to the firm leads to a decrease in illegal disposal and in the corruption probability. On the other hand, an increase in the unit fine under no corruption (X) might lead to increases in illegal disposal and/or corruption, depending on the unit fine in case of corruption (F).*

We sum up the related comparative statics in the table below.

$\frac{\partial b_n}{\partial \gamma} < 0$	$\frac{\partial b_n}{\partial X} > 0$ for H sufficiently small
$\frac{\partial \frac{(1-v)m_n - vFb_n}{H}}{\partial \gamma} < 0$	$\frac{\partial \frac{(1-v)m_n - vFb_n}{H}}{\partial X} > 0$

The intuition for the impact of γ on illegal disposal and the probability of corruption follows closely the one we derived for v. On the othe hand, the intuition behind the impact of changes in X is trickier. When X increases, the expected costs related to the no corruption case increase too. This leads the regulated agent to change b_n and m_n to increase the probability of corruption.

As the expected unit fine under corruption (vF) is lower than the corresponding unit fine under no corruption (X), the regulated agent will also have an incentive to increase b_n. When H is sufficiently small (the probability of corruption is *ceteris paribus* high) then the agent does not have to support the increase in illegal disposal with a significant increase in the bribe. On the other hand, a large H would imply the need of a large increase in m_n to "pay" the bureaucrat for the increase in illegal disposal. This might counteract the increase in convenience of b_n and lead to its reduction.

4 The Empirical Model

As corruption is by its very nature a discrete variable. As a result, we use a random effect panel probit model for our estimates.

The specification is standard:

$$(Corruption)_{it} = \alpha_i + \beta_1 log(enforcement)it + \beta_2 log(wastepolicy)_{it}$$
$$+\beta_3 log(populationDensity)_{it} + \beta_4 log(employment)_{it} + \varepsilon_{it}$$

A balanced panel data set covering the period 1999-2007 has been built up. The data concerning population, employment and waste tariffs come from official statistics, mainly ISTAT and ISPRA. However, given a general data scarcity, and the lack of reliable data on waste related corruption, we created a set of different proxies that may reflect the regional level criminality.

First Corruption Proxy

For the first proxy we used a data set containing information about the number of municipal governments that were turned over because judged guilty of mafia connections.

We constructed a first set of dummy which are equal to 1 if a region had at least one municipalities judged guilty of mafia connection, and a level of landfilled waste per capita bigger than the median value of landfilled waste per capita.

We used this explicit weight given our strong concern about illegal landfilling behaviour. It is reasonable to assume that were landfilling is higher, criminality is more likely to be related to this particular waste stream. Such dummy vary across regions and through time.

Second Corruption Proxy

For this second proxy we used a national Dataset made available by the Italian Institute of statistics (ISTAT), about: "Reati contro la P.A." (crimes against Public Administration) and, specifically, "Peculato e Malversazione" plus "Omissione atti d'ufficio" (i.e. embezzlement and negligence).

Starting from this data we created a dummy variable equal to one if the number of "Reati contro la PA" is bigger than the median level, and the amount of landfilled waste is bigger than the median level. As before, this dummy varies by year and by region.

Enforcement Proxy

In order to control for the enforcement level, we created a dummy variable equal to 1 if there are irregularities in the comparison between the amount of waste produced and legally managed. From a legal perspective in fact the total regional balance have to be equal to zero. It is consequently reasonable to assume that where these accounting discrepancies are bigger, the level of enforcement is lower. We based on the following: Waste irregularities = Waste collected - (Waste landfilled + Waste recycled + Waste incinerated). Four dummies have been constructed that are equal to 1 if the irregularities are respectively bigger than the 5%, 10%, 15%, 20% of the total waste management.

The follwoing table reports the other relevant variables, together with the expected signs of the relationship.

Variable	Description	Research Hyp
Population density	Population/surface (inhabitants/km2)	Positively related to corruption, More densely populated municipalities may experience a stronger pressure on waste management
Employment	Share of Employment	Proxy of Social cohesion, negatively correlated with corruption
Waste related taxation	Proxy - % of population covered by waste tariff	Positively correlated with corruption

5 Estimation results and remarks

The following table represent the signs and significance of the estiamated coefficients. For brevity, we only reported the relevant marginal effects. Several interesting results are worth noticing.

Copoptar	0.00006**	0.000036*	0.000054*	0.000075**	0.000002*
Ln Pop Dens	0.00429**	0.002903**	0.004093**	0.00529**	0.000041**
Ln Employment	-0.02119***	-0.01335**	-0.018575**	-0.02479***	-0.00011***
Enforcement 5%	-0.0022014				-0.000101
Enforcement 10%		-0.00097			
Enforcement 15%			-0.00082		
Enforcement 20%				-0.00077	
N	200	200	200	200	140
Dependent variable	First Dummy	First Dummy	First Dummy	First Dummy	Second Dummy

First of all, we conclude that the proxies related to waste taxation, population density and employment all show the expected results. In other words, an increase in strictness of market based instruments, as represented by an increase in the population covered by the waste tariff, implies an increase in our measures of corruption. Population density shows that significant capacity constraints (e.g. availability of landfilss) affects the probability of corruption. Also, the state of the economy and possible measures of social capital accumulation (all summed up by employment in the current setting), negatively affect waste related corruption, as predicted in our theoretical analysis on the basis of the impacts of varying H. On the other hand, not much can be said on enforcement dummies, which are never significant. This might be due to the consideration that accounting irregularities may be due more to statistical mistakes than real differences in the regional enforcement level. Further research in this field is needed.

Appendix

Preliminaries

The convexity of (1) requires:

$$2\left(\frac{1}{H}\gamma\left(1-v\right)\right)>0$$

and

$$H=\begin{vmatrix} 2\left(\frac{1}{H}\gamma\left(1-v\right)\right) & -\frac{1}{H}\left(F\gamma v^{2}-X\gamma v+X\gamma\right) \\ -\frac{1}{H}\left(F\gamma v^{2}-X\gamma v+X\gamma\right) & 2\left(\frac{1}{2}\mu-\gamma\left(\frac{F^{2}}{H}v^{2}-\frac{F}{H}Xv\right)\right) \end{vmatrix}>0$$

that is $\gamma\frac{2\mu(1-v)H-\gamma(X(1-v)+Fv(v-2))^{2}}{H^{2}}>0$ or

$$H>H_{c}=\frac{1}{2}\frac{\gamma\left(X(1-v)+Fv\left(v-2\right)\right)^{2}}{\mu\left(1-v\right)}$$

Also, in order for our results to make economic sense, we must make sure that $F\left((1-v)m_{n}-vFb_{n}\right)\in(0,1)$, which requires:

$$(1-v)m_{n}-vFb_{n}>0 \tag{4}$$

and

$$(1-v)m_{n}-vFb_{n}-H<0 \tag{5}$$

A positive corruption probability requires:

$$(1-v)m_{n}-vFb_{n}=H\left(1-v\right)\left(t-X\gamma+y\mu\right)\frac{X(1-v)+Fv\left(v-2\right)}{2\mu\left(1-v\right)H-\gamma\left(X(1-v)+Fv\left(v-2\right)\right)^{2}}>0;$$

as $t > X\gamma - y\mu$ to guarantee positive illegal disposal and bribe in equilibrium, the above inequality implies assumung additionally that $X(1-v) + Fv\,(v-2) > 0$. Also, in order for (5) to hold we must assume

$$H > H_1 = \frac{(1-v)\,(t - X\gamma + y\mu)\,(X(1-v) + Fv\,(v-2)) + \gamma\,(X(1-v) + Fv\,(v-2))^2}{2\mu\,(1-v)} > H_c$$

Proof of proposition 1

From (2) and (3) we can get the following:

$$\frac{\partial b_n}{\partial t} = 2H \frac{1-v}{2\mu\,(1-v)\,H - \gamma\,(X(1-v) + Fv\,(v-2))^2} > 0,$$

$$\frac{\partial m_n}{\partial t} = H \frac{X\,(1-v) + Fv^2}{2\mu\,(1-v)\,H - \gamma\,(X(1-v) + Fv\,(v-2))^2} > 0,$$

$$\frac{\partial \frac{(1-v)m_n - vFb_n}{H}}{\partial t} = (1-v)\,\frac{X(1-v) + Fv\,(v-2) > 0}{2\mu\,(1-v)\,H - \gamma\,(X(1-v) + Fv\,(v-2))^2} > 0$$

where the sign of the inequalities forllow from $2\mu\,(1-v)\,H - \gamma\,(X(1-v) + Fv\,(v-2))^2 > 0$ due to convexity assumptions, and $\frac{\partial \frac{(1-v)m_n - vFb_n}{H}}{\partial t}$ also stems from $X(1-v) + Fv\,(v-2) > 0$, which is assumed to guarantee that $F\,((1-v)m_n - vFb_n) > 0$.

Proof of proposition 2

Comparative statics with respect to v imply:

$$\frac{\partial b_n}{\partial v} = -\frac{2H\gamma\,(t - X\gamma + y\mu)\left(4F + X + 3Fv^2 - 6Fv - Xv\right)(X(1-v) + Fv\,(v-2))}{\left(2\mu\,(1-v)\,H - \gamma\,(X(1-v) + Fv\,(v-2))^2\right)^2} < 0$$

as we assumed $t - X\gamma + y\mu > 0$ and $X(1-v) + Fv\,(v-2) > 0$ and as it is easily shown that $F\left(4 - 6v + 3v^2\right) + X - Xv > 0$ for $v \in (0,1)$; turning to the impact on corruption probability, we get:

$$\frac{\partial \frac{(1-v)m_n - vFb_n}{H}}{\partial v} =$$

$$= \frac{(t - X\gamma + y\mu)\left(2\mu\,(1-v)^2\,(2F\,(v-1) - X)\,H - F\gamma\left(v^2 + 2 - 2v\right)(X(1-v) + Fv\,(v-2))^2\right)}{\left(2\mu\,(1-v)\,H - \gamma\,(X(1-v) + Fv\,(v-2))^2\right)^2} < 0$$

as it easily shown that $v^2 + 2 - 2v > 0$ for $v \in (0,1)$. Our assumptions on parameter values also lead to the following derivatives when the unit fine in case corruption is discovered comes into play:

$$\frac{\partial b_n}{\partial F} = -4Hv\gamma(1-v)(2-v)(t - X\gamma + y\mu)\frac{(X(1-v)+Fv(v-2))}{\left(2\mu(1-v)H - \gamma(X(1-v)+Fv(v-2))^2\right)^2} < 0$$

and

$$\frac{\partial \frac{(1-v)m_n - vFb_n}{H}}{\partial F} =$$

$$= -v(t - X\gamma + y\mu)(1-v)(2-v)\frac{2\mu(1-v)H + \gamma(X(1-v)+Fv(v-2))^2}{\left(\gamma(X(1-v)+Fv(v-2))^2 - 2\mu(1-v)H\right)^2} < 0.$$

Proof of proposition 3

Comparative statics imply in this case:

$$\frac{\partial b_n}{\partial \gamma} = 2H\frac{(1-v)\left(2X\mu(v-1)H + (X(1-v)+Fv(v-2))^2(t+y\mu)\right)}{\left(2\mu(1-v)H - \gamma(X(1-v)+Fv(v-2))^2\right)^2};$$

given our assumptions for convexity, this derivative is indeed positive for $H < H_\gamma = \frac{1}{2X\mu}\frac{t+y\mu}{1-v}(X(1-v)+Fv(v-2))^2$. As however

$H_1 - H_\gamma = \frac{1}{2}\frac{F}{X}\frac{v}{\mu(1-v)}(2-v)(t - X\gamma + y\mu)(X(1-v)+Fv(v-2)) > 0$, and as we assumed $H > H_\gamma$ to guarantee that the probability of corruption is lower than 1, then we can conclude that it is always $H > H_\gamma$, so that $\frac{\partial b_n}{\partial \gamma} < 0$.

$$\frac{\partial \frac{(1-v)m_n - vFb_n}{H}}{\partial \gamma} =$$

$$= (1-v)\frac{(X(1-v)+Fv(v-2))\left(2X\mu(v-1)H + (X(1-v)+Fv(v-2))^2(t+y\mu)\right)}{\left(2\mu(1-v)H - \gamma(X(1-v)+Fv(v-2))^2\right)^2};$$

as $(X(1-v)+Fv(v-2))$ by assumption, then $\frac{\partial \frac{(1-v)m_n - vFb_n}{H}}{\partial \gamma} < 0$ can be obtained following the same reasoning as for b_n.

Turning to the impact of a change in X, we get:

$$\frac{\partial b_n}{\partial X} = 2H\gamma(v-1)\frac{(2\mu(1-v)H - (X(1-v)+Fv(v-2))(v\gamma(v-2)F + (1-v)(2y\mu + 2t - X\gamma)))}{\left(2\mu(1-v)H - \gamma(X(1-v)+Fv(v-2))^2\right)^2};$$

under our assumptions, $X(1-v) + Fv\,(v-2) > 0$ and $(t - X\gamma + y\mu) > 0$, so that it is also $2y\mu + 2t - X\gamma > 0$. As a result a necessary condition to have $\frac{\partial b_n}{\partial X} > 0$ is $(v\gamma\,(v-2)\,F + (1-v)\,(2y\mu + 2t - X\gamma)) > 0$. This is the case when:

$$F < \frac{1}{v\gamma}\frac{1-v}{2-v}\,(2t - X\gamma + 2y\mu)$$

which is always the case when $X(1-v)+Fv\,(v-2) > 0$.As a result, it is possible to have $\frac{\partial b_n}{\partial X} > 0$ and that is indeed the case when:

$$H < H_X = \frac{1}{2\mu}\frac{(1-v)\,(2t - X\gamma + 2y\mu) - Fv\gamma\,(2-v)}{1-v}\,(X(1-v) + Fv\,(v-2))$$

Notice that $H_X - H_1 = \frac{1}{2}\,(X(1-v) + Fv\,(v-2))\,\frac{t - X\gamma + y\mu}{\mu} > 0$ so that $\frac{\partial b_n}{\partial X} > 0$ would not violate any of the regularity conditions on H.

Turning to the impact of a change in X on the probability of corruption, it can be shown to be always positive. Indeed, it is easily derived that

$$\frac{\partial\left(\frac{(1-v)m_n}{vFb_n}\right)}{\partial X} = \frac{1}{2Fv}\,(1-v) > 0$$

so that $(1-v)m_n - vFb_n$ and, as a result, $\frac{(1-v)m_n - vFb_n}{H}$ always increase with X.

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