Corruption in environmental policy: the case of waste.*

Berardino Cesi[†], Alessio D'Amato[‡], Mariangela Zoli[§]

September 30, 2013

Abstract

This paper investigates interactions between waste and enforcement policies in the presence of corruptible bureaucrats. We set up a repeated game obtained by an infinite repetition of a three stage game, where a firm producing illegal disposal can bribe a bureaucrat in charge of checking for this disposal. The bureaucrat may accept or not the bribe and chooses whether to hide or not illegal disposal to a national waste authority. Fines for illegal disposal and for corruption (when present and detected) measure enforcement effort. Also, and realistically, we assume that any attempt of corruption is unverifiable in front of a court, so that no corruption arises, in the stage game. In the repeated game, on the other hand, corruption might arise in equilibrium and illegal disposal is always higher under corruption. We obtain interesting comparative statics results with respect to the role played by the discount rate in determining equilibrium levels of illegal disposal and the bribe; also, we show that the frequency of interactions among players (in terms of frequency of controls or of number of controls made by the same bureaucrat) can affect the likelihood of an equilibrium featuring corruption to take place.

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[†]DEF Department, University of Rome "Tor Vergata".

[‡]Corresponding author: DEF Department and CEIS, University of Rome "Tor Vergata", and SEEDS, email address: damato@economia.uniroma2.it.

[§]DEF Department and CEIS, University of Rome "Tor Vergata", and SEEDS.

JEL numbers: Q53, K42, D73. **Keywords:** waste management, illegal disposal, corruption, enforcement.

1 Introduction

An increasing anecdotal evidence reports a worldwide diffusion of corruption in the waste sector. Police investigations and convictions of managers/employees responsible for the waste process and local bureaucrats involved in illegal waste practices can be found around the world regardless the geographic position (Massari and Monzini, 2010; Liddick, 2010 and 2011). This evidence confirms that corruption is exacerbating the problems related to waste management and disposal

In spite of that, research exploring the effects of corruption on the efficiency of environmental policy in the waste sector is relatively scarce. This paper aims at contributing to fill this gap by theoretically investigating interactions between waste policies and enforcement in the presence of corruptible bureaucrats. We set up a repeated game obtained by an infinite repetition of a three stage game, where a firm producing illegal disposal can bribe a bureaucrat in charge of checking for this disposal. The bureaucrat may accept or not the bribe and she is obliged to report the level of illegal disposal to a national waste authority. If the bureaucrat reports the true level, the firm has to pay a charge for each unit of illegal disposal, and the game is over. On the other hand, if the bureaucrat accepts the bribe and hides illegal disposal to the national authority, then no fine is paid by the firm; if corruption is discovered, both the firm and the bureaucrat pay a fine related to corruption (and the firm pays also the fine for illegal disposal). Realistically, we assume that any attempt of corruption is unverifiable in front of a court. This means that in the stage game there is no possibility for corruption to arise, as the bureaucrat has always an incentive to report the true level of illegal disposal to the national authority and, since the bribe is not verifiable at all by a court of law, the firm cannot complain against the cheating behaviour of the bureaucrat.

Equilibria are different when we set up the game as a repeated game. In this case, we show that there exists a pair (among the others) of equilibrium trigger strategies (one for each player) such that corruption arises and the bureaucrat hides illegal disposal to the national authority. Also, we show interesting comparative statics results in terms of the impact of the discount rate on the equilibrium values for the bribe and the level of illegal disposal under corruption: more specifically, an increase in the discount factor might increase or decrease the equilibrium bribe, and the same is true with respect to illegal disposal, the net result depending on the relative enforcement strictness in the absence and in the presence of corruption. Interesting policy implications are also derived in terms of the impact of more frequent controls or bureaucrat turnover, that can make the illegal waste disposal problem, respectively, worse or less pressing.

The rationale for this work and the basic features of our modelling framework originate in several contributions in various strands of the literature. A first strand of research is the theoretical work on waste policy in the presence of illegal dumping, starting with Sullivan (1987) and especially Fullerton and Kinnaman (1995), which characterize optimal waste policy in a general equilibrium setting, under the assumption that illicit burning or dumping cannot be taxed directly[1]. Following these initial contributions, D'Amato and Zoli (2012) investigate the role of organized crime in waste management, explicitly modelling a criminal organization which extorts (socially costly) rents from agents willing to perform illegal disposal. Their main findings suggest that, under certain conditions, a mafia presence can lead to increased levels of economic activity and lower levels of enforcement; in some cases, the related benefits may offset the damages from increased illegal disposal and the social costs of mafia rents.

We refer also to contributions on corruption of officials in order to evade regulation (see the pioneering article by Becker and Stigler, 1974), and on the idea developed in Mookherjee and Png (1995), of a regulator that delegates environmental enforcement to an inspector responsible for monitoring the pollution emitted by a firm. This action provides scope for corruption because the firm

[1] See also Choe and Fraser (1999) and Shinkuma (2003), among others.

can bribe the inspector to under-report pollution levels. Another paper that is closely connected to our work is the one by Polinsky and Shavell (2001), which addresses corruption in various forms, including bribery of public enforcers to avoid them reporting violations. The main conclusion in their paper is that corruption dilutes deterrence.

More recent contributions, linked to the corruption game and to the repeated game structure of our paper, are those by Samuel (2009) and Dechenaux and Samuel (2012), that explicitly model the possibility of pre-emptive corruption (i.e. corruption taking place to avoid inspections). In our work we only focus on ex post corruption, that is, bribery takes place after the illegal act has been discovered. The main point of departure of our paper from the existing literature is however related to the explicit modeling of equilibria featuring corruption in a waste policy setting.

The paper is organized as follows: in the following section we present the model. In section 3 we derive the equilibrium strategies of the stage game, while in section 4 we show that corruption can arise in equilibrium if the stage game is infinitely repeated. Section 4 also shows relevant comparative statics. Finally, section 5 concludes.

2 The model

2.1 Stage game

We model the interaction between a bureaucrat and a regulated firm as a repeated game. To this end, let us define the following stage game G, as a 2-player game played by the bureaucrat and the firm. The firm generates waste that can be disposed of illegally, label the corresponding level as x. A local bureaucrat is in charge of checking how much illegal disposal takes place and once illegal behaviour is detected, she can choose how much of it to be reported to a national (or regional) authority (we label the reported level of illegal disposal as r). Coherently with the main aim of our paper, we explicitly model the possibility for corruption to take place.

The stages of the static game are the following:

- **first stage**: the firm generates illegal disposal. To simplify matters, we assume that the bureaucrat always detects the true amount of waste illegally disposed of. The firm can decide whether to offer a bribe, b, to the bureaucrat. If the firm offers no bribe the game proceeds to the **second stage (a)**, if the firm offers the bribe the game proceeds to the **second stage (b).**

- **second stage (a)**: the bureaucrat reports $r = x$, the firm pays a fine T for each unit of illegal disposal and payoffs are realized.

- **second stage (b)**: the bureaucrat may accept or not the bribe. In case she does not, the bureaucrat reports $r = x$, the firm pays a fine T for any unit of illegal disposal and payoffs are realized. Reporting the true level of illegal disposal to the authority does not make the firm incur in any additional charge for corruption. In other words any attempt of (unsuccessful) corruption is unverifiable in front of the court, (i.e. there is no way to provide hard evidence concerning it). If instead the bureaucrat accepts the bribe the game proceeds to the following stage.

- **third stage**: the bureaucrat reports the level of illegal disposal to the national authority, the report may be true ($r = x$) or false ($r = 0$)[2]. In case $r = 0$, with probability v the national authority is able to detect corruption and both the bureaucrat and the firm may pay a penalty F per unit of illegal disposal and payoffs are realized. We assume that when corruption is detected the firm and the bureaucrat cannot take part to corruption related transactions anymore. Since the bribe is not verifiable by a court of law, the regulated firm cannot complain against the cheating

[2] It would be possible, in line with Mookherjee and Png (1995), to extend our model to account for continuous underreporting, i.e. $0 < r < x$. However, we expect the bulk of our results to hold unchanged if such extension is introduced.

behavior of the bureaucrat that, once taken the bribe, reports $r = x$ anyway in order to avoid the penalty.

2.2 The firm

The regulated firm is assumed, in the absence of corruption and enforcement, to minimize the overall costs of waste disposal. We normalize the total amount of waste produced to 1, so that the amount of illegal disposal is $x \in [0,1]$. The amount of legal disposal is then $1-x$. The legal disposal cost is convex and assumed to be quadratic $\frac{\mu(1-x)^2}{2}$. As a result, the firm chooses the amount of illegal disposal (and that of legal disposal) in order to minimize the following cost function:

$$C = \frac{\mu\,(1-x)^2}{2} + t\,(1-x)\,;$$

in the above cost function, which is easily shown to be decreasing in illegal disposal and convex, we label as t a waste tax on each unit of legal disposal (e.g. a landfill tax).

2.3 The bureaucrat

The wage of the bureaucrat is normalized to zero and no incentive scheme linking his salary to the detection result is assumed. This imples that no incentive arises for the bureaucrat for framing and/or manipulating the report to the waste authority[3]. At the same time, we do not explicitly address the possible role of compensation in discouraging corruption[4]. The utility of the bureaucrat is simply given by zero in case of not accepting the bribe, while in case she accepts, her utility is equal to:

$$u = \begin{cases} (1-v)\,b + v(b - Fx), & \text{if } r = 0 \\ b, & \text{if } r = x \end{cases}$$

[3] For an economic analysis of framing see Polinsky and Shavell (2001).
[4] For such an analysis see, among others, Mookherjee and Png (1995).

where b is the value of the bribe when the bureaucrat is not detected as being corrupt (probability $(1-v)$), while $(b - Fx)$ is the corresponding payoff when the bureaucrat is detected (probability v). As already outlined, these payoffs rest on the assumption that the bribe is unverifiable, so that noone can provide hard evidence to a third independent court to verify it; as a consequence, b is kept by the bureaucrat even when detected by the national authorities. For the same reason the firm cannot appeal to the court to complain about the cheating behavior of the bureaucrat in case she reports $r = x$ after accepting the bribe.

3 The equilibrium of the stage game

We solve the game by backward induction. In the last stage the corrupted bureaucrat has no incentive to hide illegal disposal because the game is over and reporting $r = x$ eliminates the possibility for the authority to charge the fine F to the bureaucrat. In case a bribe is offered by the firm, the bureaucrat also keeps the bribe. In the **second stage (b)** the bureaucrat accepts the bribe, by anticipating the best response in the last stage. At the **first stage**, given the anticipation of the bureaucrat's behavior, the firm decides not to offer the bribe. In the fist stage, therefore, the firm chooses illegal disposal solving the following problem:

$$\min_{x} \quad C^G = \frac{\mu \left(1-x\right)^2}{2} + t\left(1-x\right) + Tx$$

By taking the first order conditions and solving for x, we easily get the following result.

Proposition 1 *The equilibrium of the stage game implies* $b^G = 0$ *and* $x^G = 1 - \frac{T-t}{\mu} = \frac{t+\mu-T}{\mu}$ *with* $C^G = T - \frac{1}{2}\frac{(T-t)^2}{\mu}$.

Clearly, in order for the result to make economic sense, we need to make sure that $0 < \frac{T-t}{\mu} < 1$, requiring $T > t$ (i.e. the punishment must be larger than the legal disposal tax to discourage illegal behavior) and $T < t + \mu$ (i.e. the punishment must not be so large to imply that all disposal takes place in an illegal way). We assume therefore $t < T < t + \mu$, limiting our attention to interior solutions.

The above proposition is easily interpreted: the higher the tax on legal disposal, the more the firm will produce illegal disposal, coherently with the existing literature (D'Amato and Zoli, 2012). Also, quite intuitively, a higher fine on illegal disposal lowers its level. We simply apply the total differential to the equilibrium disposal to study whether T and t interact in determining the amount of illegal disposal.

$$\frac{dT}{dt} = -\frac{\frac{1}{\mu}}{-\frac{1}{\mu}} = 1$$

As a result, a larger tax rate on legal disposal imply that a one to one increase in enforcmenent is needed to keep illegal disposal constant. As expected, and by construction, in the stage game, corruption doesn't play any role. We now turn to the repeated game setting, to investigate whether corruption can arise as an equilibrium phenomenon even when it does not matter in the stage game.

4 The repeated game

We now set up the repeated game, $\widetilde{G}$, as an infinite repetition of the stage game G; assume that all involved players have the same discount factor δ. We propose the following *trigger strategies*, σ_F and σ_B, for equilibrium candidates under corruption. These strategies entail that the firm offers the bribe, the bureaucrat accepts it, and then she reports $r = 0$, with this occurring in every period. More in particular:

Firm's strategy, σ_F:

- **first stage**: once illegal disposal has taken place, the firm proposes a bribe b^* if the bureaucrat has always accepted the bribe and chosen $r = 0$

in any previous period. Otherwise, the firm reverts to propose no bribe for ever (the Nash equilibrium of the stage game G).

Bureaucrat's strategy, σ_B:

- **second stage**: the bureaucrat accepts the bribe if the firm has always offered it up to the first stage of the current period.
- **third stage**: the bureaucrat reports $r = 0$, otherwise reporting $r = x$.

Let's start by defining the firm's expected discounted cost in the corruption phase C^C and, preliminarily, expected discounted costs in the punishment phase C^P, which starts once the authority has detected corruption and made it impossible for corruption itself to be enforced thereafter:

$$C^P = \frac{1}{1-\delta}\left(\frac{\mu\left(1-x\right)^2}{2} + t\left(1-x\right) + Tx\right)$$

and, as a result,

$$\begin{aligned} C^C &= (1-v)\left(\frac{\mu\left(1-x\right)^2}{2} + t\left(1-x\right) + b + \delta C^C\right) + \\ &\quad + v\left(\frac{\mu\left(1-x\right)^2}{2} + t\left(1-x\right) + b + x\left(T+F\right) + \delta C^P\right) \end{aligned}$$

which, after some manipulation, can be rewritten as follows:

$$\begin{aligned} C^C &= \frac{(1-v)}{1-(1-v)\,\delta}\left(\frac{\mu\left(1-x\right)^2}{2} + t\left(1-x\right) + b\right) + \\ &\quad + \frac{v}{1-(1-v)\,\delta}\left(\frac{\mu\left(1-x\right)^2}{2} + t\left(1-x\right) + b + x\left(T+F\right) + \delta C^P\right) \end{aligned}$$

We need the assumption $b < Tx\left(1-v\right) - vxF$ in order to induce the current (short-run) payoff under corruption to be higher than the current payoff without corruption, otherwise there would be no need for a repeated game, as the latter would not generate a different outcome with respect to the static game. In particular, b is the cost of bribing and $Tx\left(1-v\right) - vxF$ is the net short run expected benefit from bribing. By simplification the condition also requires $x(T(1-v)-vF)>0 \Rightarrow T(1-v)>vF$. Of course when $b>Tx(1-v)-vxFb<Tx$ the only equilibrium is without corruption, that means bribing costs too much, and corruption never arises in equilibrium (as in the stage game).

The discounted payoff for the bureaucrat in the corruption phase, V^C, can be written as:

$$V^C=(1-v)\left(b+\delta V^C\right)+v\left(b-Fx+\delta V^P\right) \tag{1}$$

where V^P is the discounted intertemporal payoff from in the punishment phase, which under our assumptions is $V^P=0$. Then (1) becomes

$$V^C=\frac{(1-v)\,b}{(1-(1-v)\,\delta)}+\frac{v\,(b-Fx)}{(1-(1-v)\,\delta)}$$

In order for an equilirium featuring corruption to arise, the equilibrium pair x^*, b^* must be such that the bureaucrat is better off by being corrupted and revealing $r^*=0$ in every period rather than cheating on the firm by accepting the bribe and then truthfully revealing the effective illegal disposal ($r^*=x^*$). This implies the following incentive compatibility constraint (ICC):

$$V^C\geq b$$

The left hand side of (2) is the utility from being corrupted and reporting $r=0$ in every period. The right hand side is the discounted utility when deviating from the equilibrium strategy σ_B, that is, first accepting the bribe but then revealing the true illegal disposal anyway ($r=x$) to avoid the chance of being caught. The short run "deviation utility" is simply given by the bribe, b, because when the bureaucrat does not hide (i.e. truthful reports) illegal disposal, then corruption cannot be detected at all; however from the next period on, the bureaucrat is punished by the firm by never offering the bribe again. This implies that the utility for the bureaucrat during the "punishment" phase is zero.[5]

[5] Notice that we do not impose here a single period non-negativity constraint. Instead, the

In the strategy profiles σ_F and σ_B we do not specify the level of b^* and x^*, as these two values are derived when we characterize the subgame perfect corruption equilibrium strategy ($b^* > 0$, $r^* = 0$, $x^* > 0$). The proposed pair of trigger strategies forms a subgame perfect equilibrium of our game, for an adequate choice of b, x and (indirectly) r (so that the per period equilibrium payoff for each player exceeds its equilibrium payoff in the stage game) and for sufficiently patient parties (i.e. for a value of δ close enough to 1). Subgame perfection is ensured by the absence of profitable one-shot deviations (Mailath and Samuelson, 2006), where a one-shot deviation from strategy σ_i is a strategy which, at time k, prescribes a different action than σ_i for a unique history, but which plays identical to σ_i in every period other than k.

There are many combinations of b and r supporting a trigger strategy in equilibrium; our next aim is to characterize the combination which is most preferred by the firm. We let b^* and x^* (under r^*) be such a combination; this comes as solution of the following problem:

$$\min_{x,b} \quad C^C$$

$$\text{s.t. (ICC)} \quad \frac{b - Fvx}{1 - \delta (1 - v)} \geq b \tag{2}$$

In general, this type of games needs an incentive compatibility constraint for every player; nevertheless here we omit the ICC for the firm because it always holds. The result is given by our assumption that $b < xT$ implying that the firm never deviates from its strategy σ_F because if it were the case then the bureaucrat (playing as second mover) would immediately punish the firm in the same period and no short-run gain for the firm would occur.

fact that the bureaucrat never gets non-negative profits follows directly from the fact that the punishment phase is nothing but an infinite repetition of the equilibrium of the static game where, in case of a deviation, the bureaucrat is punished with the (always zero) equilibrium payoff of the static game. More technically, a single period non-negativity constraint is not assumed but it is implied by the ICC. This is equivalent to assume $(1 - v) b + v (b - Fx) > 0$ that gives $b > vFx$.

The following proposition states the equilibrium of the repeated game.

Proposition 2 *When* $(1-v)\,T > \frac{(1-v\delta)}{\delta(1-v)}Fv$ *there exists a SNE (subgame perfect Nash equilibrium) in which corruption is enforced with the bureaucrat and the firm choosing respectively* $r^* = 0$ *and* $b^* = Fv\frac{x^*}{\delta(1-v)}$ *in every period.*

Proof. The Lagrangian is:

$$L = C^C - \lambda\left(\frac{b - Fvx}{1-\delta\,(1-v)} - b\right)$$

where the cost for the firm is increasing in b and the net discounted gain from cooperation also increases in b.[6] The FOC with respect to b gives $\lambda = \frac{1}{\delta(1-v)} > 0$. Thus optimal b^* is simply given by the value such that the ICC binds, that is:

$$b^* = Fv\frac{x}{\delta\,(1-v)} \tag{3}$$

The binding FOC with respect to x gives [7]:

$$x^* = \frac{t+\mu}{\mu} - \frac{1}{\mu\,(v\delta+1)}\left(Tv\,(\delta+1) + Fv\frac{\delta\,(1-v)+1}{\delta\,(1-v)}\right)$$

with $\lambda = \frac{1}{\delta(1-v)}$ at x^* and $b^* = Fv\frac{x}{\delta(1-v)}$. The condition to be satisfied for the equilibrium to exist is $b^* < x^*\,(T - v\,(T+F))$, that after simple algebra becomes $(1-v)\,T > \frac{\delta(1-v)+1}{\delta(1-v)}vF$. This condition implies $(1-v)\,T > Fv$ (implying $b^* > 0$ and $x^* > 0$ from condition (3)), because $\frac{\delta(1-v)+1}{\delta(1-v)}v > v$. We also need to make sure that $x^* < 1$; to this end, we assume, therefore:

$$t < t_h = \frac{1}{v\delta+1}\left(Tv\,(\delta+1) + F\frac{v}{\delta}\frac{\delta\,(1-v)+1}{\delta\,(1-v)}\right) > 0.$$

■

Comparative statics on the equilibrium values can be easily shown to imply:

$$\frac{dx^*}{dT} = -\frac{v}{\mu+v\mu\delta}\,(\delta+1) < 0$$

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[6] Indeed, it is easily shown that $\frac{\partial\left(\frac{(1-v)b}{(1-(1-v)\delta)} + \frac{v(b-Fx)}{(1-(1-v)\delta)} - b\right)}{\partial b} = \delta\frac{1-v}{v\delta+1-\delta} > 0$

[7] We limit our attention to interior solutions. Second order conditions are easily shown to hold.

$$\frac{dx^*}{dF} = \frac{v}{\delta\left(\mu + v\mu\delta\right)\left(1 - v\right)}\left(-\delta + v\delta - 1\right) < 0$$

$$\frac{dx^*}{dt} = \frac{1}{\mu} > 0$$

$$\frac{dx^*}{d\delta} = \frac{\left(v\delta^2 - v^2\delta^2 + 2v\delta + 1\right)}{\delta^2\left(1 - v\right)}F - \left(1 - v\right)T$$

with $A = \frac{v\delta^2 - v^2\delta^2 + 2v\delta + 1}{\delta^2(1-v)} > 0$ for $v \in (0,1)$ and $\delta \in (0,1)$, so that:

$$\frac{dx^*}{d\delta} > 0 \text{ if } AF > \left(1 - v\right)T$$

$$\frac{dx^*}{d\delta} < 0 \text{ if } AF < \left(1 - v\right)T$$

From our assumption $(1-v)\,T > Fv\frac{\delta(1-v)+1}{\delta(1-v)}$, we can easilty get that $v\frac{\delta(1-v)+1}{\delta(1-v)} < A$, so that we can finally conclude that:

$$\frac{dx^*}{d\delta} > 0 \text{ if } Fv\frac{\delta\left(1 - v\right) + 1}{\delta\left(1 - v\right)} < \left(1 - v\right)T < AF$$

while

$$\frac{dx^*}{d\delta} < 0 \text{ if } AF < \left(1 - v\right)T.$$

It is also easily shown that the equilibrium illegal disposal decreases with the unit fine T and increases with waste related taxation, that is:

$$\frac{dx^*}{dt} = F\frac{v}{\mu\delta\left(1 - v\right)} > 0$$

$$\frac{dx^*}{dT} = F\frac{v^2}{\delta\left(\mu + v\mu\delta\right)}\frac{\delta + 1}{v - 1} < 0$$

The impact of a change in the discount factor on the equilibrium bribe is less straightforward. Indeed, we can write:

$$\frac{db^*}{d\delta} = \frac{\partial b^*}{\partial x^*}\frac{dx^*}{d\delta} + \frac{\partial b^*}{\partial\delta}$$

where the first and the second term are respectively the indirect and direct effect. As $\frac{\partial b^*}{\partial x^*} > 0$ and the direct effect is $\frac{\partial b^*}{\partial \delta} = Fv\frac{x}{\delta^2(v-1)} < 0$, we can in principle expect a patient bureaucrat not to need a very large bribe in order to make corruption possible as an equilibrium when $\frac{dx^*}{d\delta}$, while in the opposite case the net effect is ambiguous.

When $AF < (1-v)\,T$ we have $\frac{dx^*}{d\delta} < 0$ and, then, $\frac{db^*}{d\delta} < 0$. In words, a higher discount factor reduces the equilibrium bribe when the expected gain from corruption (savings in the expected fine on illegal disposal in the absence of corruption) is sufficiently high. Also, when the bureaucrat and the firm are very patient, i.e. they care a lot about the possibility of future corruption, a relatively low level of illegal disposal also arises, as the low bribe can only guarantee that a low illegal waste disposal can take place without violating the incentive compatibility constraint.

When instead $Fv\frac{\delta(1-v)+1}{\delta(1-v)} < (1-v)\,T < AF$ we have $\frac{dx^*}{d\delta} > 0$ and the total effect on the bribe is ambigous. When the expected fine $(1-v)T$ saved on each unit of illegal disposal due to corruption is not too high, given the very patient bureaucrat, the firm finds it optimal to increase its illegal disposal to push up its gain from corruption. When this indirect effect dominates the direct one, then the equilibrium bribe decreases with the patience of the bureaucract. Though interesting, this result depends, at least partly, on the penalty scheme we have introduced, which is such that the penalty for corruption increases in the level of illegal disposal.

To complete the analysis we compare the illegal disposal levels arising with and without corruption. The result is given in the following Corrollary.

Corollary 3 *When corruption exists we have $x^* > x^G$.*

Proof. *It is easily shown that*

$$x^* - x^G = \frac{(1-v)^2\,\delta T - (\delta\,(1-v)+1)\,vF}{\mu\delta\,(1-v)\,(v\delta+1)}$$

so that it could be the case that $x^* < x^G$ if only if

$$(1-v)\,T < \frac{\delta\,(1-v)+1}{\delta\,(1-v)}vF;$$

the above inequality clearly contradicts our assumption for the existence of a *"corruption" equilibrium. This is enough to show that when a corruption equilibrium exists then we always have $x^* > x^G$.* ■

Tough fine schemes have opposite impacts on the spread between $x^* - x^G$: an increase in the fine for illegal disposal in the absence of corruption (T) leads to a higher illegal disposal when corruption occurs, so that the spread widens, that is:

$$\frac{d\left(x^* - x^G\right)}{dT} = \frac{1}{\mu + v\mu\delta}\left(1 - v\right) > 0$$

On the other hand, a larger T brings about a decrease both in x^G and x^*, but, its effect is larger (in absolute terms) on x^G, so that

$$\frac{d\left(x^* - x^G\right)}{dF} = -\frac{v}{\mu\delta\left(v\delta + 1\right)\left(1 - v\right)}\left(\delta\left(1 - v\right) + 1\right) < 0$$

In general the main policy implication is that the authority should always increase the fine for illegal disposal to reduce its production, regardless the presence of corruption. However this policy is more effective under corruption. A soft penalty scheme for corruption (low F) increases illegal disposal under corruption, therefore a tough penalty scheme is always a good policy because it reduces illegal disposal when corruption takes place.

More interesting conclusions in terms of policy follows from the discount factor. The condition $x^* > x^G$ takes place when δ satisfies the following condirion[8]:

$$\delta > \widetilde{\delta} \equiv \frac{vF}{\left(1 - v\right)\left(\left(1 - v\right)T - vF\right)} \tag{4}$$

Taking the derivatives with respect to F, T and v, i.e. our enforcement parameters, we get[9]:

$$\frac{d\widetilde{\delta}}{dF} = T\frac{v}{\left(Fv - T + Tv\right)^2} > 0$$

$$\frac{d\widetilde{\delta}}{dT} = -F\frac{v}{\left(Fv - T + Tv\right)^2} < 0$$

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[8] In fact we have $\widetilde{\delta} < 1$ if $\left(1 - v\right)T > Fv\frac{v-2}{v-1}$; this condition is implied by the usual condition $\left(1 - v\right)T > Fv\frac{\delta(1-v)+1}{\delta(1-v)}$ because $Fv\frac{\delta(1-v)+1}{\delta(1-v)} > Fv\frac{v-2}{v-1}$.

[9] $\frac{d\widetilde{\delta}}{dv} < 0$ if $\frac{v}{(1+v)}vF < T\left(1 - v\right)$ that is implied by the usual condition $\frac{\delta(1-v)+1}{\delta(1-v)}vF < T\left(1 - v\right)$ because $\frac{\delta(1-v)+1}{\delta(1-v)}vF > \frac{v}{(1+v)}Fv$

$$\frac{d\widetilde{\delta}}{dv} = -\frac{F}{(v-1)^2} \frac{Fv^2 - T + Tv^2}{(Fv - T + Tv)^2} > 0$$

We can conclude that the more patient is the firm (and the bureaucrat), the higher is illegal disposal under corruption. Inequality (4) states the equilibrium condition on the discount factor, so that a more patient firm and bureaucrat (higher discount factor) makes the illegal disposal issue even worse. This result seems to suggest a relevant policy implication. Indeed, according to standard theory on repeated games, the discount factor measures the frequency of interaction among players (higher discount factor meaning high frequency of interaction between the bureaucrat and the firm); in our model the frequency might be interpreted as the number of inspections required from the bureaucrat within each period. More frequent controls would therefore imply higher illegal disposal when corruption between the bureacrat and the firm exists; this is because a high frequency (δ) works as a device to enforce corruption in the repeated interaction. More controls by the same bureaucrat increase the willingness to produce illegal disposal when corruption exists. Another interesting interpretation of this result stems from addressing the discount factor as a measure of the probability that the "same" two players still interact in the future. In this terms our results imply that when corruption exists, less frequent controls by the "same" bureaucrat are necessary to reduce illegal disposal, or, seeing it the other way round, frequent changes in the position held by the bureaucrat when corruption occurs can narrow the gap between illegal disposal levels with or without corruption (by reducing the illegal disposal under corruption toward the level without corruption). Seeing it the other way around, frequent changes in the bureaucrat makes corruption, when it exists, less drammatic in terms of illegal disposal.

The threshold value of the discount rate, $\widetilde{\delta}$, depend on the enforcement parameter in a standard way: the willingness to be corrupted increases in the fine T on illegal disposal and decreases in the probability of being caught and in the penalty. However these simple results suggest some interesting combinations: a higher fine for illegal disposal should be associated to less frequent inspections of the same bureaucrat, frequent inspections and a low turn over of the bureaucrat should be associated to a higher penalty for corruption and a good monitoring.

5 Conclusions

Despite the increasing evidence of the role played by corruption in waste related problems, very little has been said so far on this topic. The aim of our paper has been to move a first step in this respect. Indeed, our results, show that corruption might arise as an equilibrium strategy in a repeated "waste policy" game where illegal disposal is possible, even if the stage game does not imply any corruption. Also, we show interesting comparative statics results, in particular with reference to the impact of the discount rate on the equilibrium value of the bribe and on the level of illegal disposal under corruption. Finally, we derive relevant policy implications, suggesting that in order not to exacerbate the illegal waste disposal problem, a slow turnover of bureaucrats and/or too frequent controls should be avoided, as they could act as a corruption enhancing device.

6 References

Becker, G. S. and Stigler, G. J. (1974), Law Enforcement, Malfeasance and the Compensation of Enforcers, *Journal of Legal Studies*, 3: 1-18.

Choe, C. and Fraser I. (1999), An economic analysis of household waste management, *Journal of Environmental Economics and Management*, 38: 234-46.

D'Amato, A. and Zoli, M. (2012), Illegal Waste Disposal in the Time of the Mafia: a Tale of Enforcement and Social Well Being, *Journal of Environmental Planning and Management*, 55: 637-55 .

Dechenaux, E. and Samuel, A. (2012) Pre-emptive Corruption, Hold-up and Repeated Interactions, *Economica*, 79: 258–283.

Fullerton, D. and Kinnaman, T. C. (1995), Garbage, recycling, and illicit burning or dumping, *Journal of Environmental Economics and Management,* 29: 78-91.

Mailath, G.J. and L. Samuelson (2006), *Repeated Games and Reputations*, Oxford University Press

Liddick , D. (2010), The Traffic in Garbage and Hazardous Wastes: An Overview, *Trends in Organized Crime*, 13: 134 –46.

Liddick , D. (2011), *Crimes Against Nature: Illegal Industries and the Global Environment*, Westport: Praeger.

Massari , M. and Monzini, P. (2004), Dirty Business in Italy: A Case Study of Trafficking in Hazardous Waste, *Global Crime*, 6: 285-304.

Mookherjee, D. and Png, I. (1995), Corruptible Law Enforcers: How Should They Be Compensated, *Economic Journal*, 105: 145-59.

Polinsky, A.M. and Shavell S. (2001), Corruption and Optimal Law Enforcement, *Journal of Public Economics*, 81: 1-24.

Samuel, A. (2009) Preemptive Collusion among Corruptible Law Enforcers, *Journal of Economic Behavior and Organization*, 71: 441–450

Shinkuma T. (2003), On the second-best policy of household's waste recycling, *Environmental and Resource Economics*, 24: 77-95.

Sullivan, A. M. (1987), Policy options for toxics disposal: Laissez-faire, subsidization, and enforcement', *Journal of Environmental Economics and Management*, 14: 58-71.