Who left the rubbish in the street? An empirical investigation of illegal waste in England

Gionata Castaldi[*], Alessio D'Amato[†], Mariangela Zoli[‡]

Provisional draft. Do not cite without authors' permission.

This version: August 2017.

[*]Ministero dell'Ambiente e della Tutela del Territorio e del Mare - AT Sogesid.
[†]Corresponding author. University of Rome Tor Vergata and SEEDS. E-mail: damatoa@uniroma2.it.
[‡]University of Rome Tor Vergata and SEEDS.

Who left the rubbish in the street? An empirical investigation of illegal waste in England

1 Introduction

Corruption is a particularly serious problem in the environmental domain. To contrast environmental problems, governments have introduced new and more stringent regulations and controls, which have contributed to expand the sphere of activities through which corrupt administrators can extract bribes. According to the United Nations Office on Drugs and Crime (UNODC, 2012), environmental sectors are particularly prone to corruption, with disastrous environmental, social and economic consequences. Corruption actions spread over all stages of the environmental decision making process: they affect the development of environmental and natural resources policies and regulations, the use of environmental resources, the allocation of permits and certifications as well as environmental enforcement and inspections (USAID, 2002). Waste management is recognized as one of the public administration sectors more exposed to the risk of corruptible behaviors (High Commissioner against Corruption, 2006). It is now well documented that widespread corruption in local administrative authorities responsible for monitoring the entire waste management cycle plays a crucial role in facilitating illegal practices and disposal (Massari and Monzini, 2004), worsening the environmental impact of waste disposal and making even the most ambitious waste policies largely ineffective.

The literature which have explored the links between corruption and environmental outcomes has generally focused on enforcement actions as the main channel through which bribery can affect policy non-compliance. Specifically, the idea is that, when public enforcers can be corrupted, the lower expected penalties for non-compliance have the effect of diluting deterrence of enforcement actions. In this paper, we suggest another possible channel through which corruption can affect environmental non-compliance, namely through a reduction of the efficiency of the agency in charge of managing waste collection and disposal services.

Our work, then, relies on two different strands of literature.

From a theoretical point of view, much of the existing work on corruption deals with monitoring problems, which arise when a principal (such as the government) gives supervisory powers to a self-interested inspector; in this setting, the literature explores whether bribe taking can be deterred through incentive payments and fines (Damania, 2002). In Mookherjee and Png (1995), for instance, a regulator delegates environmental enforcement to an inspector responsible for monitoring the pollution emitted by a firm. This action provides scope for corruption because the firm can bribe the inspector to under-report its pollution levels. Bribery is possible because the regulator can neither control the inspector's monitoring effort nor prevent the firm from bribing the inspector. However, the regulator can try to increase the inspector's monitoring efforts by offering a reward, and imposing a penalty (on both the inspector and the firm) when the bribery is discovered. The authors show that increasing the penalties for corruption reduces the inspector's incentive to monitor, whilst increasing the inspector's compensation policy increases the inspector's incentive to monitor. In Polinsky and Shavell (2001), corruption takes (also) the form of bribery of public enforcers to avoid reporting violations. A relevant conclusion in this paper is that corruption dilutes deterrence, because the bribe payments cost less than sanctions. Also, it may be desirable to monitor and punish corruption in order to raise the offender's costs in terms of bribe payments plus the expected sanction for bribery.

The second strand of literature we rely on includes some recent papers exploring the impact of corruption on efficiency. Dal Bò and Rossi (2007), for instance, investigate the relation between corruption and the efficiency of electricity distributors in Latin America, from both a theoretical and an empirical viewpoint. Their theoretical model assumes that the firm's output depends not only on the amount of labour used in the production function, but also on the managers' supervision, which has the effect of raising the firm's productivity. The idea is that, given the number of workers, managers that supervise them closely obtain better performance and higher output. In this context, corruption diverts managerial effort away from the productive process, implying that more inputs are needed to meet the firm's service obligations. The theoretical prediction of the model is that more corrupt countries will be characterized by less efficient firms. The authors then test this prediction in the empirical part of their study, and find that more corrupt countries tend to have more inefficient firms, i.e. firms that employ more labour to produce a given level of output. Abrate et al. (2015) explore the link between corrutpion and efficiency with specific reference to solid waste collection activities in Italian municipalities and show that corruption increases significantly cost inefficiencies in the provision of waste services. In particular, the authors suggest that fighting corruption can bring significant efficiency gains, in the order of €10-50 million for two of the Italian biggest cities, Milan and Rome. Nevertheless, all previous contributions do not explore the indirect relationship between corruption and environmental non-compliance through its effects on efficiency.

In this paper, on the contrary, we aim at investigating the existence of potential interactions between corruption and environmental outcomes, mediated by effects in terms of (reduced) efficiency and enforcement efforts. To test theoretical hypotheses suggested by the model developed in Section 2, we use, as a case study, fly-tipping events in the UK in 2009-2015. Fly-tipping has the golden share of waste crime in the UK and is one of the major problems that local authorities and central governments have to tackle. In 2005, English local authorities were required to answer a survey on fly-tipping; as a result, 73 percent of them classified fly-tipping incidents as a "significant" or "major" problem, compared to 49 percent in 1997 (Webb, 2006). Concernes about this phenomenon have also increased in the latest years as a consequence of the relevant growth of fly-tipping events (+ 20 percent in 2013 with respect to 2012, DEFRA, 2014). Among the potential drivers of the increase in illegal waste disposal, inefficiencies generated by corruption can be considered as a relevant explanation.

Since collection and, in many cases, disposal of waste is managed at the local authority level in England, public officials might profit to turn a blind eye for private gains. In this sense, Transparency International UK describes the case of a local official that "had asked British Gas to add an extra charge of £% 0.04 per unit of energy to their contract as a comfort blanket", which would be reclaimed by private furnitors at the end of the year (Transaprency International, 2014). Indeed, the official was succesfully prosecuted after gaining in his bank account £400.000. The waste sector is a very vurnerable sector, since half of waste management services in local authorities are out-sourced for contracts amounting around £1.3 billion. Cases of fraud might slip over the net, since "where a waste development site is developed on council land and the council is a joint venture owner of the company which holds the contract for managing the waste", it is difficult to identify offenders (Transparency International, 2014).

All these issues suggest the need to complement the analysis of the traditional channel through wich corruption affects illegal waste disposal (*via* enforcement efforts) with an investigation of the impact through its effects on the efficiency of the waste management sector.

The rest of the paper is structured as follows. Section 2 presents the theoretical model and introduces the main research hypotheses. Section 3 describes the data and introduces the empirical model and identification strategy. Section 4 provides the empirical findings and Section 5 concludes.

2 Conceptual Framework

Theoretical Analysis and Research Hypotheses

We model a setting where a regulated waste producing firm pays a unit price on collected waste g. The total waste produced is normalized to 1 and assumed to be exogenous, so that fly tipping is given by $1 - g$. If fly tipping is discovered, the regulated agent has to pay a unit expected fine equal to F. In our very simple model this is intended to measure broadly speaking the stringency of controls by the police authority and the harshness of punishments.

Legal waste disposal is influenced by the related private costs, given by a cost function $c(g)$, with $c' > 0$ and $c'' > 0$, and by a unit PAYT tariff t, which is decided by an upstream authority, and is taken as exogenous by the waste producers. As a result, the regulated agent chooses g to solve:

$$\min_{g} c(g) + tg + F(1 - g)$$

First order conditions, which are straightforwardly necessary and sufficient, require:

$$c'(g) + t - F = 0 \tag{1}$$

Totally differentiating we get:

$$c''(g)\, dg + dt - dF = 0$$

so that, standard comparative statics results imply:

$$\frac{dg}{dt} = -\frac{1}{c''(g)} < 0 \tag{2}$$

$$\frac{dg}{dF} = \frac{1}{c''(g)} > 0 \tag{3}$$

Moving upwards, a waste management authority chooses the effort to reduce the PAYT tariff, by improving efficiency. The waste authority receives a unit wage w to perform efficiency enhancing effort, that we label as y; the costs of effort are given by an increasing and convex function $\varepsilon(y)$[1]. On the other hand, we assume that the waste related tariff is set to cover waste collection and disposal costs, according to a function $\psi(g)$ such that $\psi' > 0$, $\psi'' > 0$ and $\psi(0) = \psi'(0) = 0$, and decrease with efficiency enhancing effort y. The resulting "efficiency" adjusted costs are therefore given by $(1-y)\psi(g)$. Balancing the budget of waste management costs requires :

$$tg = (1-y)\psi(g) \tag{4}$$

namenly, tax revenues on legal disposal (tg) equal waste management costs. Totally differentiating (4) we get:

$$\frac{dt}{dy} = -\frac{\psi(g)}{\left(g + (t-(1-y)\psi'(g))\frac{dg}{dt}\right)} \tag{5}$$

which is negative if $g + (t-(1-y)\psi'(g))\frac{dg}{dt} > 0$. A sufficient condition for this is

$$\big(t-(1-y)\psi'(g)\big) = (1-y)\left(\frac{\psi(g)}{g} - \psi'(g)\right) < 0$$

where the second equality stems from the budget balancing condition, that may be rewritten as $t = (1-y)\frac{\psi(g)}{g}$. This is indeed the case, under the assumed shape of the $\psi(.)$ function. Also, comparative statics imply:

$$\frac{dt}{dF} = \frac{(t-(1-y)\psi'(g))\frac{dg}{dF}}{\left(g + (t-(1-y)\psi'(g))\frac{dg}{dt}\right)} > 0.$$

Given the budget balancing tax rate, the waste authority chooses effort y to maximize:

$$\max_y wy - \varepsilon(y).$$

First order conditions are in this case:

$$\varepsilon'(y) = w \tag{6}$$

so that, straightforward comparative statics implies:

$$\frac{dy}{dw} = \frac{1}{\varepsilon''(y)} > 0. \tag{7}$$

In the first stage, the budget authority allocates a given (say, yearly) budget B between waste related expenses (in our setting the wage w times efficiency enhancing effort y) and "unproductive" expenses, in the terminology of Abrate et al. (2015), labelled as u. These unproductive expenses generate (career, rent or election related) benefits to the budget authority. We label the (marginal and average) net benefit from unproductive expenses as τ. We assume that the benefits from unproductive expenses are larger for a larger (weaker) existing corruption (quality of institutions). As a result, the budget authority has to allocate the budget B

[1]To achieve clearer results, for example not depending on third derivatives that would be difficult to interpret, we also assume that the $\varepsilon(.)$ function features a constant second derivative.

between unproductive expenses u and the wage provided to the waste authority to improve efficiency, which totals wy. Of course, the budget authority also gets benefits from efficiency in waste management (unit marginal benefits being b). The problem can therefore be written as follows:

$$\max_w \tau u + by \tag{8}$$

subject to the budget constraint $B = u + wy$ (we allow this to be satisfied as a strict equality). As a result, $u = B - wy$. Substituting into (8), the problem of the budget authorty becomes:

$$\max_w \tau (B - wy) + by$$

As a consequence, the first order conditions are:

$$\tau \left(-y - w \frac{dy}{dw} \right) + b \frac{dy}{dw} = 0 \tag{9}$$

Totally differentiating and accounting for the assumption of a constant second derivative for $\varepsilon(.)$, we get:

$$d\tau \left(-y - w \frac{dy}{dw} \right) - 2\tau \frac{dy}{dw} dw + db \frac{dy}{dw} = 0$$

so that

$$\frac{dw}{d\tau} = - \frac{\left(y + w \frac{dy}{dw} \right)}{2\tau \frac{dy}{dw}} < 0. \tag{10}$$

Clearly, due to the fixed budget, we can conclude that $\frac{dw}{db} > 0$.

We get therefore our main testable implications.

H1. *Corruption implies larger incentives to fly tipping through a weaker enforcement.*

The conclusion that a weaker enforcement leads to a larger fly tipping is straightforward from (3), and is coherent with the literature investigating the deterrence effect of enforcement in driving environmental compliance (see, among others, Gray and Shimshack, 2011 and Almer and Goeschl, 2013). The bulk of this literature suggests that compliance increases with the level of enforcement. In this sense, waste crime is a good framework where to test the presence of deterrence effect due to enforcement, since illegal waste disposal is mainly driven by economic motives (Almer and Goeschl, 2013). Our first testable implication is then completed by referring to a first, standard, channel, through which corruption may affect illegal disposal. Indeed, according, among others, to Polinsky and Shavell (2001), corruption dilutes deterrence, implying in our model a lower F and, as a result, larger fly tipping.

H2. *Less efficient waste management implies stronger incentives to fly tipping.*

This result comes from (2) and from (5). A lower efficiency implies larger costs to be covered, given the level of legal disposal, and therefore a larger unit tax on legal disposal. This drives down (up) legal disposal (fly tipping).

Clearly, also the factors that make cost reducing effort more difficult, such as landfills availability, increase the incentives towards illegal disposal.

H3. *More pervasive corruption implies lower efficiency. This triggers an indirect impact on fly tipping.*

Our third testable implication can be obtained from (7) and (10), as $\frac{dy}{d\tau} = \frac{\partial y}{\partial w} \frac{\partial w}{\partial \tau} < 0$.

In other words, larger net benefits from corruption imply weaker incentives by the waste authority to promote efficiency. Clearly, as a more pervasive corruption decreases the efficiency related effort and, therefore, increases t (from H2), this leads to a larger fly tipping. This is, to our knowledge, a previously uninvestigated channel through which corruption may affect fly tipping and, more generally, illegal behaviour.

3 Empirics

Data

We test the theoretical hypothesis outlined in Section 2 by building, through different data sources, a unique dataset of 325 English municipalities covering the time period 2009-2015.
Data on the number of fly – tipping incidents and on enforcement actions undertaken in English municipalities originate from the DEFRA's Flycapture database. Data on the total number of fly–tipping incidents cover the period from 2009 to 2015. We enrich our dataset with figures on waste production at local authority level provided by DEFRA. These data are disaggregated into household waste (for definitions, refer to Schedule 1 of the Controlled Waste Regulation, 1992), further divided among recycled and not recycled. Recycling/reuse/composting is further disaggregated into dry recycling/reuse and household green recycling/reuse (green waste for compost). To build our *proxy* for corruption, we collect data for the level of general crime in each municipality released by the Home Office Police Recorded Crime (PRC) of the Office for National Statistics (ONS).
We gather geographic data, such as the number of authorized landfills distant 2 or 5 miles from the urban center, by the UK Environment Agency.
Socio-demographic variables are provided by the ONS and its Official Labour Market Statistics (Nomis). Examples include population density, number of unemployed people above 16, number of inhabitants divided by level of education and the number of firms in the manufacturing and construction industries.
Finally, we build our efficiency score through the data released by the Audit Commission on per–capita waste management yearly expenditure disaggregated for collection and disposal.

The Empirical Model

To test the research hypothesis derived in Section 2, we estimate causal mediation through regression analysis. Summing up, we test the existence of a causal chain between a first variable (corruption), two intervening variables (efficiency and enforcement) that in turn affect a third variable (fly–tipping). Our two variables, efficiency and enforcement, represent our mediators. Said differently, our independent variable (corruption) affects a dependent variable (fly–tipping) through two intervening variables (efficiency and corruption) (e.g., Preacher and Hayes,2008). Figure 1 depicts the path diagram of our model that following a mediation design, where corruption (path (b)) supposedly has an indirect effect on fly–tipping through the mediation of efficiency and enforcement. Mediating modelling is especially popular in sociology and medicine (see, among others, Raver and Gelfald, 2005; Holbert et al., 2003; Reynolds et al., 2004).
In order to compute our mediation model, we estimate a two–stage model: in our first stage, we regress the efficiency score on the lagged values of corruption and control for socio–demographic variables, such as the ratio of the population divided by education level, the percentage of unemployed and the number of landfills located at 5 miles distance from the urban center. This model should test **H3**, namely the hypothesis, suggested by the literature, that the level of corruption negatively affects efficiency (Abrate et al., 2015).

$$Z_{it} = \beta CI_{it-1} + \gamma Unemployment_{it} + \zeta Education_{it} + \delta Landfill_{it} + \varepsilon_{it}$$

In the same way, we estimate the effect of corruption on the enforcement variable, testing for **H1** and adding the per–capita yearly amount of waste regularly collected .

$$L_{it} = \beta CI_{it-1} + \gamma Unemployed_{it} + \zeta Education_{it} + \delta per - capitaCollectedWaste_{it} + \varepsilon_{it}$$

Through our first stage, we estimate the relationship of path (a) depicted in Figure 1. Namely, if our indipendent variable (corruption) affects our two potential mediators (efficiency and enforcement), we are then able to test the mediation process through the second stage (e.g. Sobel, 1982).
After the first stage, we take the predicted values of the efficiency score and the enforcement variable and include them at the second stage regression. In order to test the direct effect of corruption in our model, we also include it in our model[2]. We model what determines the number of fly-tipping incidents at time t (Y_{it}) according to our theoretical hypotheses:

$$Y_{it} = \lambda \hat{Eff}_{it-1} + \gamma \widehat{Enforcement}_{it-1} + \zeta corruption_{it-2} + \zeta X_{it} + \varepsilon_{it}$$

where $\hat{Eff}_{it}$ is the fitted value of the efficiency score, $\widehat{Enforcement}_{it}$ is the fitted value of our enforcement variable and X_{it} controls for the share of construction and manufacturing firms divided by size. We decide to focus on these industries since the first might be related to the level of production of inert, polluting waste that is usually a relevant case–study in fly–tipping (Webb et al., 2006), while the second one is a *proxy* of the level of economic activity in a given municipality (as in Almer and Goeschl, 2013).
Our independent variable, corruption, should be a *proxy* of the quality of the local institutions at work in a given municipality. To do so, we use three variables gathered from crime records: fraud for abuse of position, fraud for disclosing information and perverting the course of justice. These three variables are provided by the Home Office Police Recorded Crime revised by the ONS at the municipal level. The first variable is defined as someone abusing of their authority or trust for financial or personal gain. The second type of fraud is related to disclosing information to make gain for himself or another or expose loss to another. Perverting the course of justice is when someone prevents justice to being served to him or to another. All these variables link to the prevailing definition of corruption in economic and political scientists works as " ...the abuse of a public or private office for personal gain. The active or passive misuse of the powers of Public officials (appointed or elected) for private financial or other benefits" (OECD, 2008).
Let us now pass to our two mediators. We build our first mediator, efficiency, as a score ranging from 0 (least efficient) to 1 (most efficient) for each municipality through the Data Envelopment Analysis (DEA) initiated by Charnes et al. (1978) and further developed by Banker et al. (1984). The main idea behind this methodology is that within comparable decision making units (in our case, municipalities), those exhibiting best practices could be identified and

[2]In order to avoid partial collinearity with the predicted values of the enforcement variable and the efficiency score, we lag corruption by two periods. The variance inflation factors for corruption, not reported in our estimates, is 3.81, thus excluding large partial collinearity

form the efficient frontier. Inefficient units are then compared to these benchmarks. The DEA frontier is directly obtained by the data through bootstrapping and has the great advantage of relaxing any hypothesis on the functional form of the hypothetical production function. In our case, we use a first stage DEA[3], where our input is the yearly per – capita household's waste management expenditure and the output is the yearly total amount of the household's collected waste per local authority. In our case, we consider our local authorities as output oriented, that is, given the yearly budget, policymakers are willing to maximize their output[4]. We identify our second mediator, enforcement, as the number of total investigations (per 100 inhabitants) on fly – tippiing incidents. The enforcement team records the incident, identifies the evidence available and decides or has to decide the action to undertake. Similarly, we index our dependent variable, the number of fly–tipping incidents, per 100 inhabitants. Table 1 and 2 respectively report the summary statistics of the variables included in our first and second stage regression.

Identification strategy

The empirical estimation on illegal activities is statistically challenging and has to be addressed very carefully in order to avoid biased results. This is due to several reasons: first of all, higher reported crime rates may be due both to a higher incidence rate and/or to a better monitoring and enforcement activity. In order to address carefully this problem, we add socio - demographic variables that might possibly influence the level of monitoring or enforcement in our municipalities. This captures any variation in official statistics due to dark figures (Almer and Goeschl, 2013).

Secondly, endogeneity issues might arise due to the aggregation of different crimes in one crime index (Cherry and List, 2002). We concentrate on fly – tipping only. This should overcome any possible endogeneity issue due to aggregating different crime typologies in one index.

Third, not being able to address for heterogeneity issues might lead to biased results. Our small panel dataset permits to carefully address this challenge by specifying a panel data analysis.

Our next step is to choose the best estimation strategy due to data characteristics and the effects we want to estimate.

As a consequence, in order to address the above issues, we opt for a FE estimator that rules out the possibility of having omitted variables. In our case, this is particularly relevant, since we can control for important fixed effects related to fly–tipping such as the increasing rate of the landfill tax, determined at the national level.

4 Empirical Findings

In the first column of Table 3, we specify our first stage regression in order to test **H3**, namely if corruptive behaviors undermine waste management efficiency. As it is possible to see, our estimation confirms findings from the literature (Abrate et al., 2015): a higher level of corruptive behavior leads to a lower level of efficiency in the waste management sector. This could be due to different reasons: corruption, that is not directly related to waste management, could weaken the institutional framework, making it more costly to perform efficiently. This

[3]As for any non - parametric estimator, DEA is very sensitive to outliers. A thorough analysis on these was conducted before running any estimate.

[4]We performed the DEA for an input – oriented local authorities, defined as input minimizing given a certain amount of output. The results are very similar and available upon request.

is the result, for instance, in Abrate et al. (2015) where corruption is found to have a negative and significant effect on cost efficiency and this result is robust through the specification of different local indicators. Our analysis, despite using a different measure of corruption, a different estimation of the efficiency frontier and being applied to a different territorial context, yields very similar results, strenghthening the strand of research on corruption of micro-level data in the waste realm. Furthermore, our first estimate tells us that the quality of social capita matters in determing efficiency: municipalities displaying larger ratio of high–skilled citizens perform better, probably due to a higher demand for public services. This result is similar to the one in Benito-Lopez et al. (2011) where the values of social capita, proxied by per–capita GDP, increases the efficiency score in street cleaning and refuse collection service. Finally, a larger number of landfills might bring to a decrease on the efficiency side, due to the potential loss of revenues provided by policy measures such as the landfill tax.

In the second column of Table 3 we report the estimate of the first stage regression in order to test **H1**. As it is possible to see, in accordance with the theoretical literature, we cannot reject the hypothesis that corruption dilutes deterrence, thus yielding to a lower enforcement (Polinsky and Shavell, 2011). Our results, strongly predicted in the theoretical framework, is partially new on the empirical side, especially in the environmental realm where most of the findings concentrate on the deterrence effect on crime and not on factors that could undermine it. This could encourage further research on the effect of institutional quality, that we *proxy* through corruption, on enforcement and deterrence in relation to environmental crimes.

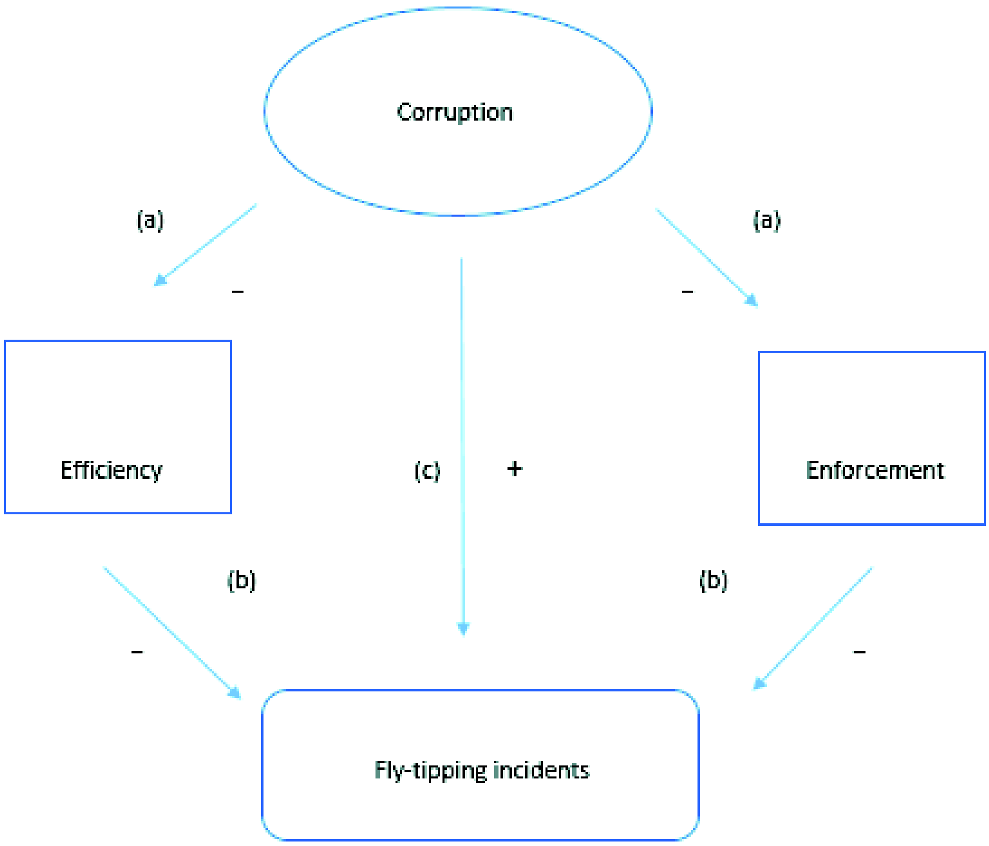
These results support the existence of path (a) in Figure 1, i.e. the hypothesized direct effect of corruption on enforcement and efficiency is non–zero. Now, in our second stage regression, we test whether our two mediators have an indirect effect on fly–tipping (path (b) in Figure 1). Moreover, we include the possible direct effect of corruption on our outcome variable (path (c) in Figure 1). In this model, if mediators are significant, then there is a mediation effect on fly–tipping. If corruption is statistically significant, we would say that there is partial mediation. If, on the opposite, corruption yields no significance, we would say that there is full mediation (Sobel, 1982).

As we can see from the third column of Table 3, estimates suggest that there is full mediation of efficiency, while the enforcement variable is not mediating on fly–tipping. Corruption yields no direct effect, thus being fully mediated by the efficiency score, at least in our model.

We now need to further investigate the mediation pathway of efficiency on fly–tipping. To do so, we refer to the Sobel–Goodman test reported in Table 4 that provides insights on the intensity of the mediating effect of corruption through efficiency. Our predicted efficiency score has a significant impact through corruption, mediating around 48% of the corruption's effect on fly–tipping[5]. As a consequence, corruption is fully mediated by efficiency and we cannot reject the hypothesis that it exert an indirect effect on fly–tipping.

[5]The test was robust to bootstrap standard errors.

Figure 1: Path diagram of the empirical model



Source: Authors' elaboration

Table 1: Summary statistics-First Stage

Variables	(1) Mean (SD)
Efficiency score	0.392
	(0.205)
Investigations	0.954
	(1.808)
Corruption	21.17
	(20.10)
Unemployment rate	7.154
	(3.039)
No educ.	9.306
	(3.874)
Other educ.	5.837
	(2.235)
Primary educ.	35.23
	(4.924)
Secondary educ.	49.63
	(7.466)
Intermediate educ.	21.75
	(3.553)
High educ.	31.64
	(8.768)
Density	6.020
	(6.438)
Number of landfills (5 miles)	2.460
	(2.825)
Per-capita collected waste	0.805
	(0.147)
Observations	530

Table 2: Summary statistics-First Stage

Variables	(1) Mean (SD)
Total incidents	2.097
	(2.465)
(Fitted) Eff.Score	0.425
	(0.244)
(Fitted) Investigations	0.911
	(2.941)
Small construction	0.0571
	(0.0184)
Medium construction	0.00636
	(0.00607)
Large construction	0.000291
	(0.00157)
Small manufacturing	0.176
	(0.0430)
Medium manufacturing	0.0461
	(0.0210)
Large manufacturing	0.00975
	(0.0125)
Observations	345

Table 3: Core model

	First Stage Efficiency Score	First Stage Total investigations	Second Stage Total incidents
Corruption_{t-2}	-0.00583***	-0.016438*	
	(0.00140)	(0.00843)	
Unemployment rate	-0.00661	0.000132	
	(0.00549)	(0.000123)	
No educ.	-0.0844	-0.00256	
	(0.116)	(0.00344)	
Other educ.	-0.0794	-0.00301	
	(0.115)	(0.00325)	
Primary educ.	-0.0841	-0.00356	
	(0.116)	(0.00335)	
Secondary educ.	-0.0676	-0.00286	
	(0.115)	(0.00328)	
Intermediate educ.	0.0204***	0.000511	
	(0.00422)	(0.000531)	
High educ.	0.0108**	-0.000164	
	(0.00459)	(0.000227)	
Density	0.0151	-0.00427	
	(0.0381)	(0.00283)	
Number of landfills (5 miles)	-0.0121*		
	(0.00619)		
Per-capita collected waste		0.0106	
		(0.00977)	
(Fitted) Eff. score_{t-1}			-2.398*
			(1.310)
(Fitted) $\text{Investigations}_{t-1}$			-23.48
			(31.10)
Corruption_{t-2}			-0.0257
			(0.0182)
Small construction			14.13
			(14.20)
Medium construction			-23.11
			(20.88)
Large construction			-41.50
			(79.11)
Small manufacturing			-1.942
			(5.320)
Medium manufacturing			-24.15**
			(10.33)
Large manufacturing			13.25
			(13.91)
Constant	7.282	0.332	4.616***
	(11.57)	(0.326)	(1.354)
Observations	530	690	345
R-squared	0.264	0.038	0.133
Number of local authorities	189	192	180

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 4: Sobel–Goodman Test

VARIABLES	Total incidents	Perc. of mediating effect
(Fitted) Eff.Score	-2.573***	48,3
	(0.570)	
Constant	2.859***	
	(0.343)	
Observations	348	
Sobel (p-value)	0.0000	
Goodman-1 (p-value)	0.0000	
Goodman 2 (p-value)	0.0000	
R-squared	0.155	

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

References

[1] Abrate, G., Erbetta, F., Fraquelli, G., and Vannoni, D., (2015). The cost of corruption in the Italian solid waste industry. Industrial and Corporate Change, 24(2), 439-465.

[2] Almer, C. and T. Goeschl (2013): The sopranos redux: The empirical economics of waste crime, Regional Studies, 49 (11), pp. 114.

[3] Banker, R. D., A. Charnes, and W. W. Cooper (1984): Some models for estimating technical and scale inefficiencies in data envelopment analysis, Management science, Vol. 30, No. 9, pp. 10781092.

[4] Benito-Lopez, B., M. del Rocio Moreno-Enguix, and J. Solana-Ibanez (2011): Determinants of efficiency in the provision of municipal street-cleaning and refuse collection services, Waste management, Vol. 31, No. 6, pp. 10991108.

[5] Charnes, A., W. W. Cooper, and E. Rhodes (1978): Measuring the efficiency of decision making units, European journal of operational research, Vol. 2, No. 6, pp. 429444.

[6] Cherry, T. L. and J. A. List (2002): Aggregation bias in the economic model of crime, Economics Letters, Vol. 75, No. 1, pp. 8186.

[7] Dal Bò, E. and Rossi, M.A., (2007). Corruption and Inefficiency: Theory and Evidence from Electric Utilities', Journal of Public Economics, 91: 939-62.

[8] Damania, R. (2002). Environmental controls with corrupt bureaucrats. Environment and Development Economics, 7(03), 407-427.

[9] Gray, W. B. and J. P. Shimshack (2011): The effectiveness of environmental monitoring and enforcement: A review of the empirical evidence, Review of Environmental Economics and Policy.

[10] High Commissioner against Corruption (Alto Commissariato per la prevenzione e il contrasto della corruzione e delle altre forme di illecito nella Pubblica Amministrazione), (2006). Studio sui pericoli di condizionamento della Pubblica Amministrazione da parte della Criminalità Organizzata.

[11] Holbert, R. L., Shah, D. V., and Kwak, N. (2003). Political implications of prime-time drama and sitcom use: Genres of representation and opinions concerning womens rights. Journal of Communication,53, 45-60.

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

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

[14] OECD (2008): Corruption, A Glossary of International Standards in Criminal Law: OECD Glossaries.

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

[16] Preacher, K. J. and Hayes, A. F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. Behavior research methods, 40(3), 879-891.

[17] Raver, J. L. and Gelfand, M. J. (2005). Beyond the individual victim: Linking sexual harassment, team processes, and team performance. Academy of Management Journal,48, 387-400.

[18] Reynolds, K. D., Bishop, D. B., Chou, C.-P., Xie, B., Nebeling, L., and Perry, C. L. (2004). Contrasting mediating variables in two 5-a-day nutrition intervention programs. Preventive Medicine, 39, 882-893.

[19] Sobel, M. E. (1982). Asymptotic confidence intervals for indirect effects in structural equations models, Sociological Methodology (pp. 290-312). San Francisco: Jossey-Bass.

[20] Transparency International UK (2014), Corruption in UK local governments: the mounting risk.

[21] UNODC, (2012). Corruption, Environment and The United Nations Convention Against Corruption, United Nations Office on Drugs and Crime, February 2012.

[22] USAID, (2002). Corruption and the Environment, Washington, DC, Authored by: Svetlana Winbourne, Contract No. AEP-I-00-00-00009-00 rapid response task sector studies.

[23] Webb, B., Marshall, B., Czarnomski, S., and Tilley, N. (2006). Fly-tipping: causes, incentives and solutions. Jill Dando Institute of Crime Science, University College London.