# The Sopranos redux: the empirical economics of waste crime

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Abstract

The evidence supporting the argument that enforcement makes environmental policies effective is limited with respect to geographical scope, enforcement tools, and regulatory context. This paper examines non-US evidence on criminal enforcement in the context of illegal waste disposal using a county-level panel dataset of 44 counties from the German state of Baden-Württemberg for the period 1995-2005. The results support the pro-enforcement argument. Cumulatively, there is clear evidence for a general deterrence effect of enforcement intensity on the amount of illegal waste crime. However, regional economic and political economy factors matter significantly for the environmental outcomes. Violations appear to be treated differently depending on their local political economy context. → 108 Words!

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## 1 Introduction

The enforcement of environmental regulation through sanctions and punishment is widely regarded eeffect: Monitoring and enforcement of environmental regulation increases compliance among the general population of regulated parties, not only among those directly targeted by past or ongoing enforcement activities.

While these findings lend support to the idea that without enforcement, environmental policy is likely to be ineffective, many aspects and policy-relevant dimensions of the deterrence mechanism remain poorly understood. This is due both to fundamental challenges of empirical research on illegal behavior with its inherent problems of the dark figure of crime (Dills et al. 2009; Levitt and Miles 2007) and to the strong regional concentration of research in North America. An up-to-date authoritative survey of the recent empirical literature (Gray and Shimshack2011) highlights five unresolved issues: A lack of evidence on international experiences regarding the deterrence effect, the unclear role of industry characteristics, the relative importance of local factors, the relative impact of regulatory tools other than administrative or civil action,and the relationship between targeted and general enforcement. The survey concludes that while our understanding has improved, there is not enough empirical evidence available in the literature to come to a conclusive judgment on how effective different enforcement strategies for environmental regulation are, and why.

The present paper contributes to an ongoing effort among scholars to address some of these unresolved issues. Like other papers examining environmental enforcement and compliance, it studies compliance in the specific context of waste regulations (Sigman 1998; Alberini and Austin 1999; Stafford 2002, Stafford 2006). In most OECD countries, waste started to attract regulatory attention during the 1970s and has remained an area of focus ever since.[i] Waste crime has become a criminal mainstream activity to such an extent that in the general public's mind, illegal waste management has become part and parcel of the standard activities of the typical modern criminal.[ii] As an empirical matter, illegal waste disposal is - at its heart - a crime driven by overwhelmingly

economic motives. Its benefits are relatively tangible: They materialize in the form of savings from bypassing costly environmental regulations and typically increase with its severity.[iii] These facts have led scholars to consider the violation of waste regulations an attractive candidate for studying enforcement effects since waste management should, at least in theory, respond particularly well to appropriate sanctions that balance the benefits and expected costs of crime in terms of expected punishment (Choe and Fraser 1999; Fullerton and Kinnaman 1995, Hoch 1994). The presence of such effects has been firmly established in the context of waste regulations in the United States and to some extent in the context of general environmental protection in the Czech Republic (Earnhart 1997, 2000) and Germany (Almer and Goeschl 2010). The present paper is the first to our knowledge to examine the important category of waste regulations using international evidence. Specifically, the paper examines county-level data on waste crime from the German state of Baden-Württemberg. This state is not only one of the largest and economically most active of the sixteen Landers of the Federal Republic of Germany, it also allows an analysis of high-quality data at the level of its 44 counties. In addition to bringing international evidence to bear on the question of effective enforcement, the present paper responds to the call for more research on enforcement tools for waste regulation other than administrative action (Stafford 2002, 2006) or civil law, e.g. strict liability regimes (Sigman 2010).[iv] The enforcement tool at the center of this paper are criminal sanctions on waste crime. These sanctions differ from administrative and civil enforcement tools in terms of the severity of sanctions available, up to and including incarceration, and in terms of the actors involved, namely police, public prosecutors, and judges at criminal courts. The focus on general deterrence in this paper follows, like in Sigman (1998), from the nature of spatially-disaggregated data on crime rates that is available for analysis. This data consist of enforcement variables and the rate of waste crime in 44 different counties within Baden-Württemberg, exploiting the significant spatial heterogeneity in the density of manufacturing and chemical production activity, population, and local political economy factors within the study area. A related study (Almer and Goeschl 2010) established the presence of a general deterrence effect of criminal law on

environmental crime in general rather than waste crime in particular. That study relied on a spatially much coarser dataset of fifteen German states that did not benefit from county-level data due to data limitations. Understanding more about the importance of enforcement relative to the potential determinants raised by Gray and Shimshack (2011), such as industrial activity and local political factors, requires a richer dataset (Cornwell and Trumbull 1994). Using such data, this paper not only enhances the degree of spatial resolution and the range of explanatory variables, but also stands as a test of replication and robustness of Almer and Goeschl (2010) using a geographical and crime-specific subsample. Waste crime represents a particularly relevant research target: Not only does illegally disposed waste constitute the largest share of environmental crime, it also has greater persistence and a spatially more concentrated impact than other types of environmental crime such as air pollution. The correspondingly higher incentive for victims to report waste crime relative to other environmental crimes facilitates the identification of other factors that are candidates for driving variations in reported waste crime, such as local political economy effects. Assessing the role of political economy factors is important in order to understand better previous empirical evidence on how these factors shape local environmental outcomes through the enforcement pathway. In addition to improved spatial resolution and a deeper examination of waste crime, the paper also examines the inter-temporal dimension by analyzing the relative importance of long-term, as opposed to short-term, effects for the various deterrence components under investigation.

The results of the present paper are threefold. First and foremost, the data support the notion of general deterrence through criminal enforcement: A higher probability of facing criminal sanctions for illegal waste management leads to a significantly reduced presence of waste-related offences. In other words, even though the evidence is drawn from outside the United States and the enforcement tool is unusual by international comparison, it confirms the general conclusion drawn on the basis of US studies on administrative (Sigman 1998, Stafford 2002) and civil enforcement tools (Sigman 2010). On the other hand, while broadly comparable in terms of direction and significance, the deterrence effects of enforcement variables of waste crime in this particular part of Germany are

generally weaker than those for generic environmental crime in Germany as a whole (Almer and Goeschl 2010), pointing to underlying structural and political economy heterogeneities.

The second finding is that the choice of the enforcement tool implies a reliance on different mechanisms of general deterrence of waste-related offences, and that the data bear this out. In the current setting, for example, key deterrents for waste crime are not just the probability of punishment (e.g. through incarceration), but also the decision by the public prosecutor to press charges in a public court of law. The main impact of this decision is not just to raise the overall judicial stakes of a prosecution, but also to bring the presence of a prosecution to the attention of the general population for the first time. In many legal systems that protect individual privacy, such publicity effects may only be available through criminal law proceedings. This is to be borne in mind when comparing different enforcement pathways. The choice of enforcement tools also matters in terms of inter-temporal impact: We find that, when considering their cumulative effects over five years, changes in the punishment probability and the trial probability give rise to substantially larger effects.

In addition to the general deterrence effect and the evidence on drivers, a third finding is that scale effects and various structural determinants impact on the amount of reported waste crime. A number of statistical specifications return income and GDP per capita as significant drivers of the number of offences. This confirms for the case of waste crime the earlier findings that the level of economic activity is a positive driver of general crime (Cornwell and Trumbull 1994), but also of environmental crime in the Czech Republic (Earnhart 2004), offences against the Clean Water Act (Shimshack and Ward 2005) and hazardous waste violations in the US (Sigman 1998). Our spatially more disaggregated level finds that the number of reported illegal waste disposals varies with the degree to which a county depends on industry activity in terms of employment (Grepperud 2002) or tax income. This evidence supports the notion that one particular pathway through which the political economy at the local level determines environmental outcomes is through variations in detection and reporting intensity.

The remainder of the paper is organized as follows. In section 2 we develop the theoretical background that gives rise to four testable hypotheses. Section 3 introduces the data, explains the empirical strategy and its robustness, and sets out the econometric specification. Section 4 presents the results of the tests of the hypothesis defined in section 2, while section 5 concludes with a short discussion.

## 2 Theoretical Considerations

This section develops the testable hypotheses that guide the empirical exercise in section 4. Two objectives drive the selection of hypotheses. The first objective is a test for the presence of deterrence effects in illegal waste management that theory predicts (Choe and Fraser 1999; Fullerton and Kinnaman 1995) and US evidence confirmed (Sigman 1998, Stafford 2002). The results of this test inform about how the empirical evidence of criminal enforcement of waste regulations in a highly industrialized part of Germany compare with the evidence on administrative and civil enforcement in the US and with criminal enforcement of generic environmental offences in Germany as a whole (Almer and Goeschl 2010). The second objective is to test and extend a range of additional determinants of reported illegal activity besides deterrence. This includes structural, economic, and political economy factors that influence environmental offences in general (Hamilton 1996, Helland 1998, Eckert 2004) and waste offences in particular (Stafford 2002, Sigman 2010). As in most other studies of illegal behavior (Cherry and List 2002), the observable evidence available for the empirical test is structurally incomplete and presents endogeneity problems. We discuss these challenges and their resolution in detail in section 3.

### 2.1 General Deterrence

The theoretical literature on illegal waste disposal (Choe and Fraser 1999; Fullerton and Kinnaman 1995) emphasizes a rational choice perspective on regulatory violations that has immediate parallels with the economic model of crime (Becker 1968). There, the gross benefits of illegal waste disposal consist of the avoided cost of proper disposal minus the cost of illegal disposal. The expected costs

consist of the monetary and non-monetary costs that are associated with expected punishment. Under risk-neutrality, its components are the probability of an offender being identified, prosecuted, and penalized for illegal waste disposal on the one hand and the economic cost of the penalty on the other. Costs comprise both monetary categories such as fines and non-monetary categories such as reputation losses and the opportunity cost of spending time in prison.

The economic model of crime is a statement about decisions by individuals. In the empirical literature on the economics of crime, data on the probability of sanctions and on the expected costs of crime at the time of decision-making is generally not available at the individual level. Instead, researcher rely on data that captures aggregate outcomes in order to test the model. The aggregate outcomes that are available for testing an economic model of waste crime for the case of Baden-Württemberg are, on an annual basis, (i) the share of convicted defendants that were sentenced to prison sentences, (ii) the share of convicted defendents that were sentenced to pay a severe fine, (iii) the share of defendents that were convicted (found guilty), (iv) the share of suspected waste criminals that had to stand trial, and (v) the share of cases for which the police identified and apprehended named suspects. These shares can also be summarized (and are known in the literature) as different 'rates': The first share, (i), denotes the incarceration (or prison) rate, (ii) the penalty rate, (iii) the conviction rate, (iv) the trial rate, and (v) the clearance rate. Analogously, at the individual level, these rates can be interpreted as average probabilities of being caught (v), then sent to court (iv), then found guilty (iii), then fined (ii), or incarcerated (i), with the understanding that individual probabilities will necessarily deviate from those of the average. The shares or rates capture the average individual probabilities in hindsight. An empirical question is to what extent potential criminals' decisions are determined by current level of these rates or by their levels in the recent past. We come to this inter-temporal question below. From a terminological perspective, shares, rates, and probabilities ultimately refer to the same empirical indicator and are measured in the same way such that these terms will be used somewhat interchangeably in what follows.

Hypothesis 1 postulates a positive relationship between deterrence and the expected costs of waste

crime for the average potential criminal. The expectation part of these costs is driven by two probabilities: One is the average likelihood of being apprehended for a crime. As explained under (v) above, this is known as the 'clearance rate' in the criminological literature. 'Clearance' is important because the successful identification of suspected offenders by the police as a prerequisite for their apprehension. In the terminology of the police, the crime is 'cleared' and then passed on to the prosecution service. A higher clearance rate implies greater probability of being subject to criminal investigation, which raises the expected costs of crime. The postulated negative effect of an increase in the clearance rate on the incidence of waste crime is also supported by empirical evidence from areas other than illegal waste (Cornwell and Trumbull 1994, Cherry and List 2002, Baltagi 2006).

The other probability driving the expected cost of waste crime for the average potential criminal is the likelihood of being subject to sanctions (i) through (iv) once apprehended. Each of these sanctions imposes different monetary and non-monetary (time, shame) costs on offenders, but each sanction also implies a cost of labor, time, physical infrastructure etc. to the public. For the potential criminal, a higher probability that one of the sanctions will be imposed raises the cost of illegal waste disposal and are hence predicted to reduce reported waste crime. Empirically, this effect has been consistently estimated as negative and significant, but with large variations in the elasticity: For example, in the case of administrative enforcement of waste regulation in the US, the elasticity of reported waste offences with respect to enforcement action is -.18 (Sigman 1998).

Hypothesis 1. Reported waste crime responds negatively to an increased likelihood of criminal sanctions: An increase in the (i) incarceration rate, (ii) penalty rate, (iii) conviction rate, (iv) trial rate, and (v) clearance rate are each predicted to lead - ceteris paribus - to a reduction in reported waste offences.

As explained, the deterrence effect that generates the prediction expressed in hypothesis 1 is

generated by a number of distinct sanctioning components, (i) through (v), each of which is predicted to impact negatively. Provided we are able to confirm hypothesis 1 then the economic theory of crime makes further predictions regarding the magnitude of the coefficients (Becker1968): The impact of each of these distinct components on the decision whether to commit a crime will be in proportion to the cost that it imposes on the criminal in expected terms. For example, prison sentences are arguably the costliest form of punishment as they impose on the criminal significant costs of time, lost income, and the social stigma attached to prison sentences,reducing future employment possibilities. In terms of cost to the criminal, severe fines are the second costliest sanction, followed by being convicted (due to reputational losses) and by the reputational losses and moderate time cost of having to appear in court (Kahan and Posner 1999, Karpoff et al. 2005). The negative response of the reported waste crime to a positive variation in the incarceration rate should therefore be stronger than that to an equally sized variation in the penalty rate, which should be stronger again than that to the trial rate, and so on. Therefore, hypothesis 2 formulates the following prediction.

Hypothesis 2: Reported waste crime is predicted to respond, in absolute terms, most strongly to variations in the incarceration rate, and increasingly less strongly to variations in the penalty rate, the trial rate, the conviction rate, and the clearance rate.

One key question that both hypotheses 1 and 2 leave open concerns the inter-temporal structure: Is it current or past levels of sanctioning that are the drivers of changes in reported waste crime, or both? In general, the evidence in the literature points to deterrent effects being driven by enforcement activities in the recent past (see e.g. Fajnzylber et al. 2002, Jacob et al. 2007, Rickman and Witt 2007). For example, the decision whether to commit a crime early in a given year is likely to be based on enforcement activities of the previous year (see also section 3.3). A second key question is the likely endogeneity of some of the variables, for example on account of increased

crime levels in the past leading to more detection effort by police in the present (e.g. Mustard 2003). The econometric treatment therefore needs to account for the likely dynamic and endogenous nature of the evidence. Section 3.3 presents the methodological answers to this challenge. That section also discusses a natural extension of explicitly considering the inter-temporal dimension of the deterrence hypotheses 1 and 2. This is to frame them in terms of the cumulative effects of changes in enforcement on waste crime over time.

2.2 Structural Factors

The price for the parsimony of the economic model of crime in the spirit of Becker (1968) is the omission of factors outside the deterrence-compliance nexus that are also drivers of illegal activity. As a remedy, much of the general literature on crime includes explanatory variables in order to capture the economic and political economy structure within which the illegal activities take place. The empirical findings give rise to two hypotheses that gauge the influence of counties' economic and political economy structure on illegal disposals.

We first consider economic issues, namely the level of economic activity across counties. The level of economic activity has been hypothesized to determine illegal waste disposal in two ways. One is the scale effect: A higher level of economic activity increases the supply of waste that could be illegally disposed of (Eckert 2004, Sigman 1998, Stafford 2002). The other is the income effect: Counties with a higher income may care more about the environment and thus have a greater proclivity to report than counties with lower incomes (Sigman 1998). Both mechanisms predict a higher number of reported cases for higher levels of economic activity. We adopt two standard measures of activity, GDP per capita and the total revenue of the manufacturing sector.

Hypothesis 3: Reported waste crime is predicted to increase - ceteris paribus - both with GDP per capita and with total manufacturing revenue.

The final hypothesis covers factors that bring a recent empirical literature on the political economy

of the environment to bear on the dataset. Other scholars have explored the extent to which political economy may drive environmental outcomes through voting processes (McKitrick 2006) or the extent to which the presence of regulatory thresholds influence firm location (Greenstone 2002) and, thus, the threat of a loss of industry presence. Gray and Shadbegian (2004) demonstrate for a US dataset covering paper mills in 38 states between 1985 and 1997 that regulatory stringency responds to the shadow value of industrial activity for the surrounding population. The political economy factors explored in this paper are the dependency of a county on industrial activity in terms of employment and the dependency of a county on corporate tax receipts from industrial activity. On the first of these factors, high levels of employment are a natural objective for politicians seeking reelection. Counties that are highly dependent on the employment in the more waste-intensive manufacturing sector are argued to find it more costly to enforce environmental criminal law and therefore carry out less monitoring. The working hypothesis would therefore postulate that in counties with a higher portion of people working in manufacturing industries there will be less reporting of environmental offences. A similar line of argument holds for the second factor, the share of county corporate tax receipts. These receipts are levied on the profit of enterprises located within the county and constitute the single most important source of direct fiscal revenues for Germany's counties. However, the relative reliance of counties on corporate taxes varies within an order of magnitude. Enforcing costly environmental laws is therefore relatively more costly to those counties that depend more heavily on corporate tax income. The working hypotheses is then to predict a negative relationship between reported illegal disposals and the share of county corporate tax receipts.

Hypothesis 4: A higher number of people working in the manufacturing industry or a higher fraction of corporate taxes on total county income leads - ceteris paribus - to a lower rate of reported illegal waste disposal.

## 2.3 Additional Covariates

In addition to the main variables of interest we include several covariates that are known to impact either the occurrence of illegal behavior or the detection and reporting of environmental offences. For example, Eckert (2004) postulates and confirms empirically that illegal waste disposals are more likely committed in counties with a lower population density. The intuition revolves around the probability of detection, which increases with population density. Turning to political variables, effort levels of regulators, police, and prosecutors to take action against environmental offences could conceivably vary with the political orientation of government. There is evidence from the US at the federal and state level that these factors are empirically salient (Helland 1998, Sigman 1998, McKitrick 2006). The priority of environmental issues for different parties in Germany is well researched (Budge et al. 2001, Klingemann et al. 2007). There is reason therefore to conjecture that local governments dominated by the pro-industry conservative party will have a lower incentive to have police and prosecutors pursue waste crime aggressively than those with a significant Green representation.[v]

# 3. Empirics

## 3.1 Data

The empirical exercise relies on panel data analysis. The cross-section of the panel consists of the 44 counties (Stadt- und Landkreise) of the German state Baden-Würtemberg and, alternatively, the 17 regional court districts (Landgerichtsbezirke) into which the counties are organized.[vi] The spatial cross-section is combined with time series data covering the years 1995 (1994 in case of reported cases and cleared cases) to 2005 with a small subset of counties having incomplete reporting, leading to an incomplete panel.

Data on reported illegal waste disposals and the clearance rate are available at the county level and taken from the official police crime statistics (PKS) published by the State Criminal Police Office (LKA) of Baden-Württemberg. Data on enforcement variables such as the number of trials,

convictions and imprisonments are available at the court district level from the official prosecution statistics (StVSt) of the Research Data Centre (FDZ) of the Federal Statistical Office. Data on structural variables that characterize individual counties, such as population, size, economic, administrative, political, and several socioeconomic variables, are taken from publications of the State Statistical Office of Baden-Württemberg. Examples include GDP per capita, industry production, the composition of county councils, data reflecting the waste market, county income and enforcement resources such as the number of civil servants, prosecutors and judges.

A common feature in studies of this type is the presence of time lags between identifying a suspect and the criminal proceeding. Combined with high variance in reported crime, this can lead to observations for which in a given year and county, the number of tried suspects exceeds the number of identified suspects. About ten percent of observations in the data set share this characteristic. In the absence of individualized data on per-case time lags, the second best response is to allow punishment probabilities to exceed one (Cherry 1999). The argument is that causally, the behavior of both public and potential offenders is driven by punishment probabilities that are derived on the basis of present amounts of crime and present amounts of enforcement.

Tables 1 and 2 provide variable definitions and summary statistics for all variables included in the core econometric specifications.

[Table 1 and 2]

Data for political, structural and waste market variables are not always available for the whole period under consideration. This drives our estimation strategy as a two-step process: As a first step, the core model as set out in the next section is implemented and estimated in order to use as many observations as possible. In a second step, we use different sets of covariates of political, structural, economic variables. We thus test whether additional variables that have been identified in the larger literature on crime and illegal waste disposals play a plausible role and provide robustness checks.

3.2 Regression Model

In this section we develop an empirical model on illegal waste disposals that is at the intersection between the crime (Ehrlich 1973, Cornwell and Trumbull 1994, etc.) and the waste regulation literature (Sigman 1998, Stafford 2002, etc.). This estimation equation maps a relationship between illegal waste disposals on the one hand and enforcement, structural, economic, and political economy variables on the other hand. This leads to the following regression model:

$$CR_{it} = A + \alpha CR_{it-1} + \beta P_{it} + \gamma X_{it} + F_i + T_t + \varepsilon_{it} \quad (1)$$

where CRit is the natural log of the reported rate of illegal waste disposals in county i in year t and A is a constant term. $F_i$ and $T_t$ capture individual county and year effects, respectively. $P_{it}$ is a vector containing the state- and year-specific probabilities of different levels of punishment for offenders located in different counties and court districts, respectively. The vector comprises the clearance rate, the rate of tried offenders, the conviction rate, the prison rate, and the rate of people sentenced to a severe fine.[vii] $X_{it}$ captures economic and political economy factors used in the second step. Finally, $\alpha$, $\beta$, $\gamma$ and $\varepsilon$ stand for the parameter (vectors) to be estimated and the disturbance term, respectively. In line with recent econometric work on the economics of crime (Fajnzylber et al. 2002, Rickman and Witt 2007), the specification allows for a lagged dependent variable $CR_{it-1}$. This application of dynamic panel data analysis is justified on account of time persistence in illegal waste disposals as we show in the following section.

3.3 Estimation and Model Selection

The empirical estimation of economic models of crime involves several challenges, and illegal waste disposal is no exception to this well-known rule. First, neglecting the existence of dark figures of unreported crime may lead to biased results (Levitt 1998 and McDonald 2001, 2002). The reason is that variations in official crime statistics might either be due to variations in actual crime or due to variations in detection or reporting. To address this problem, we include - in the second

step of the analysis - economic and political economy variables that are candidates for influencing detection and reporting efforts and thus capture variations in official statistics that are due to the dark figure. This strategy aims at disentangling changes in both the amount of actual crime and the amount of detected crimes when the true amount of crime is not observable.

Second, different types of endogeneity might bias later results if they are not controlled for properly. Mustard (2003) shows, e.g. that there is evidence for an omitted variable bias if one does not include conviction probabilities and time served in prison in the empirical exercise. We address this issue by including variables for all 4 stages of the German enforcement process (see section 2) in our later analysis. Another source of endogeneity emerges when aggregating different types of crime to one aggregated index. Cherry and List (2002) show that deterrence effects are different for different types of crime and adding up the data to one index leads to biased results. In our analysis, we focus exclusively on illegal waste disposals which are regulated by one specific article in the German Penal Code. Moreover, several earlier studies used cross-sectional data to test the economic model of crime. Cornwell and Trumbull (1994) and Cherry (1999) show that not being able to control for unobserved heterogeneity may then cause biased results. We use panel data to address this challenge explicitly. Finally, the estimation may conceivably suffer from simultaneity in that enforcement not only affects crime, but crime also enforcement. Simultaneity issues are discussed in detail in section 4.3.2.

Third, the recent literature on illegal activities shows (Fajnzylber et al. 2002, Rickman and Witt 2007, Jacob et al. 2007) that crime rates often exhibit a considerable degree of persistency.[viii] This requires the use of appropriate estimation techniques such as dynamic panel data analysis (Arellano and Bond 1991 and Arellano and Bover 1995). As we show in the following section, there is evidence for a dynamic structure in our dataset. Finally, as mentioned in section 2, the temporal structure between enforcement and deterrence may be subject to time lags. Other authors, looking at evidence on drug crime and violent crime, have found evidence for a lagged deterrence effect for selected components of the enforcement system (Corman and Mocan 2000, Mustard 2003). We

examine the lagged nature of deterrence in section 4.3.2 for waste crime and find evidence for a lagged deterrence effect for prison rates.

In the next two subsections, we discuss different specification tests and account for simultaneity and time lags before we move on to interpret the results in section 4.4.

3.3.1 Specification Tests

Table 3 presents the parameter estimates for the core model and for different estimation procedures. 'FE' indicates the standard fixed-effects model. 'Sys. GMM' stands for the Arellano and Bover (1995)/Blundell and Bond (1998) one-step system GMM estimator with robust standard errors. The choice of the most appropriate estimation procedure among FE and GMM is a matter of data characteristics.

The parameter estimates for the lagged dependent variable (columns 2-6) show a significant degree of persistency. This rules out FE as an appropriate choice and justifies the use of dynamic panel estimators. Using all available internal instruments when applying GMM, the Sargan test of overidentifying restrictions gives some reason for caution for the specification displayed in column 3 of Table 3.[ix] Given that there is evidence not only for ar(1) but also ar(2) (and no evidence for ar(3)) we restrict the set of instruments in later specifications. In particular, we control for ar(2) by restricting the number of lags of the dependent variable to serve as instruments to 3+ in the specification in column 4 (Table 3). Under this specification, the Sargan test no longer rejects the Null of validity of the overidentifying restrictions at common significance levels.

[Table 3]

3.3.2 Simultaneity and Lag Structure

Beginning with Ehrlich (1973), there is a ongoing discussion on simultaneity when estimating the economic model of crime empirically. There is always the possibility of both potential criminals responding to changes in enforcement efforts and enforcement institutions responding to changes in

the behavior of criminals. Observing an increasing crime rate, police, prosecutors and courts may tend to increase efforts in order to keep the amount of crimes at an acceptable level. Simultaneity is therefore of special interest for the included enforcement variables. In contrast, it is implausible that the amount of illegal waste disposals affects the economic, political or structural composition of a county. To control for potential simultaneity, we therefore estimate the core model (column 4 in Table 3) treating the different enforcement variables as being endogenous in GMM. The results are displayed in columns 5 and 6 (Table 3).

[Table 4]

The results make clear that two parameter estimates are particularly vulnerable with respect to an endogenous model specification. First, the effect for clearance rates becomes both economically and statistically less significant. Second, prison rates exhibit a positive and now significant effect on illegal waste disposals. All remaining enforcement variables still have a negative sign and are significant in case of the rate of tried offenders.

Temporal delays in the causal relationships between enforcement and deterrence are a second challenge (see section 2). To test whether enforcement variables exhibit a lagged effect on criminal behavior, we re-estimate the model in column 1 and 2 of Table 4 including the first lag of the prison rate. The intuition for this is that it is usually the case that prosecution time increases with the severity of the offence. At the same time, potential offenders are likely to devote particular attention to the outcome of severe cases when judging the probability of receiving a prison sentence. We find a significant negative effect of the lagged prison rate with the contemporaneous prison rate becoming insignificant in case of the FE specification in column 1 (Table 4). The data set therefore lends support to the conjecture that increases in the rate of incarceration give rise to lagged deterrence effect. In fact, by estimating a specification using lags for all enforcement variables (Table 6, left panel), we only observe a lagged deterrence effect for prison rates.

### 3.4 Estimation Results

#### 3.4.1 Deterrence

The results of the econometric estimation, contained in tables 3 and 4, broadly confirm Hypothesis 1 both in terms of direction and magnitudes. Among the different steps, three deterrence components deserve special mention. The first is the clearance rate, i.e. the police effort dedicated at identifying offenders responsible for illegal waste disposals. The predicted relationship between clearance rate and reported crime rates is a negative one. The econometric estimates for clearance rates bear out this prediction, returning a negative sign (with one exception) but being not significant for our endogenous GMM specifications. This could be due to informational obstacles (clearance is difficult to observe for potential offenders) and due to the endogenous link between clearance rates and the volume of waste crime: The increased deterrence of police effort leads to less waste crime, which in turn leads to reduced need for police effort.

The second important deterrence component is the rate of tried offenders. Its elasticities range from -.14 to -.46 (Tables 3 and 4) and are highly significant in almost all specifications. The third noteworthy determinant of deterrence is the incarceration rate, lagged. Here, elasticities range from -.7 to -1 (Table 4) with strong significance across specifications. That is, a one (within-county) standard deviation increase in the rate of tried offenders (.34) would imply a decrease in the amount of waste crime by 1.04 - 1.92 cases. Similarly, a one (within-county) standard deviation increase in the prison rate (.06) would imply a reduction in waste crime of 0.8 - 1.15 cases. The results for other deterrence variables, conviction rates and the rate of severe fines, are also in line with the theoretical predictions and, though not directly comparable, with empirical estimates from waste offences in the US. Both show negative parameter estimates for almost all specifications, but do not cross the significance hurdle at the 10% level (tables 3 and 4).

Given the suspected lagged deterrence effects (see section 3.1.), we estimate specifications including multiple lags of all punishment variables. Table 5 in the appendix (left panel) shows in particular a specification including lags 0 and 1. Apart from the prison rate, we do not find evidence

for a lagged deterrence effect for any other punishment variable.[x] Table 5 (right panel) also contains results for the cumulative effects (long-run elasticities) for the specification with lags 0 and 1 (column 1) and for the cumulative effects for the lags 0-4 (column 2). Both specifications confirm the importance of the rate of tried offenders and the prison rate with the 5 years cumulative effects (lags 0-4) being even larger than the short-run elasticities ( tried: -1.7; prison: -5.3).

Result 1: There is evidence for a cumulative deterrence effect on the rate of illegal waste disposal of enforcement action comprising clearance, trial of offenders, conviction, fines, and incarceration. As predicted by hypothesis 1, the individual sanctioning components return negative estimates, with significant key drivers being the rate of tried offenders and the prison rate, lagged.

Hypothesis 2 stresses the relative contribution of the different enforcement components to aggregate deterrence. Examining tables 3 and 4, the conjecture of deterrence increasing in severity contained in Hypothesis 2 is partially borne out in the data. Leaving aside the insignificant parameter estimates, the elasticity of the crime rate with respect to the rate of incarceration consistently exceeds that with respect to the rate of tried offenders. This leads to result 2.

Result 2: The relative contributions of different enforcement components to aggregate deterrence effect partially confirm hypothesis 2. For the prison rate and the rate of tried offenders, the elasticities with respect to deterrence vary in line with the severity of the sanction.

Results 1 and 2 jointly provide evidence that the criminal enforcement of waste regulations in Baden-Württemberg generates a general deterrence effect. This adds robustness to previous findings in two significant ways. It means that despite a different enforcement tool and a different geographical setting, we find an effect that is similar to the deterrence effects established in the context of waste regulations in the US (Sigman 1998; Stafford 2002; Sigman 2010) and generic

environmental crime in Germany (Almer and Goeschl 2010). At the same time, compared to the results on administrative and civil action in the US (Sigman 1998; Stafford 2002; Sigman 2010), the results also make clear that different components of the enforcement chain contribute in different ways to general deterrence, and that some components can be more relied upon than others to result in increased deterrence. The choice of enforcement tool therefore matters greatly in terms of policy outcome. Our results also suggest that deterrence effects are even stronger in the long run. That is, persistent enforcement efforts seem to be particularly helpful in avoiding illegal waste disposals.

3.4.2 Structural Factors

Here we summarize the results for the structural factors of an economic and political economy type that are included in the specifications displayed in Table 4. The results for the economic activity variables are in line with the predictions of Hypothesis 3: Revenue generated in the manufacturing industry shows positive parameter estimates with elasticities ranging between .4 and 1.31 and estimates are significant at the 10 percent level in column 4 and close to significance at the 10% level in columns 3 and 6 of Table 4. The results for GDP per capita are similar: Estimates are positive and in most cases significant (columns 5 and 6) with elasticities of 3.4 and 4.2.

Result 3: There is evidence for scale effects in the crime rate: Both the revenue of the manufacturing sector and GDP per capita have a positive impact on illegal disposals.

Hypothesis 4 focused on the dependence of a county on the manufacturing industry, providing a causal channel from dependence to lenience in detection, reporting, and prosecution. Both indicators for the degree of dependency show the expected negative sign and are highly significant in case of corporate tax revenue. Elasticities in case of system GMM are -.48 for the share of county corporate tax revenue in county total income and between -1.4 and 1.6 for the share of county population working in the manufacturing industry. However, whereas estimates for the employment variable are only significant in case of FE, the estimates for corporate taxes are significant for both

system GMM and one FE specification.

Result 4: There is evidence for a local political economy effect driving environmental crime rates. For both the share of county populations working in the manufacturing industry and the share of county corporate tax income in total county income, a negative relationship between local dependence on industry and the amount of reported illegal disposals is plausible on the basis of the consistent and in case of corporate taxes highly significant parameter estimates.

Result 4 is not conclusive evidence for, but consistent with a narrative in which counties that are highly dependent on a prospering industry show a lower rate of reported illegal disposals. Counties with a higher share of people working in the manufacturing sector show a lower rate of reported illegal waste disposals. The results for the share of county corporate tax revenue in total county income point in the same direction. This findings are novel in that the existing literature on illegal waste disposals only included more general structural variables likes GDP per capita, income per capita, population density or conventional political variables (Sigman 1998, Stafford 2002, Helland 1998).

3.4.3 Additional Covariates

For the additional covariates capturing other structural and political factors included in Table 5, the results are mixed. We test, for example, whether detection probabilities - by the way of population densities - drive environmental crime rates. Looking at tables 3 and 4, such a correlation fails to emerge: Parameter estimates for population density are positive throughout but only significant for one specification (column 4 in Table 3). Conjectures regarding the relationship between political factors and reported environmental crime lead to similar results. Testing for the presence of such a relationship in the data returns highly variable parameter estimates for the share of conservatives and greens in county councils and little significant results. This is not unexpected. Both county councils and the state government of Baden-Württemberg have been dominated by the conservative

party (CDU) for more than 50 years.

## 4 Conclusion

Understanding how enforcement can support effective environmental policy is of interest to scholars and policy-makers alike. While there is an emerging consensus on the deterrence effect of enforcement, there is also agreement that the evidence in favor is limited with respect to geographical scope, enforcement tools, and regulatory context. By bringing international evidence on criminal enforcement in the waste context to the fore, the present paper contributes to a wider effort to overcome the limitations of the currently available evidence.

The main message of the paper supports the emerging consensus that the presence of a deterrence effect in environmental regulation is independent of geographical location, the enforcement tool, and the regulatory context. Cumulatively, we find clear evidence for a general deterrence effect of enforcement intensity on the amount of reported waste crime in the German state of Baden-Württemberg, one of the economically most active Landers in the Federal Republic of Germany. Despite the limitations of the evidence base, the emphasis on deterrence as a pillar of effective environmental policy can thus be extrapolated more confidently.

While providing further substance for the universality of the deterrence hypothesis, the paper also adds subtlety by emphasizing that criminal enforcement relies on different drivers than administrative and civil sanctions. This subtlety also applies to the regional factors that reflect the economic and political economy processes operating at lower levels of spatial aggregation. Regional factors enter in several ways. They are a likely explanation for differences in the deterrence effect between Germany as a whole and the specific case of Baden-Württemberg. Finally, the data supports the emerging notion in the empirical literature that local political economy matters in measurable ways for the effective implementation of environmental regulation.

We emphasize that the usual caveats of the empirical literature on environmental crime, and the economics of crime in general, apply to our results. Perpetrators of waste crime do not voluntarily

disclose the nature and volume of their activities. Efforts from either second (victims) and third parties (public agents or unaffected by-standers) are required to make waste crime observable. While waste crime is less likely to be underreported by victims than other types of environmental crime, thus facilitating identification of deterrence and structural effects, this could give rise to second-order effects. For example, waste criminals might invest more effort into concealment activities. While this would not invalidate our results, it could weaken the magnitude of the estimated effects. It is also important to point out that the results do not provide normative guidance on environmental regulation and its enforcement. Enforcement, while evidently effective, is costly, and the empirical results cannot speak to the issue of how much enforcement is effcient. While we find that political economy factors are present and weaken the effectiveness of regulation, their presence is not necessarily harmful to welfare. It could constitute a meaningful local response to excessively rigid guidelines at the federal or state level.

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| Variable | Definition |
|---|---|
| Rate of illegal waste disposals (CR) | Number of reported cases divided by population |
| Clearance rate (clear) | share of cases for which suspects are identified |
| Rate of tried suspects (tried) | share of identified suspects brought to court |
| Conviction rate (convicted) | share of accused suspects convicted in court |
| Prison rate (prison) | share of convicted offenders receiving a prison sentence |
| Rate of severe fines (fine) | share of convicted offenders receiving a heavy fine |
| Population density (pop.den) | population divided by county size |
| Share of greens (greens) | share of Green Party politicians in county council |
| Share of conservatives (conservatives) | share of CDU politicians in county council |
| GDP per capita (gdp) | natural log of real GDP per capita |
| Total revenue in manufacturing (rev.manu) | natural log of real revenue of the manufacturing sector |
| Share of employees in manufacturing sector (emp.manu) | nat. log of population working in manufacturing sector |
| Importance of corporate taxes (corp.tax) | nat. log of corporate taxes divided by county income |

*Table 1: Variable Definitions*

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| CR | 505 | 0.00009 | 0.00008 | 0 | 0.00065 |
| clear | 526 | 0.67366 | 0.24974 | 0 | 1 |
| tried | 468 | 0.52243 | 0.4124 | 0.06667 | 3.66667 |
| convicted | 470 | 0.73923 | 0.19131 | 0 | 1 |
| prison | 467 | 0.02972 | 0.0658 | 0 | 0.5 |
| fine | 467 | 0.0509 | 0.11388 | 0 | 1 |
| pop.den | 528 | 5.2732 | 6.55267 | 1.02939 | 76.41714 |
| greens | 528 | 0.08341 | 0.04463 | 0 | 0.27083 |
| conservatives | 528 | 0.41076 | 0.07419 | 0.24138 | 0.56522 |
| gdp | 440 | 29889 | 8527 | 19544 | 58335 |
| rev.manu | 484 | 5445835 | 4937229 | 707989 | 34700000 |
| emp.manu | 440 | 0.09062 | 0.13352 | 0.00795 | 0.69395 |
| cor.tax | 350 | 0.43732 | 0.13119 | 0.11511 | 0.91859 |

*Table 2: Summary Statistics*

| | FE | FE | Sys GMM | Sys GMM | Sys GMM | Sys GMM |
|---|---|---|---|---|---|---|
| CR, lag | | 0.309 | 0.306 | 0.38 | 0.512 | 0.47 |
| | | (0.000) | (0.000) | (0.001) | (0.000) | (0.000) |
| cleared | -0.201 | -0.24 | -0.524 | -0.598 | -0.108 | -0.101 |
| | (0.466) | (0.325) | (0.025) | (0.014) | (0.627) | (0.649) |
| tried | -0.179 | -0.232 | -0.264 | -0.327 | -0.253 | -0.259 |
| | (0.065) | (0.049) | (0.033) | (0.009) | (0.026) | (0.041) |
| convicted | -0.164 | -0.176 | -0.0217 | -0.141 | -0.131 | -0.172 |
| | (0.328) | (0.312) | (0.926) | (0.558) | (0.504) | (0.358) |
| prison | 0.28 | 0.195 | 0.651 | 0.442 | 0.798 | 0.9 |
| | (0.424) | (0.549) | (0.103) | (0.250) | (0.033) | (0.022) |
| fine | -0.320 | -0.177 | -0.356 | -0.303 | -0.177 | -0.138 |
| | (0.337) | (0.527) | (0.237) | (0.305) | (0.508) | (0.623) |
| pop.den | 5.035 | 5.588 | 0.139 | 0.708 | | 0.0616 |
| | (0.405) | (0.199) | (0.588) | (0.024) | | (0.722) |
| green | 0.0025 | 0.0485 | 0.0981 | -0.243 | | -0.104 |
| | (0.988) | (0.702) | (0.801) | (0.593) | | (0.622) |
| conservatives | 0.613 | 0.0473 | -0.594 | 1.432 | | -0.252 |
| | (0.561) | (0.952) | (0.545) | (0.145) | | (0.642) |
| N | 421 | 407 | 407 | 407 | 427 | 407 |
| R2 within | .134 | .248 | | | | |
| R2 between | 0.0004 | .0043 | | | | |
| Specification Tests | | | | | | |
| Sargan | | | (.0525) | (.206) | -0.181 | -0.137 |
| Autocorrelation | | | | | | |
| First Order | | | (.0000) | (.0000) | (.0000) | (.0000) |
| Second Order | | | (.0566) | (.0583) | -0.12 | -0.0982 |
| Third Order | | | (.953) | (.936) | -0.486 | -0.518 |

Note: Time dummies and a constant have been included but omitted here. P-values in parenthesis. All GMM specifications (implemented in Stata 12 via xtdpd and xtdpdsys, respectively) have been applied using one-step system GMM with robust standard errors (not for obtaining the Sargan statistic). Columns 5 and 6 display estimates for the endogenous specication (i.e., treating all deterrence variables as being endogenous).

*Table 3: Estimation Results for Core Equation*

| | FE | Sys GMM | FE | FE | Sys GMM | Sys GMM |
|---|---|---|---|---|---|---|
| CR,lag | 0.278 | 0.495 | 0.264 | 0.231 | 0.277 | 0.205 |
| | (0.000) | (0.000) | (0.001) | (0.016) | (0.064) | (0.158) |
| cleared | -0.272 | 0.0164 | -0.125 | -0.0876 | -0.414 | -0.43 |
| | (0.358) | (0.944) | (0.632) | (0.745) | (0.163) | (0.140) |
| tried | -0.158 | -0.188 | -0.252 | -0.144 | -0.461 | -0.435 |
| | (0.101) | (0.082) | (0.154) | (0.341) | (0.008) | (0.008) |
| convicted | -0.135 | -0.12 | -0.14 | -0.168 | 0.0728 | 0.07 |
| | (0.499) | (0.531) | (0.555) | (0.473) | (0.787) | (0.773) |
| prison | -0.101 | 0.721 | -0.0168 | -0.0415 | -0.0125 | 0.228 |
| | (0.787) | (0.096) | (0.962) | (0.912) | (0.970) | (0.499) |
| prison,lag | -0.992 | -0.922 | -0.85 | -0.872 | -0.999 | -0.693 |
| | (0.051) | (0.017) | (0.113) | (0.131) | (0.038) | (0.106) |
| fine | -0.144 | -0.136 | -0.244 | -0.258 | -1.013 | -1.026 |
| | (0.601) | (0.617) | (0.628) | (0.620) | (0.086) | (0.061) |
| pop.den | 7.053 | 0.0717 | | 3.619 | | 0.381 |
| | (0.170) | (0.666) | | (0.665) | | (0.670) |
| green | 0.181 | -0.0399 | | 0.0205 | | -0.37 |
| | (0.248) | (0.832) | | (0.894) | | (0.193) |
| conservatives | 0.479 | -0.251 | | 1.109 | | 0.946 |
| | (0.534) | (0.646) | | (0.298) | | (0.579) |
| manu.rev | | | 1.089 | 1.306 | 0.402 | 0.71 |
| | | | (0.112) | (0.080) | (0.224) | (0.140) |
| gdp.cap | | | 1.566 | 1.383 | 4.246 | 3.426 |
| | | | (0.313) | (0.382) | (0.025) | (0.080) |
| cor.tax | | | -0.233 | -0.311 | -0.478 | -0.478 |
| | | | (0.159) | (0.082) | (0.022) | (0.036) |
| emp.manu | | | -3.072 | -3.439 | -1.577 | -1.411 |
| | | | (0.089) | (0.062) | (0.219) | (0.335) |
| N | 363 | 363 | 285 | 275 | 285 | 275 |
| R2within | 0.199 | | 0.257 | 0.234 | | |
| R2between | 0.0037 | | 0.0309 | 0.0097 | | |
| SpecificationTests | | | | | | |
| Sargan | | (.289) | | | (.377) | (.452) |
| Autocorrelation | | | | | | |
| FirstOrder | | (.0000) | | | (.0009) | (.0012) |
| SecondOrder | | (.061) | | | (.261) | (.368) |
| ThirdOrder | | (.973) | | | (.84) | (.652) |

Note: Time dummies and a constant have been included but omitted here. P-values in parenthesis.

*Table 4: Estimation Results for Time Lags and Extended Model*

| | Sys GMM | |
|---|---|---|
| CR,lag | 0.522 | (0.001) |
| cleared | -0.454 | (0.113) |
| cleared,lag | 0.44 | (0.078) |
| tried | -0.391 | (0.002) |
| tried,lag | -0.107 | (0.341) |
| convicted | -0.0527 | (0.847) |
| convicted,lag | -0.0493 | (0.829) |
| prison | -0.041 | (0.907) |
| prison,lag | -0.898 | (0.081) |
| fine | -0.366 | (0.246) |
| fine,lag | 0.265 | (0.573) |
| pop.den | 0.31 | (0.366) |
| greens | -0.482 | (0.092) |
| conservative | 1.15 | (0.263) |
| N | 363 | |
| SpecificationTests | | |
| Sargan | (0.226) | |
| Autocorrelation | | |
| FirstOrder | (0.0002) | |
| SecondOrder | (0.0413) | |
| ThirdOrder | (0.344) | |

Note: p-values in parentheses. Extension of our core model (see Table 3) including lags for all punishment variables.

| | (1) | (2) |
|---|---|---|
| cleared | -0.0145 | 0.937 |
| | (0.967) | (0.310) |
| tried | -0.498 | -1.676 |
| | (0.00646) | (0.00181) |
| convicted | -0.102 | 1.457 |
| | (0.788) | (0.235) |
| prison | -0.939 | -5.257 |
| | (0.122) | (0.0201) |
| fine | -0.101 | 0.794 |
| | (0.845) | (0.648) |
| N | 363 | 238 |

Note: p-values in parentheses. Cumulative effects for all punishment variables based on the the core specification in Table 3 and the corresponding time lags. Column 1 displays cumulative estimates for the specification in the left panel (including lags 0 and 1) and estimates in column 2 are based on lags 0 to 4 of all punishment variables.

*Table 5: Lagged Effects and Long-Run Elasticities*