The Economics of Environmental Crime: Theoretical Aspects and Econometric Investigations

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Christian Alexander Almer

geboren in Augsburg

To

my wife Luise

my mother Edeltraud

and

my father Helmut

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1 Introduction

1.1 Purpose of the Thesis and Main Findings

In general, penal codes undertake the task of punishing crimes against a person or a person's property. In this context, the punishment itself fulfills two major purposes. The first is to sanction the criminal and therefore to provide individual deterrence. The second and equally important purpose is to provide general deterrence with keeping potential offenders from committing similar crimes. It is not the intention of criminal prosecution to compensate victims for the loss suffered but to make clear that society opposes criminal behavior. In contrast to sanctions like compensation in civil law, it is *ex ante* not clear to the decision maker whether the expected punishment a criminal faces really has the intended effects. Hence, from an economic point of view, there is foremost one question of particular importance in this context: To what extend does an existing sanctioning regime and its specific components deter people from committing crimes?

It is the aim of the present thesis to answer this question for environmental crimes in Germany. More specifically, the thesis empirically analyzes the effectiveness of the German Penal Code (*Strafgesetzbuch*) in deterring environmental crimes. Although environmental crimes are perfectly accessible by economic theory as they are mostly economically motivated, this focus is rather novel. Environmental crimes have several special characteristics that have not been studied so far. Existing studies examining the effectiveness of criminal enforcement focused on felonies like murder, rape, assault, etc.. Environmental crimes are distinct from those in that they constitute crimes against a public good. Environmental crimes in most cases do not harm a person or a person's property directly but only in-

directly and in the long run through environmental degradation. Violations of environmental laws are therefore in many cases seen as minor crimes that may be prosecuted differently. Previous studies of other types of crimes are therefore not immediately applicable when it comes to environmental offences. Another strand of economic literature analyzes the effectiveness of administrative law in punishing violations against the environment. This literature again provides no evidence for the effectiveness of criminal law in enforcing environmental regulations. Since administrative law and criminal law differ significantly in incurred costs and available sanctions, it is necessary for consistent policy-making to have reliable information on the effectiveness of both regimes. In addition to the gap in the existing literature, studying the effectiveness of the enforcement of environmental law trough the German Penal Code is an important research question for several reasons.

First, as there is no way to evaluate the effectiveness *ex ante*, it is overdue to examine this issue since criminal sanctioning for environmental crimes takes place in Germany for almost 30 years. This applies especially as there is a current discussion in German law literature that questions the usefulness of criminal enforcement in the context of environmental law. Germany decided already in 1980 to include important environmental laws and the specific criminal sanctions in the Penal Code. At this early stage only few other countries, including the U.S., followed similar strategies to sanction violations of environmental laws and regulations.

Second, there is an ongoing policy debate in many industrialized countries and especially within the EU discussing whether to further strengthen criminal enforcement in the context of environmental law - or not. However, neither proponents nor opponents of stiffer sanctions are able to base their arguments on sound em-

pirical evidence. To provide evidence for Germany is of great importance in this context as the German case is often considered as a reference point.

Third, it is evident that environmental crimes cause severe damages to society. For example, in 2006 parties involved in hazardous waste pollution in the U.S. had to pay a total of $391 Mill. to study and clean up contamination of 15 million cubic yards soil and 1.3 billion cubic yards ground water (EPA 2006).

Finally, the analysis of Germany provides a new geographical focus as the major part of the surrounding literature analyzes U.S. data with a small part focusing on the UK. It is not clear whether results for the U.S. or UK carry over to other parts of the world. The legal environments may be different enough in each country to make direct comparisons impractical.

Against the background of the existing evidence gap, the thesis makes three contributions: The first (part II) is to examine whether the empirical data supports the hypothesis that criminal sanctions are successful in deterring environmental crime. The empirical evidence is contained in a unique dataset on recorded environmental crime, prosecution, trials in criminal courts, and corresponding criminal sanctions, including imprisonment. Covering the eleven-year period from 1995 - 2005 and 15 German states, a dynamic panel analysis is employed to exploit both intertemporal and state-level variations. By doing so, the thesis provides a novel focus on criminal sanctioning in the context of environmental regulations. In addition, the analysis determines the individual contributions of different components of the sanctioning regime to the deterrent effect. Typical components are the clearance rate (i.e. rate of crimes for which an offender has been identified), the rate of offenders tried in court, the conviction probability, the probability of pecuniary fines and the probability of prison sentences. Given the differences of costs be-

tween different components, the relative benefits in terms of deterrence delivered by different components is clearly of importance.

Another special focus of this part addresses explicitly the reporting bias in environmental crime. Reporting bias is a common problem for empirical work on criminal offences since typically only a fraction of actual crimes are reported to and recorded by official authorities leading to potentially substantial dark figures. To address the reporting bias, an analytical framework is developed that characterizes the observed crime rate as an outcome that is co-determined by two sets of players: Potential criminals considering the amount of crimes to commit; and the public and enforcement agencies considering how much aggregate detection effort to supply. On this analytical basis, the thesis introduces plausible proxy measures for detection effort in order to disentangle these two determinants of reported crime rates. Controlling for the possibility of dark figures is rarely done in economics literature but may be of importance for other types of legal violations.

The main findings are threefold: First, criminal sanctions do provide the deterrent effects intended by policy-makers. This finding lends support to the claim that criminal sanctions are effective in combating environmental offences and is in line with the emerging empirical consensus on criminal sanctions in general. In this respect, environmental offences are not fundamentally different from other types of crime and amenable to the same enforcement instruments. The finding also contradicts the view, that due to the small number of cases prosecuted, criminal sanctions are largely invisible and hence unlikely to provide significant deterrence.

Second, while I find most of the typical components of the criminal sanctioning regime operating in line with expectations, there are novel results on selected components. One is that the probability of being tried - rather than being convicted -

provides one of the most significant deterrents. This strengthens previous findings on the role of reputational losses as components of the sanctioning regime and raises important issues about the desirable degree of publicness of sanctioning.

Third, political economy factors are statistically significant drivers of reported environmental crime rates. Greater environmental preferences of citizens lead to a more than proportional increase in reported crime. While the limitations of the data do not allow to pinpoint the causal channels, I hypothesize on the basis of experimental evidence and empirical studies that citizens' preferences result in greater detection effort by both the public and enforcement agencies. By contrast, having a pro-industry party in government leads to a reduction in reported environmental crime. One explanation for this result rests on the presumed decrease in detection effort by the government. These findings are supported by previous findings on the political economy of environmental offences and by German law literature.

The second contribution (part III) of the thesis is to extent findings of the previous part (II) by analyzing the development of illegal waste disposals for the counties of Baden-Württemberg and the years 1995 - 2005. Illegal disposals of waste are the major type of environmental crime in Germany (see figure 1) and are therefore of special interest when studying the effectiveness of the enforcement regime applied in this context. The reason for taking this more regional and disaggregated perspective is that information reflecting specific characteristics of waste disposals are only accessible by a finer analysis. Although it is not possible to include the full set of variables analyzed in part II, the disaggregated perspective offers a huge amount of further informations especially for local waste markets and the structural composition of counties.

Results are fourfold. First of all, with respect to the deterrence effect of different criminal sanctioning components, results obtained for this dataset support to a huge extent both previous findings for German states and results obtained in the general crime literature at this disaggregated level. Especially the fact of being identified as a suspect and being tried in court deters people from committing environmental offences. In contrast to the results on state level (part II), there is no evidence that the probability of a prison sentence deters people from disposing waste illegally. Moreover, there is no evidence for the German conservatives to affect reporting in Baden-Württemberg negatively. However, several structural factors reflecting industry composition seem to influence local decision makers in their decision how much effort to put into the enforcement process.

As for the waste market data, it is not possible to reveal significant effects. As it is unlikely the case that the legal market for waste disposal does not affect the illegal counterpart, the most obvious reason is that data quality is not sufficient to convey the relevant information. This reasoning is supported by the existing literature on monitoring and enforcement of environmental regulations. There is evidence especially for prices to affect the amount of illegal disposals.

Fourth, results suggest that structural variables like population density, GDP per capita and the revenue generated in the manufacturing sector affect the amount of reported illegal disposal. This is line with general findings as socioeconomic variables seem to play an important role for all criminal behavior.

The third contribution (part IV) reverses the focus. It examines whether the effectiveness of institutions involved in the criminal enforcement of environmental law is independent of surrounding institutions or external factors such as political forces. The political economy of regulatory enforcement has attracted a good deal

of scholarly attention, resulting in an impressive body of empirical evidence on what determines regulatory action. The typical case considered in the literature studies the behavior of one particular regulator enforcing one regulation. Across the studies, there is evidence that the political economy factors are allocatively relevant. The enforcement context in the present thesis also focuses on a single regulation, i.e. the German Penal Code, but studies the behavior not of a single regulator but several different institutions at once. This multitude of institutions offers the opportunity of comparing the determinants of enforcement decisions of different institutions along a single enforcement chain with each other and against widely held assumptions about how this system works.

Key results are threefold. The first is that economic factors matter at all stages of the enforcement process. This implies that - very much in line with the economic theory of enforcement - institutions deliberately direct resources away from the enforcement of environmental law as its opportunity cost increases. This responsiveness with respect to costs is evident at all levels, including criminal courts, which enjoy the greatest degree of independence.

The second result is that political economy factors influence enforcement decisions at a statistically significant level at all stages of the process. This demonstrates that even in the most independent parts of the criminal justice system, there is evidence of political reach-through.

The third result is that the relative weight of political economy factors is not fully in line with the declared degree of independence: Prosecutors' and judges' decisions seem to be as responsive to political economy variables as the police force.

Taken together, the present thesis makes a first step to close the evidence gap

between the law and economics literature and the literature on the monitoring and enforcement of environmental regulations. In doing so, the thesis provides important results that have far-reaching policy implications for both Germany and the rest of the world. In contrast to some speculations, criminal law proves to be a very powerful tool in the enforcement of environmental law. Increasing the compliance with environmental laws through criminal enforcement may therefore help to reduce the damage to society caused by environmental offences to sufficient extent. The thesis is also able to confirm results for deterrence in a different geographical context. It seems like people from different countries and within different legal environments to react similar to economic incentives provided trough the enforcement of environmental law.

The next section provides some background information to illustrate the economic importance of environmental crimes and the development of criminal sanctions for environmental offences. As the thesis relies on German data, section 1.3 explains the peculiarities of German environmental law. Finally, section 1.4 gives a short summary of the development of environmental crimes in Germany.

1.2 Criminal Enforcement of Environmental Laws

Environmental crime consists of unauthorized acts that violate national and international laws put in place in order to protect the environment and that are subject to criminal prosecution and sanction. Standard examples are the illegal disposal of hazardous waste in waterways or in the ground and the illegal capture and sale of protected species. Typically, environmental crime has an economic motivation, with savings from bypassing costly environmental regulations being the

main motive. The economic value of environmental crime is significant: Globally, the annual turnover in the illegal trade of environmentally sensitive commodities is estimated at around \$21 – 33 billion. In the United States alone, estimated earnings of \$10-12 billion per year are generated by the illicit treatment of waste, \$6-8 billion per year by violations of the Convention on the International Trade with Endangered Species (CITES). The illegal trade in substances banned under the Montreal Protocol are imputed to earn offenders \$25-60 million per year (IWG 2000).

The origins of criminalizing environmental offences lie in the 1980s: EPA's criminal enforcement program was established in 1982, with full law enforcement authority granted in 1988 (Situ and Emmons 2000). On this basis, the EPA has initiated between 300 to 650 criminal cases per year in the period from 1995 to 2006 (EPA 1999, 2002, 2006). Germany included environmental offences in criminal law for the first time in 1980, expanding the range of offences again in 1994 (Schall 2006). In the last ten years, German enforcement agencies recorded between 15000 and 33000 offences annually as environmental crimes and prosecuted an average of approximately 4300 offenders per year. Other OECD countries have similar statutes in place, even though differences in particular regulations between countries can be substantial (Faure and Heine 2006).

Against the background of existing sanctions, environmental lawmakers and regulators both in the United States and the European Union have recently been actively reviewing how to strengthen the use of criminal sanctions. The U.S. Senate Judiciary Committee, for example, held hearings on strengthening criminal enforcement for environmental offences in 2002 (U.S. Senate 2003). In the UK, the House of Commons Environmental Audit Committee held an inquiry on cor-

porate environmental crime and the scope for greater criminal prosecutions (HoC 2005). Likewise, the European Commission has started to aggressively pursue the introduction and strengthening of criminal sanctions for environmental offences committed within the European Union (EC 2007). At the same time, there is an ongoing debate among environmental lawyers over the usefulness of instruments of criminal sanctions for environmental offences. For the case of Germany, the low volume of criminal convictions provides an argument that the deterrent effect must - if anything - be negligible (Schall 2006). Ogus and Abbott (2002) criticize the excessive escalation implicit in criminal sanctions in England and Wales.

A general shortcoming of the discussion on the merits of criminal sanctions is that the empirical evidence on their effectiveness has so far not been systematically examined. This contrasts with the case of administrative sanctions for which a rich literature is available (e.g. Heyes 1998, Eckert 2004, Earnhart 2004, Shimshack and Ward 2005, etc.).

As this thesis focuses on German data in analyzing environmental criminal law, I will first give a brief introduction to the specific characteristics of the environmental part of the German Penal Code. Subsequently, there will be a short paragraph illustrating the development of reported environmental crime and its enforcement in Germany in recent years.

1.3 Environmental Criminal Law in Germany

German environmental law is a very widespread area of legal activity. Prescriptions regarding the environment are found in the German constitution, the German Penal Code, state laws and regulations and many more. Furthermore, there are

also several institutions enforcing environmental law in Germany. Environmental offences may be recorded by the police, prosecutors, administrative authorities and custom investigation. Another specific feature of German environmental law is its administrative accessoriness (*Verwaltungsakzessorietät*). This means that the decision whether a particular behavior is legal or not is not always defined ex ante but is sometimes administrative discretion. Neither the law itself nor its enforcement has a clear-cut structure. Therefore, Germany recently tries to adopt a uniform environmental code in order to make things more tractable. Nevertheless, it should be interesting to get a better understanding of the activities of the different enforcement agencies and their punishment schemes.

The German Penal Code was extended in 1980 to include environmental offences. At this time, Germany was one of the first countries that decided to use the powerful but weighty instrument of a Penal Code to enforce environmental laws. In contrast to enforcement of administrative law, criminal law offers the possibility of more severe sanctions including imprisonment. However, at the same time Penal Codes are a very expensive enforcement mechanism as criminal proceedings involve police, prosecution and courts. The enforcement of administrative law is usually carried out by a single administrative agency.

The intention behind the extension of the German Penal Code was (i) to raise the level of general deterrence on account of harsher sanctions being available through the criminal justice system, (ii) to harness the additional policing and prosecutorial resources available in the criminal justice system, and (iii) to improve general awareness of the need for greater environmental protection (Hoch 1994, Schall 2006). Stiffer sanctions were introduced into the German Penal Code in 1994, following the inclusion of environmental protection in the German Consti-

tution as a distinct constitutional objective. Articles treating environmental crime are subsumed in part 29 of the German Penal Code. Table 1 shows the relevant types of environmental crime included in the German Penal Code. Although there are criminal sanctions for types of offences one may also subsume under environmental offences (e.g. violation against the protection of species, see BMI 2006), the thesis exclusively focuses on those displayed in table 1.

Table 1: Types of Environmental Crime in the German Penal Code

Article	**Offense**
§ 324	water pollution
§ 324a	ground pollution
§ 325	air pollution
§ 325a	noise, tremor or radiation
§ 326	illegal waste disposal
§ 327	illegal operation of plants
§ 328	illegal handling of nuclear radiation
§ 329	endangerment of nature reserves
§ 330a	endangerment by discharging toxic

While the German Penal Code is federal law, the implementation of the law, i.e. detection, prosecution, and sanctioning, is delegated comprehensively to the level of the 16 States (*Länder*) within the Federal Republic. Unlike in the U.S., there is no federal shadow system of federal prosecutors or EPA officers that monitor, assist, remedy, and possibly preempt state-level enforcement. Although there are several agencies in Germany both on federal and on state level which have functions similar to those of the EPA, there is no single agency occupying such far-reaching competencies. Like in the U.S., German criminal law only provides the possibility to accuse natural persons. Contrasting with administrative law, there is no possibility to accuse firms or other institutions for committing a crime.

Further differences to U.S. enforcement of environmental criminal law relate to

the type of major lawsuits. In the U.S., most environmental offences are tried in civil lawsuits with punitive damages being an important type of sanctioning. In Germany, however, almost all environmental offences are tried in criminal proceedings with fines being the usual sentence. Another difference relates to the rules of procedure. In Germany, judges are not just refereeing but it is their duty to actively pilot a lawsuit.

These complex legal and institutional structures require a careful empirical analysis to understand how enforcement works in German environmental law, and how effective it is. It is therefore an interesting topic to analyze the functioning of German environmental policy in more detail since this has not been done adequately until now.

1.4 Environmental Crime in Germany: 1973 - 2006

While environmental crime has been on the increase across most EU member countries, Germany has witnessed a severely non-monotonous development over the last 15 years. Figure 1 shows the development of reported cases of environmental crime in general (Chapter 29, §§324 - 330a StGB) and of illegal waste disposals (§ 326 StGB excluding section 2) for West-Germany[1] and the years 1973 - 2006.[2]

Contemporaneously to this spike in 1998 there emerged a vital discussion in German law literature on how this development can be explained (Schall 2006). One possible explanation may be the changing legal environment with the amendments of the environmental criminal code in 1994. It might be the case that the further strengthening of the Penal Code had a lagged effect on crime or the imple-

[1] Data for Eastern Germany is available from 1993 onwards.
[2] Data for illegal waste disposal is only available from 1987 onwards.

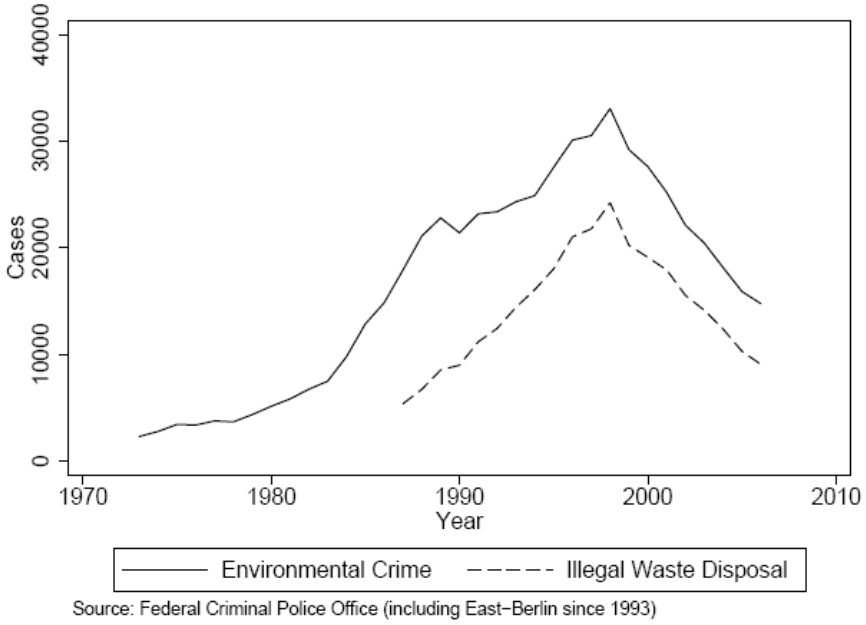
mentation of the new law on recycling and waste management (*KrW-/AbfG*) in 1996 changed incentives for potential offenders. Especially the last argument will be subject to further investigations in part III of the thesis. Another suggestion for the rapid change in overall environmental crimes is proposed by the German law literature (see e.g. Schall 2006). There exists the conjecture that diminishing environmental awareness in German society resulted in decreasing reporting behavior and decreasing incentives for police and prosecution to sanction environmental crime. To test whether this is true I included variables indicating environmental preferences in the regression analysis of part II. Findings for the indicator variable for public environmental preferences support this hypothesis (see section 10.2).

However, decomposing illegal waste disposals into single states[3] reveals that this spike is driven by a small number of states including Hesse, Berlin and Saxony-Anhalt. If one looks at the development of environmental crime excluding Hesse and Berlin as displayed in figure 2, it is evident that the amplitude of the spike is significantly reduced. According to the State Office of Criminal Investigation of Hesse I know that there has been one big lawsuit in 1998 including about 1900 cases of illegal waste disposal. Hence, this part of the spike can be explained. In case of Berlin and Saxony-Anhalt[4] informations point towards the hypothesis that the spikes are mainly driven by relics due to waste sites of the former German Democratic Republic. The waste sites were closed in the late 1990s such that the possibilities for illegal waste disposals were eliminated in these areas. However, a general understanding of the mechanisms underpinning these dynamics is desirable.

[3] See the figures provided in appendix to section 1.3.

[4] Saxony-Anhalt is not included in figures 1 and 2 as it is Eastern Germany. The reader finds the relevant information in the appendix to section 1.3.

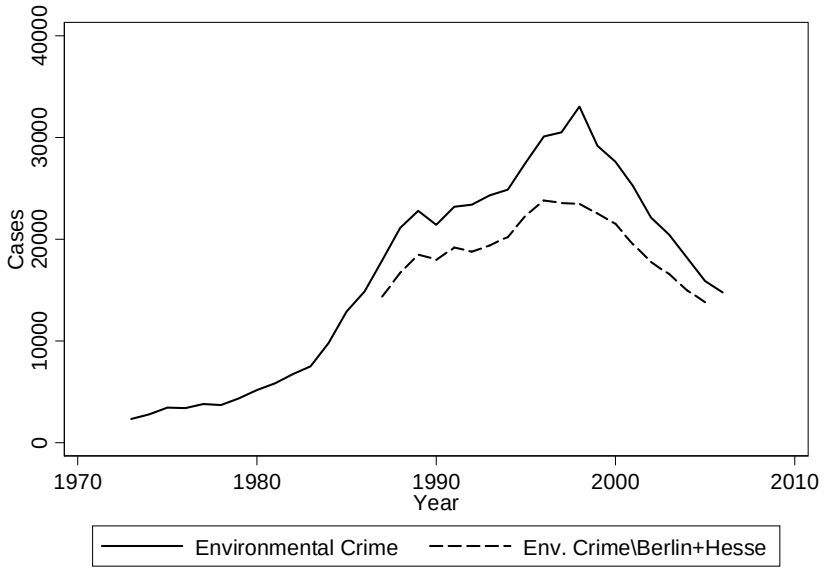
Figure 1: Environmental Crime in West-Germany (1973 - 2006)



It is also evident when looking at figure 1 that illegal waste disposals have a large and steadily increasing impact on overall environmental crime.

Figure 3 therefore contrasts the major types of environmental crimes committed in Germany (East and West together). About 75 percent of all cases involve offences related to waste disposal. Until the late 1980s, however, water pollution (§ 324 StGB) has been the dominating type of environmental crime in Germany. Illegal waste disposal (§ 326\(2) StGB) took over in 1991 (see BMJ 2001) with a rapidly growing discrepancy from thereon. However, since reported cases of illegal waste disposal decrease more rapidly than those of water pollution in the years following 1998, there may again be an intersection in the future. The figure also shows some other important types of environmental crime in Germany like the illegal transport of waste (§ 326(2) StGB), air pollution (§ 325 StGB), noise and tremor (§ 325a StGB), and the illegal operation of plants (§ 327 StGB).

Figure 2: Environmental Crime in West-Germany: Excluding Hesse and Berlin



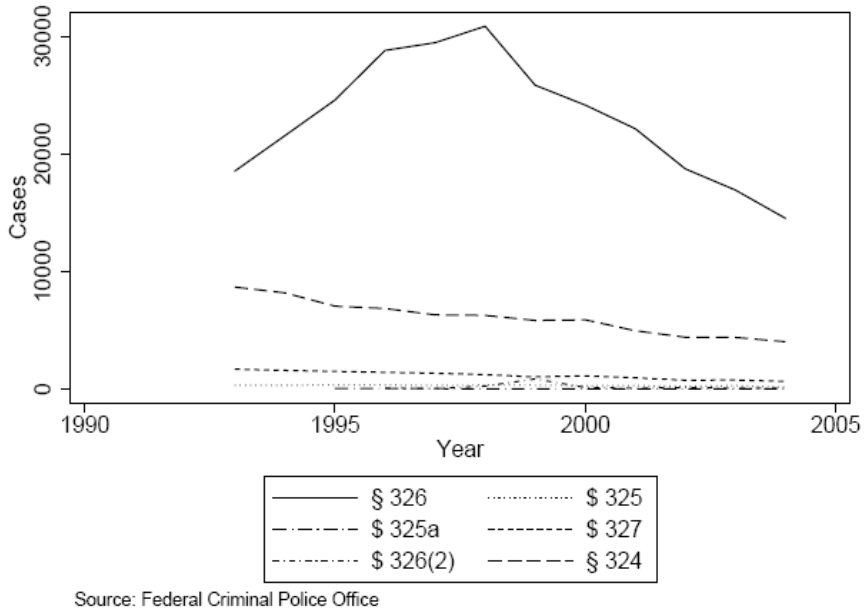
Source: Federal Criminal Police Office (including East-Berlin since 1993)

Figure 4 shows the evolution of illegal waste disposal in the state of Baden-Württemberg. This will be of special relevance for part III of the thesis where a more regional perspective is taken including several additional structural, political and waste specific variables in the analysis. Similarly to the case for Germany, the development of illegal waste disposals in the 44 counties of Baden-Württemberg in mainly driven by the counties and cities of Stuttgart, Ludwigsburg, Esslingen, Biberach and Böblingen. With the exception of Biberach all mentioned counties and cities belong to the metropolitan area of the state capital Stuttgart. Excluding those five counties leads to a far more stationary development.

Interesting is also the composition and origin of cases recorded in the official crime statistics. The main but decreasing (86% in 1998, 70% in 2003)[5] share of all lawsuits regarding violations of environmental law in Germany are initiated

[5]Statistisches Bundesamt (2003).

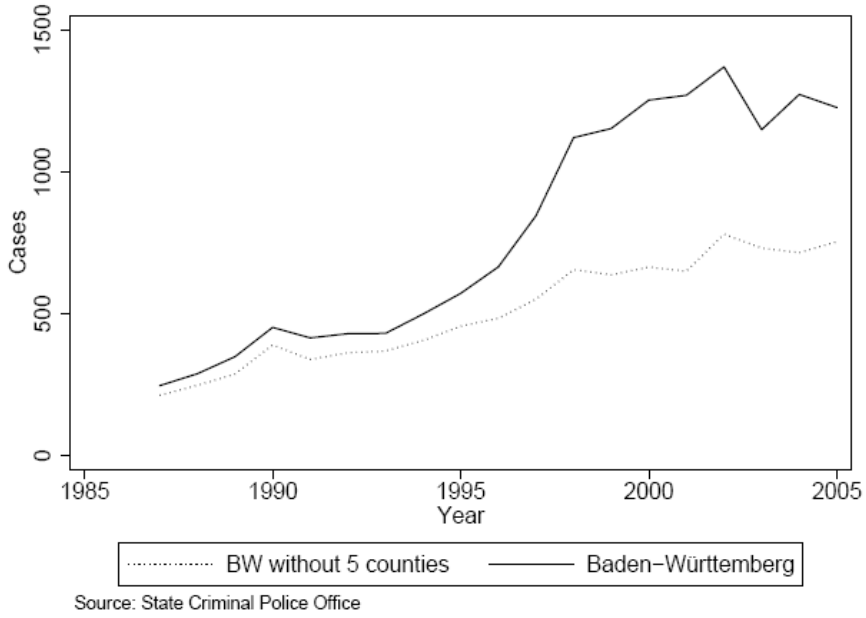
Figure 3: The Development of Cases for Different Articles of the German Penal Code (1993 - 2005)



by police. Theses cases may result from a hint given by some citizen or from a discovery made during patrol. A smaller but steadily rising part is initiated by prosecution (11% in 1998, 25% in 2003). A very small but also increasing fraction is initiated by administrative authorities (1,8% in 1998, 3,2% in 2003). In case of environmental offences the main part of these should be due to the commercial regulatory authority (*Gewerbeaufsichtsamt*) and should therefore reflect the fraction of violations committed by firms. Finally, a more or less negligible part is initiated by custom investigation (0,3% in 1998, 0,6% in 2003).

As the development of crime usually depends on several factors including the stringency of enforcement of the executive, it is of special interest to analyze the success of police, prosecution, and courts in enforcing environmental criminal law in detail. Figure 5 shows the development of clearance rates, the rate of tried

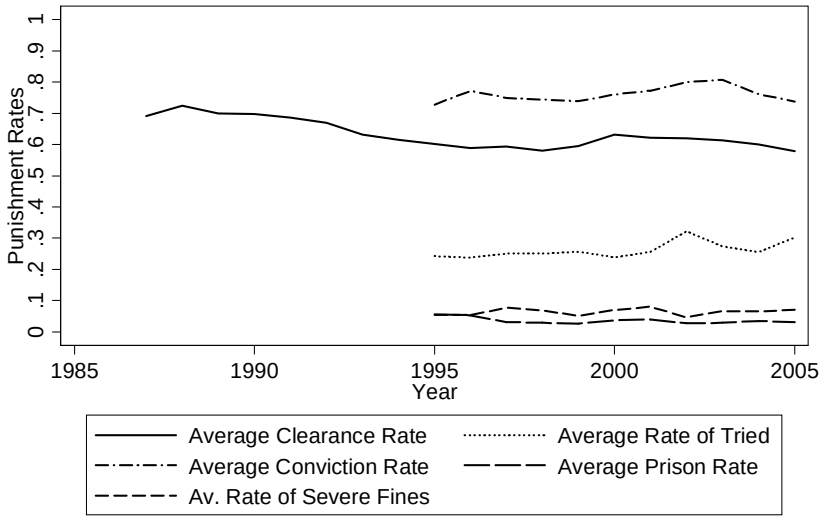
Figure 4: Illegal Waste Disposal in Baden-Württemberg (1987 - 2005)



offenders, conviction rates, the rate of severe fines, and prison rates for environmental crime. These are relevant for my analysis in part IV. As in later regressions, the enforcement variables have been generated sequentially. That is, the clearance rate represents the portion of cleared cases in comparison to all reported cases. The portion of accused suspects divided by all identified suspects is called the rate of tried offenders. The fraction of tried offenders who are convicted reflects the conviction rate and the fraction of convicted offenders sent to prison is called prison rate. Finally, the rate of severe fines indicates the portion of criminals sentenced to a fine above 90 daily rates (*Tagessätze*). Getting a fine above 90 daily rates implies a lasting record in the Criminal Records Bureau Check and may affect future job opportunities.

It is fairly evident that, in contrast to the amount of environmental crimes, the punishment rates remained rather constant over the last decade. The clearance

Figure 5: Average Punishment Rates for German States (1987/1995 - 2005)



Source: Federal Criminal Police Office/Federal Statistical Office.
Note: Data for clearance rates is available from 1987. Data for all other punishment variables is only available at the state level beginning with 1995.

rate of reported environmental crime is on average 62 percent, i.e. in 6 out of 10 cases one or more offenders are positively linked to the crime. Approximately 26 percent of identified offenders are prosecuted in courts. The remainder of cases are either dismissed for lack of evidence or insufficient severity of the offence or the offender punished using lighter administrative fines that establish no criminal record. Out of those ending up in court, over three quarters (76%) are sentenced, of which 6.4 percent are sentenced to a severe fine and 3.5 percent are sentenced to a prison sentence which in most cases is placed on probation. The rest faces a standard fine that is converted into a prison sentence only if there is refusal to pay. Therefore, within the population of reported crimes only approximately 0.4 percent face a prison term, the severest form of sanction. While these low shares of severe sanctions have led legal scholars to conclude that the deterrence

effect of environmental criminal law must be negligible (Lutterer and Hoch 1997; Schall 2006), the economist would point out that this could also be evidence of a particularly effective sanctioning regime.

To summarize, Germany has with its long experience in the criminal enforcement of environmental laws and the interesting development of reported cases of environmental crimes a very attractive setting for a profound analysis. In order to be able to compare the findings of the analysis obtained in parts II-IV with the existing literature, part I will give a review of the findings of the surrounding literature.

Part I

Review of the Relevant Literature

2 The Economics of Crime Literature

There are many theories around trying to explain why someone commits a crime or violation. Some criminologists believed and still believe that criminals are e.g. atavistic beings, reversions to primitive ages, mental disordered, hormonal imbalanced or even individuals with a low IQ.[6] They believe that individuals commit crimes because they are driven by some morbid mental dysfunctions. Some of them also argue that one can identify criminals on the basis of different physical characteristics, mental diseases or heritable components (see e.g. Raine 2002).

In contrast, Becker (1968) developed a model of crime that is based on decisions made by rational agents facing economic incentives. An individual will commit a crime if the gain trough this crime exceeds its (opportunity) costs. In this view criminals are no weird subjects but rather usual individuals maximizing their utility. This economic model of crime had far-reaching consequences since its introduction. With this model at hand society is no longer relegated to inactiveness as it was the case with previous approaches. Assuming that criminals occupy some sort of mental or genetic dysfunction implicates that society has very few options to influence potential criminals in order to deter them from illegal activities. Some kind of criminal addiction should be very resistant to changing circumstances like socioeconomic factors or law enforcement. In addition, punishing or medicating

[6] Levitt and Miles (2006) give a brief introduction to related work.

people just because they have some suspicious characteristics violates fundamental human rights.

On the other hand, rational individuals undertaking some kind of cost-benefit-analysis are highly influenceable. Aside from the arising social cost of deterrence, in order to erase crime one just has to make sure that the expected costs of crime exceed its gains. Taking costs of law enforcement into account, it will be in most cases neither socially optimal nor affordable to fully eliminate crime. Hence, one is also able to calculate some kind of socially optimal equilibrium crime rate in which neither actor (criminals, private individuals and government) has incentives to change their behavior (see Ehrlich 1996).

With the economic model of crime society has various instruments to reduce crime to an 'optimal level'. Admittedly, it is not plausible to assume that every decision to commit a crime is a fully rational one. There are still some types of crime for which it is hard to belief that the offender made a pure cost-benefit analysis. As a result, the response to enforcement activities will be different for particular crimes. Nevertheless, there is a huge amount of crimes, e.g. property crimes, fraud, white collar crimes and of course environmental crimes, for which economic reasoning is very plausible.

In the last few decades following Becker's (1968) article there emerged a vast empirical literature dealing with this economic model of crime. The empirical literature had thereby two major purposes. First of all it was the aim of many researchers, beginning with Ehrlich (1973), to test the economic model of crime empirically. The question here was whether data supports Becker's (1968) model and it turns out that it does for many cases (see sections 2.3 - 2.5). The other purpose was to figure out how to effectively and efficiently adjust the different

determinants of crime like potential gains and expected punishment.

Although the model of Becker is one of individual decision-making, most empirical studies used aggregated data on county, state or country level simply because of data constraints.[7] The purpose of the present part is to give a survey of the major findings of the empirical work conducted so far.

It should be mentioned yet that there are quite a few problems concerning data quality in the crime literature which affect the amount of applicable empirical methods. It is clear to everyone analyzing crime empirically that one will always face the problem of dark figures. Not every violation is recorded and therefore will not show up in official statistics.[8] This could yield great measurement error bias in empirical studies and therefore reduce explanatory power dramatically.

Another problem arises with different forms of endogeneity like simultaneity, unobserved heterogeneity and omitted variables. In case of simultaneity it turned out that variables like police force or severity of punishment etc. do not just have an effect on crime but also the other way round. Another topic in the empirical literature concerns the unobserved heterogeneity bias emerging when simple cross-section data is used. Furthermore, biases resulting from omitted variables show up in the area of crime like in every empirical project.

Two last concerns are made covering the bias arising through the aggregation of different crime rates and the possibility of time lags in the economic model of crime. Some studies aggregate different crimes to one crime index blending the individual effects to one. One additional factor which is not addressed very often

[7] For a review of work using individual data, see Witte (1980), Myers (1983), Cornwell & Trumbull (1994), Levitt (2002a) or Levitt and Miles (2006).

[8] Although there are great differences in the extent between various crimes. The dark figure of murder e.g. will be rather small in comparison to fraud.

in literature is the possibility of delayed responses. Since the economic model of crime is one of individual behavior, it may be that individuals need time to adjust their beliefs when the enforcement changes. If this is not incorporated in the model, results may not reflect the true relationships between particular variables.

The remainder of part I is organized as follows. Section 2.1 will give a short introduction into the theoretical basis of the economic model crime from which empirical studies derive their estimation equation. Sections 2.2 - 2.5 then give an overview of the results of empirical work conducted so far. Econometric methods are explained as well as effects of different deterrent variables, incapacitation or changing socioeconomic factors. Section 2.6 addresses the data problems a researcher faces when dealing with the economic model of crime empirically and section 2.7 concludes.

2.1 The Basic Economic Model of Crime

The economic approach to crime introduced by Becker's (1968) is a model of individual behavior. In its simplest form it argues that someone will commit a crime or violate some legal rule if the gain through this exceeds its costs in terms of expected punishment. A potential criminal is therefore seen as a rational individual maximizing its utility.

More formally, following Polinsky and Shavell (2000, 2006), a risk neutral individual will commit a crime or violation, iff:

$$B > p \cdot F = p(f + d(t)), \tag{1}$$

with

B : net benefit an individual obtains from illegal activity: gain obtained from illegal activity minus gain from legal activity (opportunity costs)

p : probability of detection;[9]

F: severity of punishment

f : possible fine for specific violation , $f \in [0, f_{\max}]$;[10]

t : possible length of imprisonment term for specific violation, $t \in [0, t_{\max}]$;[11]

$d(t)$: disutility per unit of imprisonment term t; $d(0)=0$; $d'(t) > 0$.[12]

In this very simple form, the model builds up a direct relationship between potential benefit B and expected punishment $p \cdot F$. The main finding is that increasing either p or F or both will result in greater expected costs of punishment for a potential offender and thus provide a higher level of deterrence. Assuming that offenders are risk neutral it makes no difference for the level of deterrence whether to increase p or F. Form an economic perspective, however, increasing the probability of detection and sending an offender to prison is more socially costly than to impose fines. This is the case, because the detection of criminals depends on the amount of police and increasing the amount of imprisonment implies higher expenditures for prisons. Stigler (1970) concluded that economic reasoning suggests that society should set fines to a maximum and the probability of detection to a minimum in order to generate the efficient amount of deterrence. As we will see in sections 2.2 and 2.3, empirical analysis only partly supports this suggestions. For

[9] Including the possibility of a dark figure into this model, p can be broken down into: $p = \frac{C}{N} = \frac{C}{Q-V}$, with: C : amount of criminals being detected; N : amount of recorded violations; Q : total amount of crime; V : dark figure.

[10] $f_{\max}$ may be at the individual wealth constraint of the offender.

[11] $t_{\max}$ may differ from crime to crime with the absolute maximum being a lifelong prison sentence.

[12] $d()$ should rise proportional to s, i.e. $d(s)=s$, if the individual is risk neutral in imprisonment term, see Polinsky and Shavell (2000/2006).

the case of environmental crime in Germany, the empirical analysis in parts II and III finds rather different results. Although it was not possible to include specific information for the severity of punishment, my results suggest that especially the very costly parts of enforcement like the probability of detection, the probability of accusation and the probability of imprisonment do generate the biggest deterrence effects.

The basic model of crime experienced numerous extensions. Interesting extensions for my purpose include variables for the probability of getting a fine p_f and being arrested p_i, and functions for f and t that depend on the severity of the crime s (marginal deterrence).[13] Furthermore, the particular probabilities may depend on the expenditures e for police, prosecution, courts or other public enforcement agencies and on the severity of the crime s. It is also likely the case that the probability of detection will be a function of the expenditures for police and other public institutions detecting legal violations. In the same manner the probability of getting a fine may depend on the expenditures for prosecution and for courts. Finally, the probability of imprisonment may depend amongst others on the expenditures for prisons and all probabilities may depend on the severity of the committed crime. Finally, one presumes that gain g, fine f and imprisonment term t rise with an increase in the severity of a violation.[14] Furthermore, the probabilities of detection, getting a fine and getting arrested rise with both enforcement expenditures and the severity of the violation.[15]

[13] For a more complete list of extensions, see Polinsky and Shavell (2000/2006).

[14] More formally: $\frac{\Delta g}{\Delta s} > 0$, $\frac{\Delta f}{\Delta s} > 0$, $\frac{\Delta t}{\Delta s} > 0$, and finally, $\frac{\Delta d}{\Delta s} = \frac{\Delta d}{\Delta t}\frac{\Delta t}{\Delta s} > 0$.

[15] More formally: $\frac{\Delta p_D}{\Delta e} > 0$, $\frac{\Delta p_D}{\Delta s} \geq 0$, $\frac{\Delta p_m}{\Delta e} > 0$, $\frac{\Delta p_m}{\Delta s} > 0$, $\frac{\Delta p_a}{\Delta e} > 0$, $\frac{\Delta p_a}{\Delta s} > 0$.

Taken together, one can write the economic model of crime more elaborate as:

$$g(s) > p_d(s,e)[p_f(s,e)f(s) + p_i(s,e)d(t(s))]. \tag{2}$$

Although it should be obvious why the probabilities of getting a fine or being arrested are assumed to rise with severity of the crime, it may not be obvious for the probability of detection. However, the more severe the crime, the more efforts will be made to detect the offender (Polinsky and Shavell 2000). For example, one has just to think of the mobilization of special forces to free hostages or to arrest serial killers. As this may not hold for all types of crimes I assume that the probability of being detected will at least not decrease with severity of the crime. Although there is not enough information available to test this model with all its characteristics together in one estimation approach, the remaining parts of the present thesis analyzes this model step by step. Parts II and III test the more basic model of deterrence on different levels of aggregation in order to address the various characteristics of environmental crime in Germany. Part IV finally provides a specific analysis for the determinants of the sanctioning regime applied in Germany. More specifically, it will give a first insight whether German data supports theoretical suggestions that the probabilities of being sanctioned in either way do not only depend on the available resources and the criminal‘s guilt.

In order to test the theoretical predictions with real life data, the next section now translates the theoretical model of crime into an empirical estimation equation.

2.2 The Empirical Version of the Economic Model of Crime

Since there is not much variation neither in the type of model nor in the econometric strategies used to estimate Becker's (1968) model, I labeled this chapter 'The Empirical Version...' indicating that there is only one version. As we will see soon, most papers use a more or less similar version of the model presented by Ehrlich (1973) which is based on the theoretical model of Becker (1968). Although Becker's (1968) model is one of individual behavior most studies use aggregated data (Ehrlich 1973, Cornwell and Trumbull 1994, Andreoni 1995, etc.). This is mainly because of data availability. As this is also the case for the German data used for my empirical analysis, I will concentrate on papers that are based on aggregated data.

Using a log-linear or log-log form, most models look very similar to the following named 'The Supply-of-Offenses Equation' by Ehrlich (1973):

$$ln\left(\frac{Q}{N}\right) = A + \beta P + \gamma S + \delta Y + \epsilon, \tag{3}$$

where Q reflects the number of offences, N the number of persons in the community, A is some constant and P is a vector containing variables affecting the probability of punishment. Furthermore, S is a vector consisting of variables indicating the severity of punishment, Y is a vector for socioeconomic factors and $\beta, \gamma, \delta, \epsilon$ stand for the parameters to be estimated and the disturbance, respectively. P again exhibits variables like the police force and/or detection rates, conviction rates, arrest rates or imprisonment rates.

Especially in the presence of dark figures there might be a measurement error bias when using different punishment rates since they all are somewhat 'endoge-

nous' (Pudney et al. 2000). For example, the probability of detection is nothing else than the number of detections divided by the number of offences Q. So all these punishment rates should somehow be related to Q. The potential problems arising through dark figures will be of special concern in my empirical analysis on environmental crime as dark figures are considered to be relatively high for this type of crime.

Moreover, S usually includes either the size of prison population or the length of imprisonment with the latter seeming to be more obvious for most purposes. P and S together are meant to reflect the deterrence part of the economic model of crime. Y may contain very different socioeconomic factors ranging from unemployment, gender, minority fractions, education, wages, to population density or different income (distribution) variables. As we will see later, there is an increasing part of literature in present years dealing with all kinds of socioeconomic factors.

Most studies reviewed in this chapter use this or a slightly adjusted version of the mentioned model depending on data structure, estimation methods and research question. As stated previously, there are different problems one has to deal with when estimating the economic model of crime. Dealing with unobserved heterogeneity or endogeneity in general, many models use Random/Fixed-Effects procedures or 2SLS, 3SLS and GMM and therefore include unobserved effects or instruments in their analysis. Papers using time series of crimes need to control for special problems arising through autocorrelation, (co-)integration, time lags, trends etc. It is therefore necessary to customize the model but in most cases the core estimation equation remains the same.

The next section will give a detailed review of the results of the existing literature dealing with the economic model of crime. I will particularly focus on the

deterrence literature but also stress socioeconomic factors. After analyzing individual effects, I will summarize to which extent the economic model of crime by Becker (1968) is confirmed by the empirical literature.

2.3 Deterrence

In this chapter I discuss the findings of the deterrence literature that represents the major part of the crime literature (at least in the field of economics). As already mentioned, it is one of Becker's (1968) merits that we have a theoretical model explaining the relationship between law enforcement and the amount of crime. An individual being accessible to economic incentives or rational behavior should at least to some extend respond to changing law enforcement conditions. More precisely, a more severe enforcement in the sense that the probability of detection or conviction, the severity of punishment, or both increase causes increasing expected costs of crime. Increasing the costs of crime will have a deterrent effect on rational criminals. In the next section I will discuss whether this is confirmed by the empirical literature.

2.3.1 Probability of Punishment

First, I want to address the deterrent effect the probability of punishment has on criminal behavior. There are several measures for this. Many studies just use direct probabilities like the arrest, conviction or imprisonment rate. Very little studies use the detection rate as a deterrence variable. The detection rate reflects the portion of offenders that are identified by legal authorities.[16] This does not

[16] For many crimes, especially for felonies, the detection rate should coincide with the arrest rate (as long as every criminal gets caught) since suspected criminals will be arrested for these

coercively imply that this offender will also be punished but it should not be in the interest of the offender to get known to enforcement authorities.

In contrast, the arrest rate directly implies that this portion of offenders already received some kind of punishment but does not tell anything about how sure their conviction is. The conviction rate reflects the portion of offenders that are convicted and thus face any kind of punishment. The imprisonment rate finally reflects the portion of imprisonments but not stating for how long on average.

Another variable, namely police force, is more a determinant of the probability of punishment rather than a direct measure. However, police should have a direct influence on the detection and arrest rate, whereas the conviction and imprisonment rate should be more affected by the amount of prosecutors and judges, respectively.[17]

To foreclose the results, when dealing with the already mentioned problem of simultaneity, the majority of recent studies is in favour of a deterrent effect due to the probability of punishment.

Punishment Rate

As my later empirical analysis rely to a great extent on the deterrence effect various punishment probabilities have for the German Environmental Penal Code, I will give a more extensive literature review on this factors.

Ehrlich (1973) used a proxy for the imprisonment rate[18] finding the resulting negative parameter estimates and thus the deterrent effect to be both economically and statistically significant for all types of crimes. Andreoni (1995) also finds a

types of crimes.

[17]Data on the number of prosecuters and judges is rarely used in practice.

[18]The author uses state-wide prison commitments per year.

significant deterrent effect of the imprisonment rate noting that there might be endogeneity between the severity of punishment and probability of punishment due to 'avoidance' or 'reasonable doubt' effects. Levitt (1998b) tries to separate the deterrence from the incapacitation effect estimating a huge and statistically significant deterrence effect for burglary with one more arrest eliminating two burglaries. One very often cited panel data study conducted by Cornwell and Trumbull (1994) also estimated significant deterrent effects for the arrest, conviction and prison rates. Cherry and List (2002) repeated their estimation trying to prevent the bias due to the aggregation of different crimes into one index as apparent in Cornwell and Trumbull (1994). The authors find significant deterrent effects for most types of crimes but also a great variability in the estimated effects. Baltagi's (2006) reestimates also show significant deterrent effects with elasticities of -0.35 for the probability of arrest, -0.28 for the probability of conviction, and -0.17 for the probability of imprisonment. Cherry (1999) also used panel data and confirms previous results for the probability of arrest with elasticities between -0.07 (Larceny) and -0.3 (Robbery). He also claims that not controlling for unobserved heterogeneity overstates the deterrent effect in his sample by about 20%. Mustard (2003) estimated the economic model of crime with a special focus on the arrest and conviction rate. He also finds a deterrent effect which is significant for most types of crimes and therefore also supports the deterrent hypothesis of the probability of punishment. Viren (2001) estimated the economic model of crime with Finnish and international data. The author confirms the deterrence hypothesis of both apprehension and punishment in almost all different specifications and estimation routines used. Gould et al. (2002) get the same results for the deterrent effect of the arrest rate on all types of crimes analyzed. To summarize, there

is great support that the mentioned punishment probabilities have the intended deterrent effect on criminal behavior.

However, as most studies only include some of the mentioned enforcement stages it is difficult to assign the relative contribution of the different probabilities to the deterrence effect. In general, the elasticities range between almost 0 to up to about -3 in some rare cases. The results of my own analysis fit perfectly in this frame as I will show in parts II and III. The elasticities range from ambiguous and not statistically significant to -1.5 (prison rates, part II) and highly significant effects. Moreover, parts II and III of the thesis include variables for all stages of the enforcement process and are therefore able to compare the relative contributions.

As this section suggests, there is no doubt that the probability of getting sentenced deters people from committing crimes. However, some authors tried to determine the deterrent effect of the probability of getting caught indirectly via the amount of police. Is is therefore the aim of the next section to discuss this in more detail.

Police force

The amount of police should heavily influence the probability of getting caught although there are of course other factors like individual characteristics of criminals, victims or crimes which govern the probability of punishment. Nevertheless, estimates for the effect of police expenditures on the probability of punishment have the expected positive sign, but they are not statistically significant (Ehrlich 1973, Andreoni 1995) . This could have several reasons. Either expenditures are not the right measure for the amount of police, the marginal effect of additional police has a rather weak deterrent effect (there is one as we will see soon), or the

focus of police investigation has changed (see Corman and Mocan 2000).

Estimation results for directly measuring the effect of the size of police force on crime are very heterogenous.[19] Cornwell and Trumbull (1994) and Baltagi (2006) find positive and in most cases significant effects of police on crime. Baltagi (2006) has two possible explanations for this. Either a greater police force directly increases the number of recorded crimes or there is an endogeneity problem since more crime attracts more police.

The estimates of Cherry and List (2002) show that using the aggregated crime index as Cornwell and Trumbull (1994) did results in a positive effect whereas splitting into different crime categories yields to a negative and significant effect of police on crime.[20] The authors find a positive and significant effect of 0.41 for the index and negative and (for most categories) significant effects for individual crimes ranging from -0.12 (assault) to -0.4 (Larceny).

However, Cherry (1999) also using panel data at the individual crime level reveals again positive and significant effects.[21] Gould et al. (2002) included (log) police expenditures per capita and (log) police employment per capita as indicators for police force. They find positive and (mostly) significant effects for police expenditures and negative and insignificant effects for police employment. Levitt (1997) addressed this question finding the number of sworn police officers to be negatively related to crime rates but only significant as an index not for individual categories of crime. Nevertheless, he concludes that a 10% increase in police force leads to a 3% to 10% decrease in crime. Using another instrument for police force

[19] For a further survey see Cameron (1988) or Levitt and Miles (2006).

[20] Cornwell and Trumbull (1994), Baltagi (2006) and Cherry and List (2002) all use police per capita as measure for police force.

[21] The author states that this findings are robust even when controlling for simultaneity.

and reestimating the model, Levitt (2002b) finds the elasticity between police per capita and crime to be -0.43 for violent and -0.5 for property crimes which are significant for both cases. Evans and Owens (2006) use special grants for police officers (Cops program) in the US to determine the effect of police on crime. They find a negative effect of police on crime for all crime categories but only significant effects for four out of eight crime types.

So far, one only observes a weak evidence for the deterrence effect of police on crime. However, there are some authors who tried different empirical strategies like time series analysis or some exogenous event to circumvent problems like simultaneity, lagged effects and unobserved heterogeneity.

Marvell and Moody (1996) applied time series analysis and the concept of Granger-causality to break simultaneity. In their sample including state and city data for over twenty years, they found that increasing police force leads to future declines in the crime rates. Corman and Mocan (2000) used a monthly time series for NYC and the concept of Granger-causality estimating the deterrent effect of police on crime to be between -0.41 and -0.53 (elasticities) but not significant for two out of four crime categories.

Another method to deal with potential simultaneity is the use of purely exogenous events that influence the amount or allocation of police forces. Di Tella and Schargrodsky (2004) and Klick and Tabarrok (2005) e.g. estimated the effect of police on crime after a terrorist attack and changing terror alert levels, respectively. Di Tella and Schargrodsky (2004) find that neighborhoods in Buenos Aires with a special police protection after a terrorist attack benefit from an average decline of car thefts of about 75% in comparison to other districts. Klick and Tabarrok (2005) find that crimes on high-alert days in Washington D.C. are reduced by

about 6.6%. They argue that the source of reduced crimes on high-alert days is due to greater police presence on streets at these days.

What can we conclude for the deterrent effect of police on crime since there is some variation in the results especially for the link between expenditures and crime rates? One thing to conclude is that simultaneity seems to be a important problem in this context. It is therefore very important for the reliability of results to use the right estimation strategy.

In line with this, the estimates for the state-level analysis of part II do not reveal a significant effect of police on crime (see table 25 provided in the appendix). This may have several reasons. First, this may be due to endogeneity issues discussed in the previous literature. The second reason may be that, as already stated by Baltagi (2006), the deterrent effect may be overlaid by an detection effect. Another reason pertains the special characteristics of the German case. As environmental offences do not have priority compared to felonies, increasing the number of policemen may not reflect more effort to detect and clear environmental offences. Unfortunately, there is no data on the number of policemen responsible for environmental offences available.

2.3.2 Magnitude of Penalty

The second determinant of deterrence in the economic model of crime is the magnitude or severity of punishment. In most cases punishment means either fines or imprisonment, or both. As most studies use imprisonment variables like the average length of prison sentences or the size of the prison population, I will concentrate on those and just briefly discuss the effect of fines. The economics of crime literature merely focuses on the analysis of felonies. This implies that the usual

sentence for a convicted criminal will be imprisonment. This contrasts with the literature on the enforcement of environmental regulations where fines are most important. This is also true for environmental crimes in Germany, where also fines are the major type of punishment.

Like it is the case for the probability of punishment, simultaneity is also an issue in this case. With recognizing a higher crime rate, governments or judges could be tended to increase the severity of punishment. However, there is one more concern one has to take care of. It is not obvious whether a reduction of crime due to imprisonment is the source of deterrence or incapacitation. The amount of crime could just be reduced, because future crimes are prevented by locking up repeated offenders. As we will see soon, this problem is only discussed by very few studies. In the next section, I will focus on those studies that do not address this problem and implicitly assume a pure general deterrence effect. The subsequent section will be dedicated to the part of the literature trying to separate the incapacitation and the deterrence effect from each other.

Imprisonment

Ehrlich (1973) used the average time spent in prison as an indicator for the severity of punishment and finds elasticities between -0.02 (murder) and -0.91 (burglary). However, estimates have all the expected sign but are only significant in some cases. Andreoni (1995) using the same indicator but for an index of all crimes finds the elasticity with respect to the crime rate to be -1.06 and significant. The author also regressed different crime rates on imprisonment length stating a negative relationship for almost all crimes (except murder) that is significant for many categories. Andreoni (1995) interprets this as evidence for a strong deter-

rence effect for the severity of punishment. Cornwell and Trumbull (1994), Cherry and List (2002), Mustard (2003) and Baltagi (2006) used panel data and also average prison length to examine the deterrent effect of the severity of sanctioning. Cornwell and Trumbull (1994) and Baltagi (2006) find a negative but insignificant relationship between prison length and crime for the index of all crimes. Cherry and List (2002) disaggregated the Cornwell and Trumbull (1994) data and find both ambiguous signs and insignificant effects. In line with this, Mustard's (2003) estimates reveal positive and insignificant effects for all eight crime categories.

Cherry (1999) also uses panel data but prison population as an indicator for the severity of punishment. Like most others, his estimates for different crime types have different signs and are insignificant.

In general, there may be several reasons for this ambiguous findings. First of all the studies so far did not stress the possible existence of the incapacitation effect. However, this should overstate the deterrent effect and can therefore not explain the findings so far. Another concern is simultaneity. As already mentioned, higher crime rates could be associated with longer prison terms. Not controlling for this the deterrence effect of the severity of punishment is understated and this could be an explanation for previous estimation results. In what follows, I will discuss papers especially dealing with possible simultaneity.

Corman and Mocan (2000) used monthly time series data and they find a significant deterrent effect of the lagged growth of arrests for all five crime categories. Marvell and Moody (1994) also using time series analysis and changes in prison population find that a 1% increase in prison population results in 0.16% fewer overall crimes. The elasticities for individual crimes vary between -0.06 (Homicide, insignificant) to -0.26 (robbery, significant). In general, the estimates seem

to be robust for property crimes like robbery, burglary, larceny and vehicle theft. Levitt (1996) used an instrumental variable approach to estimate the effect of prison population on crime. In order to break simultaneity, he uses a variable indicating special prison overcrowding litigations for different U.S. states. The estimates reveal a negative and significant relationship between prison population[22] and crime with elasticities of -0.37 for violent crimes and -0.26 for property crimes.

Similarly to the police variables, the deterrent effect of the severity of punishment is only definite when one controls for simultaneity. Dealing with simultaneity results in a negative and significant effect of punishment on crime. However, in all studies mentioned so far, there is no distinction between deterrence and incapacitation. I will now briefly discuss the deterrent effect of fines before I switch to studies that try to separate both effects.

As we will see in parts II and III, the enforcement data for Germany does not allow to construct reliable indicators for the average prison length. Publications by the Federal Statistical Office do not exhibit the true amount of the prison sentence but categorizes each prison term into different ranges.

Fines

Although fines seem to be an appropriate measure for the severity of punishment, there are not many studies around using it. As already mentioned, this may be due to the fact that the crime literature mainly analyzes felonies with imprisonment as the typical sanction. However, as fines are the major type of punishment for environmental crimes in Germany, it is important to have some benchmark.

Bar-Ilan and Sacerdote (2004) used fines in the context of red-light running.

[22] Levitt (1996) uses per capita incarceration rates as an indicator for prison population.

The authors claim that their special dataset has several advantages. First, there is no dark figure since every violation is proved by hidden cameras. Second, due to the fact that there is usually no imprisonment after traffic violations, there should be no incapacitation effect like it is the case for imprisonment. Other advantages regard the quality of informations for single offenders and the occurrence of an exogenous shift in the penalty. Bar-Ilan and Sacerdote (2004) use data for San Francisco and Israel, where fines for red-light running increased significantly. The authors find elasticities for the response of criminals to increasing fines to be between -0.20 and -0.30.

Since there are many legal violations around which are sentenced by fines and fines therefore are an important instrument for deterrence, it would be nice to have more evidence for the deterrent effect of fines.

2.4 Incapacitation versus Deterrence

As already mentioned in the last section, there is a problem with regressing crime on the severity of punishment approximated by the size of prison population or the average length of imprisonment. It is not clear whether the estimated coefficients show the deterrent effect of imprisonment or the effect due to hindering a criminal from committing further crimes. Levitt (1998b) tried to distinguish both effects arguing that a increasing the severity of punishment for one particular crime should redirect potential criminals to substitutable crimes. For example, if sentences for robbery increase, criminals may tend to switch to larceny instead. However, if in response to more severe sentencing for one particular crime the amount of crime falls in general, then this may the result of incapacitation. Levitt (1998b) tries

to separate the deterrence and incapacitation effect of increasing arrest rates and therefore incorporates the arrest rates for other crimes in the particular crime equation. The author concludes that deterrence is relatively more important than incapacitation. Levitt (1998b) finds negative coefficients for all crimes and both deterrence and incapacitation, although deterrence is not significant for murder and rape and incapacitation is only significant for rape (-0.518) and robbery (-0.688). The remaining deterrence effects range from -0.365 for assault to -2.342 for burglary.

Levitt (1998c) compares crime rates of various states in the U.S., where the transition from juvenile to adult justice system is treated differently in terms of the severity of punishment. The author runs regressions using a measure he calls relative punitiveness which compares adult imprisonment rates and juvenile imprisonment rates. Levitt (1998c) argues that an ad hoc decrease of crimes during the transition from juvenile to adult crime in states with a relatively severe punishment strategy for adults should be the source of deterrence. The effect of incapacitation should have a time delay since offenders first have to commit a crime and then have to be sentenced to prison. Levitt (1998c) concludes that in states with a relative harsh adult justice system, crimes fell by almost 10% - 15% for property crimes and 25% for violent crimes relative to states with lenient adult crime systems.

Kessler and Levitt (1999) tried to separate both effects using the influence of a referendum called Proposition 8 on crime rates in California.[23] The authors argue that this proposition should have no effect on prison population at least in the short run, because the particular crimes were punished with imprisonment anyway. Kessler and Levitt (1999) suggest that this sentence enhancement should,

[23] A referendum that provides sentence enhancements for repeat-offenders and different felonies.

at least in the short run, only have a deterrent effect on criminal behavior. The authors find an immediate decline in eligible crimes of 3.9% and after three years the decline went up to 7.9%. Kessler and Levitt (1999) conclude that this effect can be attributed to deterrence and not to incapacitation.

Corman and Mocan (2000) estimate the incapacitation effect as part of a very broad analysis of the economic model of crime. They quantify the elasticities to be between -0,006 (murder) and -0,032 (assault).

Not only the last study by Corman and Mocan shows that the incapacitation effect may be very small in most cases. Nevertheless, one can not conclude that it is appropriate to neglect the effect a priory. When using prison population or prison length measures, the applied econometrician should take the possibility of incapacitation into account and, when possible, control for it.

2.5 Socioeconomic Factors

Socioeconomic variables are included in most models because they are assumed to reflect the legal opportunities of the population under consideration and therefore also the legal income opportunities of potential criminals. In an environment with low wages, high unemployment, high poverty and high inequality, people usually think that crime is more attractive than under opposite circumstances. It is therefore the intention of this section to discuss the importance of socioeconomic variables in explaining criminal behavior.

There is a rich empirical literature focusing on the effects of socioeconomic variables on crime. These papers do not explicitly refer to the economic model of crime but nevertheless contribute to its discussion. There is also a great number of

socioeconomic variables like population density, percentage of males, etc. included in many papers and these variables sometimes have a significant effect on crime. Nevertheless, this is not what I want to concentrate on in this section. Instead I will briefly discuss those socioeconomic effects that may also have an influence on the amount of environmental crime in Germany.

Unemployment and Labor Force Participation

Unemployment and labor force participation are factors that seem to be of importance for both crimes in general and environmental offences (see section 3.3.3) in particular.

Ehrlich (1973) included the unemployment rate of males with the age of 14-24 and 35-39 and a variable for labor force participation of 14-24 year old males. The author does not find a significant effect for unemployment, effects for labor force participation were only negative and significant for murder and rape and not for property crimes. More generally, Cherry (1999) used the portion of population that is not employed and finds significant positive effects for the index and in particular for assault, burglary, larceny, assault and burglary. Zhang (1997) finds the relationship between unemployment and crime to be positive but insignificant. Surprisingly, Viren (2001) finds negative and sometimes even highly significant effects of unemployment on crime for his analysis of Finnish municipal data. Bourguignon et al. (2003) use Colombian panel data and find a positive and significant effect of unemployment on crime and a negative and not significant effect for labor force participation. Levitt (1996) incorporated the growth of unemployment in his analysis estimating the effect to be positive for all crimes but only significant for property crimes. Almost identical results are obtained in

another paper by Levitt (1997). However, Levitt (1998b) finds ambiguous results. Whilst the estimates for property crimes have the expected positive sign and are significant for burglary and larceny, the effects for crimes against persons are negative and even significant for murder and rape. Levitt (1998c) runs regressions on juvenile and adult crimes rates as well as for the transition from one to the other. He finds a positive and significant effect of the state unemployment rate for property crimes in all equations and sometimes negative and significant effects for violent crimes. Gould et al. (2002) use the unemployment rates of U.S. states in various regressions and conclude that unemployment has a positive and significant effect for property crimes and ambiguous effects for violent crimes. The authors estimate that the 3% increase of unemployment in the period between 1979-1993 raised property and violent crimes by 7.1% and 3.8%, respectively.

In addition, there are quite a few time series analysis that stress the relationship between unemployment and crime. Cantor and Land (1985) focusing on the relationship between unemployment and crime distinguish between a criminal opportunity and a criminal motivation effect and conclude that unemployment has a overall positive effect on poverty and violent crime. Marvell and Moody (1996) in their time series analysis find a negative but not significant relationship between employment and the seven index crimes. Greenberg (2001), as a response to Cantor and Land (1985), also concentrates on the analysis of the effect of unemployment on violent and property crime. After controlling for lagged unemployment and duration of unemployment, he is not able to get significant estimates. At last, there is another time series study dealing with the economic model of crime in general and the effect of unemployment on crime in particular. Saridakis (2004) incorporated the percentage of employed female population as well as duration of

unemployment (mean of weeks unemployed) in his analysis of violent crime. He argues that the former displays the reduction of parental supervision and thus could be positively related to crime. The author could not find a significant effect, neither for portion of employed female population nor for unemployment duration, on crime.

To conclude, there seems to be reliable evidence for the positive effect of unemployment on property crimes, but not for violent crimes. Although the former seems to be not valid for time series studies. This is in line with the suggestion that unemployment leads to less income and therefore property crimes get more attractive. Results for labor force participation allow no clear-cut conclusion.

For my own empirical analysis in parts II and III unemployment or labor force participation did not have a significant impact on environmental crime (see table 25 provided in the appendix).

Income and Poverty

Ehrlich (1973) also includes income and inequality measures in his very comprehensive analysis. The author uses median income of families as an indicator for income. Estimates show up to be positive for all crime categories but only significant for property crimes. Andreoni (1995) also incorporates median family income in his analysis comprising Ehrlich's (1973) results. Hsieh and Pugh (1993) conduct a meta-analysis including 34 studies and find the average estimate for poverty on crime to be positive (0.44) and significant. Marvell and Moody (1996) find a positive relationship for income and poverty rate in their Granger analysis but both effects are not significant. Zhang (1997) includes per capita disposable income, aid for families with dependent children (AFDC), medical payments (Medicaid),

payments for school lunch program, public housing expenditures and different variables for welfare payments in his analysis. The author constitutes that especially AFDC, Medicaid and public housing are "the core of the transfer system for the low-income population" (Zhang, 1997). He finds positive but insignificant effects for income and negative and significant effects for the different welfare programs. AFDC had a negative but not significant and public housing a negative and significant effect, respectively. The effects for school lunch and medical aid programs also appear to be insignificant. Levitt (1997) includes public welfare spending per capita finding a negative but in all cases insignificant relationship for property crimes. In another paper (Levitt 1998b), the author finds very heterogenous results varying in sign and significance for property and violent crimes. Cherry (1999) uses real income per capita as an explanatory variable in his crime equation and finds unambiguous effects for his Random/Fixed-Effect estimation that are only significant (and positive in this cases) for assault and auto theft. Corman and Mocan (2000) include AFDC as a measure for poverty and estimate a positive effect on crime that is only significant for murder and assault and not for robbery, burglary, and motor-vehicle theft. Viren (2001) includes an income variable in both, his cross country and pooled analysis for Finnish municipal data. In both cases he estimates a positive and in most cases highly significant effect. Fajnzylber et al. (2002a/b) include GNP per capita and GDP growth rate in their panel data analysis for different countries. The authors estimate a negative effect for GDP growth on both, homicide and robbery. GNP per capita, however, seems to have no effect on both crime categories.

Gould et al. (2002) use state income per capita in their panel data analysis for the U.S.. The authors find positive and significant effects for most regressions

for both, absolute values and growth rates. Kelly (2000) includes poverty in his analysis finding positive effects in most cases, especially when police force is treated as being endogenous.

Taken together, it is not quite clear how income affects crime. Low income measures could mean that there are many poor people and therefore many people with high incentives for property crimes. On the other side, high income also is associated with high earning opportunities through crimes. In the reviewed papers, there seems to be more evidence for the positive effect of income on crime.

Poverty variables tend to have a positive effect on crime, as one might expect. The results for welfare programs and GDP are more ambiguous. In most cases findings suggest a negative effect on crime .

I also include variables for GDP per capita, income per capita and welfare spending into my analysis of environmental crime. However, none of the mentioned variables shows up to have a robust effect on environmental crime in Germany (see part II and table 25 provided in the appendix).

2.6 Empirical Shortcomings

As already mentioned, there are quite a few problems one has to deal with when estimating the economic model of crime with real life data. The first challenge one faces when studying crime rates is the possibility of a dark figure. Nobody can make sure that every offence will be observed and then reported to and recorded by official authorities. Depending on which factors influence the amount of dark figures there might be a great measurement error bias when ignoring this. Subsection 2.6.1 will therefore address this issue and give an overview of the relevant

literature. Furthermore, various types of endogeneity play a crucial role in extracting the 'true' causal relationship within Becker's (1968) model. The majority of previous work did therefore concentrate on this topic as described in subsection 2.6.2. The last part of this section focuses on the work by Cherry and List (2002) who extrapolate the bias resulting through aggregating different crime rates to one crime index.

2.6.1 Dark Figure

For many types of crime and especially for environmental offences there is usually a substantial amount of violations that is not included in official statistics. This shortcoming may play a crucial role when interpreting estimated effects as being causal. It may e.g. be the case that increasing police force just leads to a reduction of dark figures, not a reduction in the amount of crime itself. Neglecting the existence of dark figures then results in a spurious positive effect of police on crime. Therefore, official statistics have to fulfil at least one of two conditions in order to get unbiased estimators when ignoring the possibility of a dark figure. As Eide (2000) points out, the regional and temporal reporting or recording behavior has to be constant in order to get unbiased estimates. Further on, there should also be no problem if the dark figure is fluctuating randomly such that it is not related to any kind of variable explaining crime (McDonald 2002). If this is not the case it will be questionable whether results are reliable. Blumstein et al. (1978) e.g. find differences in dark figures to cause a spurious negative relationship between crime and clearance rates. It is therefore an important task to study the properties of dark figures in order to perform reliable analysis.

To proceed it is important to define what a dark figure is. There are two

definitions around which are often not explicitly differentiated. In few cases dark figure means the ratio between crimes included in official statistics and the 'real' amount of crime. Another definition uses the difference between the 'real' amount of crime and official crime statistics. In this thesis, I will assign the term dark figure to the second definition.

There are two main reasons why a criminal activity may not be included in official statistics. First there is the possibility that a potential[24] crime is not recorded to the police. The reason for this may either be that the crime was not observed by anyone or it has been observed but not recorded to any authority. Naturally, one is not able to say anything about the amount of the former. According to the annual conducted British Crime Survey (BCS), however, the latter amounts to 57% of all crimes in 2004 (Nicholas et al. 2005). Additionally, there is also a great difference in reporting behavior between different types of crime.[25] Victims asked why they did not report to the police respond in 71% of all cases with "incident was to trivial", "there was no loss" or "police could not do much about it". Besides this, in 20% of all cases the respondent stated that the incident was private matter (in violent crimes even 41%).

The second reason for a crime being not listed in official statistics is the possibility that a crime is reported to official authorities but not recorded by them. This amounts of 11% in the BCS in 2004 and a substantial amount of under-recording seems to be due to human failure.

Taking both aspects together, these numbers imply that only 32% of all offences

[24]Not every presumed violation is also an illegal activity in the sense of law. However, this holds also in the opposite direction.

[25]For vehicle thefts it was about 95%, whereas the rate for vandalism and theft from person was only at 32% (Nicholas et al. 2005).

are listed in official statistics in 2004 for England and Wales. Albeit this rate appears to be relatively constant over time (39% in 2000), its variation could have highly distorting effects in multivariate settings.[26]

The U.S. National Crime Victimization Survey (NCVS) is also a periodic victimization survey which included 42,000 households and 72,000 people in 2004 (USDOJ 2006). Similar to the BCS, the NCVS finds merely constant but little reporting behavior in the American population. In 2004, 41.5% (40.5% in 2003) of all victims reported the violation to the police with great variation between various offences. As reasons for not reporting personal crimes to the police, US respondents stated in 20.3% (28.8% for property crimes) of all cases that the offender was unsuccessful, 19.2% (6.6% for property crimes) stated that crime was private or personal matter.

Data for the Netherlands also indicate huge differences between police statistics and victimization surveys. In 1980, police recorded 26,500 violent crimes whereas data from the Justice and Security Survey (ERV) indicate 654,000 crimes (Wittebrood and Junger 2002). In addition to the different levels of violence, Wittebrood and Junger (2002) also find no observable correlation in the development of both.

Unfortunately, there are still many countries, like Germany, France, etc., were there are no periodic victim or crime surveys and therefore necessary data is not available to lighten their dark figures (Obergfell-Fuchs et al. 2003). The latest victim survey for Germany dates from 1997 and found an average reporting rate of 60%. The previous survey of 1992 found smaller reporting rates, ranging from 40% to 58%, depending on victims age (BMJ 2001). Victim surveys for single

[26] In a study for Germany the variation over time was even higher (Landeskriminalamt NRW, 2006).

German cities imply an even smaller reporting rate of on average 30% (Heinz and Spieß 1995).

However, as this thesis analyzes environmental crimes it is questionable if victimization surveys for environmental offences really would make sense. Not only that it is in many cases difficult for citizens to decide whether their first observation is a crime or not, most types of environmental crimes harm many victims independently from each other. Simple surveys would thus not necessarily reveal the true amount of environmental offences.

The striking question for my purposes is then, whether the existence or specific properties of dark figures cause a bias in econometric analysis? There is some, but not much work done so far to answer this question.

MacDonald (2001, 2002) addressed this question trying to find the determinants of non-reporting via data of the BCS. The author analyzes which of the time varying variables do have a (statistically) significant influence on reporting behavior. He uses microeconometric (probit) analysis and finds that variables like unemployment and age have a significant effect on the decision whether to report or not. He concludes that researchers should take these factor into account when estimating the economic model of crime. As mentioned in previous sections unemployment did not show up to be significant in my empirical analysis. However, I am aware that dark figures may be substantial for environmental crimes. I therefore included variables that are tailored for the case of environmental crime into my empirical analysis. The results for those rather political variables are explained in section 10.2.

Another study dealing with dark figures is the one by Pudney et al. (2000). The authors use BCS data and data from the British General Household Survey

(GHS), a error correction model (ECM) and Monte Carlo simulation methods to identify the biases resulting through under-recording. They find measurement errors as "statistically significant, but in most cases negligible for all practical purposes" (Pudney et al. 2000). Measurement errors seem to be systematic and multiplicative and only slightly problematic for the short- and long-run effects of conviction rates. However, the findings for England and Wales are no evidence that there are also no problems for other countries.

2.6.2 Endogeneity

The problems arising through potential endogeneity appear in almost every econometric analysis. Nevertheless, there are some issues that are special to the economic model of crime and should therefore be mentioned. Most studies estimating the economic model of crime stress the question of simultaneity between crime rates and different explanatory variables like the probability of apprehension, conviction, punishment or the severity of punishment. As this seems to be the source of substantial bias, I will dedicate the main part of this section to this topic.

Another form of endogeneity results trough the use of cross section data and therefore ignores the possibility of unobserved heterogeneity. Cornwell and Trumbull (1994) first covered this shortcoming and revealed sizeable effects. The last subsection accounts for the biases resulting through omitted variables.

Simultaneity There exists a huge empirical literature dealing with the problem of simultaneity, in particular for deterrent variables, in the economic model of crime.[27] Within this literature, there is to some extend consensus regarding

[27] See Ehrlich (1973), Cornell and Trumbull (1994), Andreoni (1995), Viren (2001), Mustard (2003), Levitt (2002b), Gould et al. (2002), DiTella and Schargrodsky (2004), Evans and Owens

the deterrent effect of different crime control policies like police force or severity of punishment (see section 2.3). However, most researchers also agree upon the influence of crime on crime control policies (see part IV of the present thesis). In most cases, a higher presence of police forces or more severe penalties should yield less criminal activities. In contrast, with recognizing more crimes the officials will be tempted either to increase the amount of police or the severity of punishment, or both. Results of part IV of the thesis are able to confirm this for environmental crimes in Germany (see section 25). Another possible effect is the reduction of the probability of apprehension via a rising crime rate which results from a capacity overload of police forces. Whereas the first and third effect result in a negative relationship between crime and deterrence, the second effect leads to a positive effect. One will therefore get biased estimates, if this issue is not attended to in a capable manner.[28]

In many earlier studies dealing with the connection between law enforcement and crime, the authors did not address the possibility of simultaneity. As a result (see section 2.3.1) they merely found a positive influence of police on crime.

One solution for this problem is the use of a simultaneous equation model, in which the possibility of simultaneity between crime and law enforcement is explicitly modeled. Ehrlich (1973)[29] was one of the first using this method in the context of crime and expanding the usual, as he calls it, "supply of offences function" with "a production function of direct law enforcement activity" and a "(public) demand function for such activity" (Ehrlich 1973). The author uses a

(2006), Baltagi (2006) and many others; for an additional overview see Cameron (1988) and Levitt and Miles (2006).

[28] There are a couple of studies that find a positive relation between crime and enforcement, see Cameron (1988) or Levitt & Miles (2006) for an overview.

[29] See also Ehrlich & Liu (1999).

production function of the Cobb-Douglas type to model the relationship between the probability of apprehension and variables like the crime rate, the expenditures on police and courts and a vector of covariates (see part IV). The demand function for enforcement or deterrence expenditures is described through the probability of victimization (equals the crime rate) and the potential loss from crime.

Another possible solution for simultaneity is the use of instrumental variables. Levitt (1997) uses local elections as instruments for variations in police force. He argues that most of the major variations in American police force coincides with local election dates and therefore uses election dates as instrument for police force. Unfortunately, Levitt's (1997) analysis suffered from some technical shortcomings and a corrected regression found no influence of police on crime (McCrary 2002). Re-estimating his work, Levitt (2002b) uses the amount of firefighters as an instrument for police force and finds again evidence for the deterrent hypothesis.

Evans and Owens (2006) use the Cops program (Community Oriented Police Services) as instrument for the size of police. The Cops program is a grant for local police agencies to finance various local crime prevention initiatives. Kelly (2000) proposes per capita income, the share of non-police expenditures in total local income and the percentage of voters against the democratic candidate in the presidential election as three other instruments that he shows to be suitable. In another article, Levitt (1996) uses court decisions in prison overcrowding lawsuits as instrument for prison population.[30] Cornwell and Trumbull (1994), Andreoni (1995) and Baltagi (2006) use very similar model specifications to address simultaneity.

[30] For further examples using the instrumental variables approach, see Virèn (2001) and Gould et al. (2002).

The third solution concept used by Marvell and Moody (1996) is based on time series analysis and applies the concept of 'Granger-causality' introduced by Granger (1969). In this context variable a Granger causes variable b if changes in a yield future changes in b. The authors are able to confirm the hypothesis that not only police force influences crime but also crime affects the size of police force. The same results also appear in the time series analysis of Corman and Mocan (2000). In another study, Marvell and Moody (1994) address the simultaneity problem in the context of the severity of punishment. There may be not just a deterrence or incapacitation (see section 2.4) effect, but also an effect of crime rates on severity of punishment. Facing higher crime rates, governments may tend to increase prison population by either longer sentence terms or more imprisonments.

Time series analysis also stresses the problem of time in the economic model of crime. However, most data is annual and since the time lag for the response of officials to increased crime is found to be about 6 month (Corman and Mocan, 2000), one is not able to account for this in annual data sets. Corman and Mocan (2000) solve this problem by using monthly data and find support the deterrent effect of police.

Other studies trying to avoid the problem of simultaneity are the ones by Di Tella and Schargrodsky (2004) and Klick and Tabarrok (2005). They use the exogenous events of a terrorist attack and changes of terror alert levels, respectively, to examine the effect of police size on crime. The authors of both papers find a significant deterrent effect of police on crime.

With respect to the empirical analysis in parts II and III, respectively, I do not find simultaneity to be a serious problem. Results do not change significantly

when using a instrumental variables approach (GMM) or lagged effects[31] and thus controlling for potential endogeneity.

Unobserved Heterogeneity Unobserved heterogeneity between different observation units (individuals, counties, states, nations, etc.) is another source of endogeneity. One can get biased estimates if this possibility is ignored. Cornwell and Trumbull (1994) and Cherry (1999) address this question arguing that most studies so far just used cross-sectional analysis and thus were not able to control for unobserved heterogeneity. In their analysis, Cornwell and Trumbull (1994) deal with both sources of endogeneity, simultaneity and unobserved heterogeneity using a simultaneous equations model and panel data. Re-estimated by Baltagi (2006), all three studies find unobserved heterogeneity to be a crucial problem when estimating the economic model of crime. Cherry (1999) estimates a pooled model and compares the results with appropriate random and fixed effects panel data estimates. In line with Cornwell and Trumbull (1994), the author finds significantly different results for both models stating the upward bias resulting through unobserved heterogeneity to be at about 20% for all crimes. In addition, Cherry (1999) extends his analysis by estimating the model for different types of crime separately. Doing this the authors find biases ranging from 0% for robbery to 70% for burglary. To solve the problem of unobserved heterogeneity, the later empirical analysis in parts II-IV rely on panel data.

Omitted Variables Every econometric analysis is at risk of omitting a (more or less) important variable. This is therefore not a special problem of the eco-

[31] However, the data in later empirical analysis in annual and it is therefore questionable if one is able to circumvent the problem of endogeneity by using lagged effects.

nomic model of crime. However, Mustard (2003) argues that in many studies the authors omit at least two important determinants of crime. One of them is the conviction rate and the other is average sentence length. Many studies just use arrest rates as indicator for the probability of punishment and thus omit conviction rates. Furthermore there are some studies omitting any measure for the severity of punishment or just using prison population as a indicator for that. Whether the average sentence length, the prison population or both is the best measure for the severity of punishment remains to be seen. Mustard (2003) also claims that if there exists a negative or positive correlation between arrest rates and one of the omitted variables then the deterrence effect of arrest rates will be under- or overstated, respectively.

Due to data constraints the empirical analysis in parts II and III excluded informations on the severity of punishment. However, this should cause no problems as both fines and prison sentences for environmental crimes in Germany mainly are at the lower bound.

There are also some papers that focus either on the deterrent effect of law enforcement or the effect of socioeconomic factors on crime but do not address both. These studies may also suffer from omitted variables bias since both scopes seem to influence criminal behavior.

To account for this, later regressions do not only include socioeconomic and enforcement variables but also political factors that may affect reported crime.

2.6.3 Aggregation Bias

The last but one concern I want to discuss briefly is the aggregation bias. Cherry and List (2002) indicate that many previous studies like the ones by Ehrlich (1973),

Andreoni (1995), Cornwell and Trumbull (1994) and many more use a aggregated crime index instead of analyzing every type of crime separately. The authors run the aggregated analysis as well as a disaggregated one finding significantly different estimates and great variation between different crimes. Cherry and List (2002) denote the possibility that overall aggregation of crimes could lead to biased estimates since the pure effects are blurred. This is not very surprising since there should be differences in the deterrent effect or changing socioeconomic factors between particular crimes . It seems very plausible that the deterrent effects is greater for property crimes than for violent crimes as shown by Cherry and List (2002).[32] Especially in part II of the present thesis, the empirical analysis focuses on environmental crime in general and may be thus biased by this aggregation. I therefore provide separate estimates for illegal waste disposals as they are the major type of environmental crime in Germany. However, as the thesis focuses on environmental crimes this is not as demanding as for the case of different types of felonies.

2.6.4 Time Lags

A topic that has not been addressed very often so far is the possibility of a delayed updating of potential criminals (Marvell and Moody 1994, 1996, Levitt 1998a, Corman and Mocan 2000, Greenberg 2001, Saridakis 2004). A change in the law enforcement variables or changing socioeconomic factors have to be anticipated by the potential criminal in order to adjust behavior. It seems to be not very realistic that individuals observe and respond to these changes right in the moment where

[32] The authors find the deterrent effect of the probability of arrest to be 45% higher for property crimes than for violent crimes.

they happen. However, this is assumed when there are no tests for time lags in the empirical model. Exceptions are papers using time series analysis that mostly stress this issue. Corman and Mocan (2000) include a time lag of one month for arrests which is meant to reflect delayed updating of potential criminals. They also estimate a delayed response of police on increasing crime to be at least 6 months[33] (Corman and Mocan 2000). However, for panel and time series analysis using yearly data, time lags only exhibit some problems if the delay is longer than a year. Having this in mind, there will be a section for delayed updating in parts II and III of the thesis. However, as the data is annual, it is no surprise that results do not suggest time lags to be a major source of difficulties.

2.7 Does Empirical Analysis support Becker's suggestions?

To foreclose the answer: In general, yes. Nevertheless, as frequently mentioned in this section, there are many shortcomings, especially because of data constraints and interdependencies among the different determinants of crime, which make it hard to identify the causal effects. Hence, it is not very surprising that there seems to be no clear-cut evidence for some variables frequently used to estimate the economic model of crime. However, most deterrence variables seem to have a strong influence on criminal behavior as parameter estimates show up to have the expected negative sign and are significant in many cases.

Direct measures of the probability of punishment, such as the arrest, conviction and imprisonment rates nearly all have the expected negative and significant effect on crime. It gets more challenging when one tries to examine the causal effect of

[33] The reason is that a police officer in the U.S. has to absolve a 6-month program at Police Academy.

police force on crime. Nevertheless, after controlling for simultaneity police appears to have a negative effect on crime, too.

The same is true for the severity of punishment represented by the average length of imprisonment or prison population. The varying effects on crime mostly disappear if the problem of simultaneity is included in the empirical analysis. To conclude, there seems to be clear evidence for deterrence in the economic model of crime.

As with deterrence, it looks like socioeconomic factors also having an important impact on crime. However, this is not true for all mentioned variables. Unemployment seems to have only a significant positive effect on property crimes, the effect on violent crimes is sometimes even negative. Albeit the latter is not as easy to explain, the former is in line with general suggestions. Labor force participation is not very often included in previous studies and has no definite effect overall. However, there seems to be a very clear-cut negative effect of income inequality on crime.

Overall, most empirical implementations of the economic model of crime confirm Becker's (1968) suggestions. The probability of being sanctioned and the expected severity of punishment do both deter from criminal activities. Hence, there is evidence for the deterrence effect of law enforcement. Socioeconomic variables indicating the possible benefits from legal substitutes also show to have an important impact on crime.

3 The Economics of M&E of Environmental Regulation

The models describing the monitoring and enforcement (M&E) of environmental regulations and the resulting compliance or non-compliance of firms are based on the economic model of crime introduced by Becker (1968).[34] However, environmental economists made several adjustments in order to account for the special characteristics environmental regulations and related enforcement institutions have. It is the aim of this section to give an introduction to the literature on the M&E of environmental regulations. As the present thesis analyzes environmental crime and is thus closer related to crime literature this section will be rather short. Nevertheless, it is important to take the effectiveness of administrative law into account when comparing both types of enforcement. I will therefore give a short overview of the theoretical model on the enforcement of environmental regulations and then add a more detailed discussion on the empirical findings obtained so far.

3.1 The Theoretical Model of Enforcement and Compliance

As indicated above, most of the models used to describe firms‘ behavior concerning environmental regulations base on the economic model of crime. Firms facing environmental regulations just minimize the sum of compliance cost and expected

[34] See Heyes (2000) for a survey of related papers.

penalties. Speaking differently, a risk neutral firm chooses not to comply if:

$$c > p \cdot f, \tag{4}$$

with c as the cost of compliance with a particular regulation. That is, a firm will violate a regulation if the gain or the cost avoidance through this violation exceeds the expected costs of punishment ($p \cdot f$, see section 2.1). The basic idea is therefore identical to the economic model of crime. As we will see in the next section, however, there may arise some problems when comparing the individual setup of the economic model of crime with the behavior of a firm.

One problem is that many decisions regarding compliance with environmental regulations are not binary ones as described above but rather continuous ones. Hence, f may depend on the actual amount of pollution s and some standard S. This means that $f(s,S)=0 \; \forall s \leq S$ and $f(s,S)>0 \; \forall s > S$, respectively.[35] Additionally, $\forall s > S$ one presumes that $\frac{\Delta f(s,S)}{\Delta s} > 0$ and $\frac{\Delta f(s,S)}{\Delta S} < 0$.

In the binary case c then reflects the abatement costs $a(s,S)$ to comply with S when emitting s, assuming $a(s,S)>0 \; \forall s > S$. Therefore a firm will not comply, if:

$$a(s, S) > p \cdot f(s, S) \tag{5}$$

with $\frac{\Delta a(s,S)}{\Delta s} > 0 \; and \; \frac{\Delta a(s,S)}{\Delta S} < 0$. Furthermore, the amount of non-compliance will depend on marginal deterrence and on marginal abatement costs. More formally, if non-compliant a firm will choose a point where:

$$\frac{\Delta a(s, S)}{\Delta s} = p \frac{\Delta f(s, S)}{\Delta s} \tag{6}$$

[35] As long as there is no type II error, see Heyes (2000).

for a fixed pollution standard S.

As in the Becker model (see section 2.1), there is probably an upper bound for *f(·)* which is either some practical or political limit or the wealth constraint of the particular firm (Heyes 2000).

A further extension, again very similar to the economic model of crime, includes the 'endogeneity' of 'inspectability' as Heyes (2000) calls it. Hence, p may depend on pollution level s, standard S and public expenditures e, *p(s,S,e)*, with $\frac{\Delta p(s,S,e)}{\Delta s} > 0 \; \forall s > S$, $\frac{\Delta p(s,S,e)}{\Delta S} < 0$ and $\frac{\Delta p(s,S,e)}{\Delta e} > 0$. This could either mean that a very small violation is rarely detected because it is difficult to observe or that enforcement efforts are increased and/or concentrated if there is a strong suspicion for a serious violation.[36] Moreover, increasing public enforcement expenditures are assumed to have a positive influence on the probability of detecting a non-compliant firm.

Including this into my basic inequality (5) leads to a more general setting, where a firm decides how much to pollute:

$$a(s,S) > p(s,S,e) \cdot f(s,S) \tag{7}$$

and the non-compliant firm operating at:

$$\frac{\Delta a(s,S)}{\Delta s} = p(s,S,e)\frac{\Delta f(s,S)}{\Delta s} + \frac{\Delta p(s,S,e)}{\Delta s} f(s,S). \tag{8}$$

Heyes (2000) discusses a huge amount of further extensions of the model including firms' investments to decrease inspectability, possible investments in effective lawyers, considering a multi-stage game, multiple polluters, self-reporting, multi-

[36] Heyes (2000) also points out that a firm in return may invest in uninspectability meaning that a firm could be able to reduce p.

period and multi-context interactions and many more. This section will concentrate on the basic model in order to keep the focus on the underlying motivation which is to compare the empirical literature on the economic model of crime with the empirical literature on compliance with environmental regulations.

3.2 The Empirical Model of Enforcement and Compliance

Simultaneous to the theoretical literature on compliance with environmental regulations there emerged the empirical counterpart estimating what is commonly called 'compliance function' (Heyes 2000). Very similar to the crime literature, the questions in this context is whether greater enforcement efforts and a more severe punishment really lead to greater compliance. In comparison to the general economic model of crime, there are relatively few empirical papers published that stress compliance with environmental regulations. Cohen (1999) points out that this may be due to huge data constraints researcher face in this context. Although the U.S. EPA is successively making relevant data available for researchers, data is still very scarce in other countries.

The typical estimation equation for compliance with environmental regulations[37] very often has the following form:

$$Q = A + \beta P + \delta Y + \varepsilon, \tag{9}$$

where Q stands for the level (or the duration)[38] of the harmful activity (e.g. oil

[37] This literature often analyzes very different settings and industries. Examples include the enforcement in case of oil spills, nuclear power plants, pollutions regulation for steal industry, paper industry, etc. (see section 3.3).

[38] See Nadeau (1997).

spills, pollution, etc.), P for a vector of different M&E activities and Y for a vector of firm or region specific characteristics. A, β and δ are the parameter vectors to be estimated. This model is almost identical to the one used in the economics of crime literature.

Many of the empirical shortcomings researchers found in the context of the economic model of crime also are apparent in the literature dealing with environmental regulations. The possibility that a violation is not observed by any legal authority, meaning that there exists a dark figure, is obvious. In comparison to the crime literature, however, it is even more difficult to light the dark figure in the context of environmental offences since many violations are not observed by anyone except the violator. At least to some extend and for some types of crime, some countries try to measure the real amount of crime via comprehensive and periodical victim surveys (see section 2.6.1). This is in many cases not possible for environmental offences since there is often no direct victim or no well defined number of victims, or victims do not know that they have been harmed.

Researchers analyzing firms‘ compliance with environmental regulations also are aware of potential simultaneities. Gray and Deily (1996) e.g. find that greater enforcement results in greater compliance and greater compliance leads to less enforcement. Additionally, Helland (1998) tries to answer the question whether firms being found in violation face a higher probability of inspection. Furthermore, Magat and Viscusi (1990) stress the possibility of time lags that could exist in the relationship between different enforcement, deterrence and compliance variables. However, almost all problems associated with the empirical crime literature can be carried over to the estimation of enforcement and compliance.

3.3 Deterrence and Important Policy-Variables

This section focuses on important monitoring and enforcement variables that are relevant for environmental regulations.

3.3.1 Monitoring

One of the most important policy-variables in this context is the frequency of monitoring a firm faces. The more often or more accurate monitoring takes place, the higher is the probability that a violation is observed. Monitoring is therefore meant to reflect the probability of detection and thus the probability of getting punished in either way (fines, obligation, etc.). Epple and Visscher (1984) use several monitoring variables finding that, ceteris paribus, increasing monitoring leads to a lower volume of oil spills with elasticities ranging between -.08 to -.91. However, the authors estimate different specifications for different data and reveal an opposite effect for the number of oil spills. There, the enforcement effort by the cost guard measured as man hours per transfer have a positive and significant effect on the number of oil spills with elasticities of .13 and .21. Epple and Visscher (1984) conclude that in this case the detection effect has to outweigh the deterrence effect. Cohen (1987) uses the same dataset and distinguishes different monitoring activities. Findings suggest that monitoring oil transfer operations (-.14 to -.18) and random port patrols (-.18 to -.21) seem to have the highest and significant deterrence effect whereas the effect of routine inspections seems to be negligible.

Viladrich-Grau and Groves (1997), using more detailed data, estimate the deterrence effect of monitoring to be larger for oil spill frequency than for spill size. The estimated elasticities range from -.005 to -.72 for the effects monitoring of

transfers have on oil spill size and frequency. Magat and Viscusi (1990), analyzing compliance for the U.S. pulp and paper industry with water pollution regulations, confirm previous results. They are additionally able to designate a one quarter time lag for the positive effect of EPA enforcement actions on compliance. Results also suggest that being not inspected on average doubles the probability of being noncompliant.

Cohen (1997) refers to an unpublished study by Liu (1995) who uses additional data and finds no clear-cut evidence for the deterrence effect of EPA's monitoring efforts. Liu (1995) divides monitoring into two types, discretionary and routine. Similar to Epple and Visscher (1984), routine inspections seem to increase the number of known violations and only discretionary monitoring has the expected negative effect.

Laplante and Rilstone (1996) use an approach very similar to that of Magat and Viscusi (1990) and confirm their results for Canadian data. The authors estimate a positive effect of inspections on compliance with lagged inspections reducing absolute discharge of Biological oxygen demand emission (BOD) by around 7%. Gray and Deily (1996), using data for the U.S. steel industry and EPA's enforcement efforts, again estimate a positive lagged effect of monitoring on compliance with an elasticity of 1.13.

Nadeau (1997) uses duration analysis and tries to extrapolate the effect of monitoring and enforcement on the length of non-compliance. The author estimates that a 10% increase in monitoring leads to a 0.6% to 4.2% reduction in violation time. Weil (1996) analyzes compliance decision of firms with the Occupational Health and Safety Act (OSHA). The data reveal that inspecting a plant more than once (2-6 times) increases the probability of compliance by 1.078 to 1.586. Win-

ter and May (2001) analyze Danish farmer's compliance with agro-environmental regulations. The authors predict a increase (from the lowest quartile to highest quartile) in the likelihood of detection and magnitude of fine to change compliance by 2.1 (significant) and -.2 percent (not significant), respectively. Stafford (2002) analyzes the effect of M&E on firm compliance with hazardous waste regulations and is not able to extract a negative effect of inspections on violations. Eckert (2004) provides evidence for Canadian data that the inspection probability deters violation with marginal effects between -.75 and -.81. Earnhart (2004) analyzes M&E of publicly-owned treatment plants. Findings partially support deterrence in case of EPA inspections with one more inspection reducing BOD relative average emission by 1.483 percent. Shimshack and Ward (2005) find in their analysis that inspections up to one year ago lowers the probability of a plant being noncompliant by -.18.

To conclude, nearly all of the reviewed empirical work supports the hypothesis that more and tighter monitoring and therefore a higher probability of being detected leads to greater compliance. Similar to the case of crime, the estimates range from almost no effect to about 1.5.

3.3.2 Enforcement

This section reviews the existing empirical evidence on how effective enforcement actions are in deterring non-compliance with environmental regulations. Viladrich-Grau and Groves (1997) included several variables in their regression trying to find a robust effect of fines on oil spill size and frequency. However, none of the variables had a significant influence on oil spills.

Nadeau (1997) analyzes the effect of enforcement on the length of noncom-

pliance. The author finds that a 10% increase in enforcement activities like administrative orders, penalties, civil actions and criminal actions leads to a 4 to 4.7% reduction in violation time. Weil (1996) studies the effect penalties have on compliance of plants with OSHA. The author finds that a 1% increase of penalties raises compliance in a range of .374 to .620 percent at least for the significant estimates.

Sigman (1998) analyzes the effects of legal sanctions on the number of oil dumping incidents. In this analysis, increasing enforcement activities like administrative actions, civil referrals, and criminal referrals by 1% reduces the number of oil dumps by .18 percent. Stafford (2002) studies the effect of a regime change in penalties. The legal amendments in the enforcement of illegal waste disposal reduced the probability of a violation for a firm by 15%. Earnhart (2004) uses data on the number of EPA and KDHE enforcement actions and finds a significant effect on BOD emissions for both with estimates of -.071 and -.009 (log-linear specification), respectively. Similar to the case of inspections, Shimshack and Ward (2005) also find evidence for the effectiveness of fines imposed. A dummy variable indicating whether there has been a fine to anyone in the last 12 months lowers the probability of a firm being noncompliant by -.509.

In summary, although the effects are not as clear-cut as it is the case for monitoring activities there is strong evidence that enforcement plays an important role in ensuring compliance with environmental regulations. Moreover, the estimates are in line with those for fines and imprisonment in the crime literature. Finally, before there will be a summary on the results to this part on M&E, I will briefly discuss other factors potentially influencing compliance behavior of firms.

3.3.3 Structural Factors

Epple and Visscher (1984) include the price for oil in their empirical investigation and find negative effects on oil spill size and volume.[39] In addition, Sigman (1998) examines the effect prices have on illegal waste disposals. The author concludes that increasing prices for waste disposals seem to increase the amount of illegal disposals. May and Winter (2001) included an indicator for the cost of compliance with agro-environmental regulations resulting in a negative and significant estimator. Higher cost of compliance are associated with a higher probability of non-compliance. Gray and Deily (1996) include the total cost to bring a firm into compliance and find a significant negative effect on compliance. Stafford (2002) finds a positive and significant relationship between state environmental membership and firms being noncompliant. However, including regional characteristics changes this somewhat counterintuitive effect and leads to a negative estimate.

Weil (1996) and Earnhart (1997) include plant size in their analysis and at least Earnhart (1997) finds some evidence that the size of a plant or a firm has a positive impact on non-compliance. Eckert (2004) is able to estimate a negative effect of population density on violations. Shimshack and Ward (2005, 2008) include local unemployment rates in their analysis finding negative effects of unemployment on compliance. However, the rest of their community characteristics do not show up to have any impact on compliance of firms.

The findings confirm the results of the crime literature and also my own results in parts II and III that political and structural variables do have an influence on reported violations. As we will see later (part II), detection or reporting efforts

[39] The authors implemented several specifications and find significant results for most cases.

play a crucial role as already pointed out by Epple and Visscher (1984).

3.4 Is there Evidence for the Effectiveness of M&E?

The previous sections reviewed the literature on compliance or non- compliance with environmental regulations. Similar to the literature on the economics of crime there is strong evidence that environmental offenders follow economic incentives. In most cases monitoring, enforcement, structural and political variables have the expected effect on environmental offences. The existing literature provides great support for the deterrence hypothesis which states that increasing the expected costs of punishment in terms of the probability and the severity of sentencing reduces violations of environmental laws. As the effectiveness of sanctioning seems to be high in both settings compliance with environmental regulations and general crimes, the next paragraph discusses some differences between criminal law and administrative law.

4 Differences between M&E and Criminal Enforcement

A very obvious difference between the two strands of the literature is that Becker‘s (1968) model of crime is based on individual decision making whereas the literature on environmental regulation focuses on the behavior of firms. The relationship between the firm and the employee in the model of compliance can be seen as a principal-agent setting with the firm being the principal. Applying this setting causes no bias if principal and agent are able to reallocate fines and are not able

to decrease total burden (Polinsky and Shavell 2000, 2006). In case where the employee's response to public enforcement would be different from the optimal behavior suggested by the firm, firm and employee should be able to adjust contracts in a way that optimal decisions coincide. Moreover, if there is any possibility for principal and agent to avoid (at least parts of) the sanctions, then deterrence might be undermined. Polinsky and Shavell (2000) state that if the wealth constraints of the employee make it impossible to pay the fine, then principal and agent do not take the originally imposed amount of the fine into account. Policy-makers then have either to resort to prison sentences or to impose the (remaining part of the) fine on the principal. This aspect is of special interest in the case of environmental offences as most of the more severe violations are assumed to be committed in a commercial environment. Unfortunately, in the following empirical analysis, there is no data available indicating whether the violation has a private or commercial background.

Another possible and important difference between enforcement in both settings is due to the differences in available mechanisms. Despite the simultaneity between different enforcement variables, the literature on crime is usually a rather static setting. The criminal commits a harmful act whereupon public enforcement institutions react with some sort of punishment (fine, burden and/or imprisonment). However, in the setting of environmental regulations there is much more interaction taking place. Usually, if the enforcement agency (EPA in the U.S., *Gewerbeaufsichtsamt* in Germany) is suspicious whether a firm may violate some legal standard, in most cases it will first of all warn that firm first. In this early stage, the firm has not been punished yet. The firm is now able to react to this detection. After the firm's reaction, the agency can again react and either close

proceedings if the firm complies or impose a fine or burden if the firm still violates. After all, if a firm's violation lasts for a long time or the violation is very severe the agency may forward the case to prosecutors. This may imply a fine and/or a prison sentence for the violating firm. To conclude, enforcement of environmental regulations is a rather dynamic setting with a lot of interaction taking place. It is important to take this into account when comparing the effectiveness of sentencing for both types of enforcement.

5 Conclusion to Part I

In general, there seems to be convincing evidence that both criminals and non-compliers with environmental regulations follow the incentives economist consider to be relevant for these cases. There is clear support that the 'calculus of deterrence' as postulated by Becker (1968) is operational in the context of crimes and environmental offences. In the following three parts, the thesis will therefore adopt previous findings when analyzing the effectiveness of the German Penal Code empirically. The findings of part I will serve as a benchmark and a starting point in order to conduct an appropriate analysis. Furthermore, it seems to be very important to choose the right estimation method and the right data structure to get reasonable results when estimating the economic model of crime. Consequently, the remaining parts of the thesis use panel data to circumvent many of the mentioned problems.

Part II

Environmental Crime and Punishment

6 Introduction to Part II

More than 20 years after their introduction in most industrialized countries, the use of criminal sanctions against environmental offenders is again being debated. Criminal sanctions differ in at least two important aspects from the more traditional administrative enforcement process. One important difference concerns the institutions involved in enforcement: While administrative law relies on regulators, criminal sanctioning regimes rely on police, public prosecutors, and the courts in order to generate enforcement. The second difference is in terms of the types of sanctions imposed: While administrative sanctions center around pecuniary fines, criminal sanctions include more severe penalties such as incarceration and heavy court-imposed fines that become part of an offender's criminal record for prolonged time periods.

A general shortcoming of the policy discussions on the merits of criminal sanctions is that the empirical evidence on their deterrent effect has so far not been systematically examined, neither in the USA nor elsewhere. The rich empirical literature on environmental enforcement has a clear focus on the enforcement activities of regulators such as the EPA and others using administrative law. Illustrative examples among many excellent studies are Magat and Viscusi (1990) on

the EPA's enforcement strategy for industrial effluents, Gray and Deily (1996) on the enforcement of air pollution standards, Decker (2003) on regulatory delay as an enforcement strategy, Eckert (2004) on enforcement and compliance in petroleum storage, Shimshack and Ward (2005) on the role of the regulator's reputation for compliance, and Innes and Sam (2008) on the interplay between voluntary pollution reductions and regulators' enforcement policy. In these papers, the possibility of criminal sanctions is frequently alluded to, but rarely explored. Cohen (2001) and Garoupa and Gomez-Pomar (2004), on the other hand, offer theoretical - rather than empirical - perspectives on criminal sanctions vis-à-vis environmental offences. This part of the thesis employs available data on the use of criminal sanctions to provide an empirical perspective on this active area of policy developments based on an economic model of environmental crime.

Building on Becker's seminal paper on the economics of crime (Becker 1968) and its modern implementations (e.g. Rickman and Witt 2007, Machin and Meghir 2004), this part of the thesis makes three contributions to closing the evidence gap on the effects of criminal sanctions on environmental crime: The first is to examine whether empirical data supports the unconfirmed hypothesis that criminal sanctions are successful in deterring environmental crime. The empirical evidence is contained in a unique dataset from Germany on recorded environmental crime, prosecution, trials in criminal courts, and corresponding criminal sanctions, including imprisonment. Covering the eleven-year period from 1995 - 2005 and 15 German states, this dataset provides an opportunity to employ modern econometric tools of panel data analysis to exploit both intertemporal and state-level variations. By doing so, the paper provides a novel regulatory focus on criminal sanctioning in the context of environmental regulations and a novel geographic

focus on enforcement outside North America.

The second contribution of the thesis is to determine the individual contributions of different components of the sanctioning regime to the deterrence effect. Typical components are the clearance rate (i.e. share of crimes for which an offender has been identified), the share of identified violators brought to court, the probability of pecuniary fines and the probability of prison sentences. Given that the different sanctioning components differ in expected costs both to offenders and the public, the relative benefits in terms of deterrence delivered by different components is clearly of importance. This requires controlling for important endogeneity of reported crime rates. One key area are various forms of reporting bias, i.e. the fact that only a fraction of actual crimes are reported to or detected by official authorities (McDonald 2002, Levitt 1998a). Environmental crime suffers to a particular extent from this problem, as the criminological literature on environmental crime universally acknowledges (Faure 2004, Lohr 1996). The reporting bias in environmental crime implies that particular caution is warranted when interpreting changes in the amount of crime reported as both changes in actual crime and changes in detection and reporting efforts are relevant drivers.

The third contribution of the paper is to exploit some of the specificity of environmental crime in order to learn more about the role of political economy variables in enforcement. In contrast to crime as a generic phenomenon, environmental crime typically affects one very specific public good. This specificity with respect to the environment allows to exploit data on citizens' environmental preferences and data on the political identity of state-level governments. Since different political parties opt for different trade-offs between environmental quality and industry interests, these ideological differences may conceivably show up

in the data. This empirical analysis complements previous work on how political factors determine enforcement policies chosen by regulators (Helland 1998, 2001; Decker 2003).

My main findings are threefold: First, criminal sanctions do provide the deterrent effects intended by policy-makers. The economic model of crime correctly predicts the observed variations in the rate of environmental crime. While no proof of efficiency, this finding lends support to the claim that criminal sanctions are effective in combating environmental offences and is in line with the emerging empirical consensus on criminal sanctions in general (Levitt and Miles 2006, Baltagi 2006). Environmental offences are therefore not fundamentally different from other types of crime and amenable to the same enforcement instruments. The finding also contradicts the view, popular for example among regulators (Hoch 1994, US Senate 2003) and legal scholars (Schall 2006), that due to the small number of cases prosecuted, criminal sanctions are largely invisible and hence unlikely to provide significant deterrence.

Second, while I find most of the typical components of the criminal sanctioning regime operating in line with expectations, there are novel results on selected components. One is that the probability of being tried - rather than being convicted - provides one of the most significant deterrents. Independent of the outcome of trials, an increase in the share of offenders brought to court by one percent decreases the crime rate by roughly one percent. This strengthens previous findings on the role of reputational losses as components of the sanctioning regime (Karpoff et al. 2005) and raises important issues about the desirable degree of publicness of sanctioning (Kahan and Posner 1999, Funk 2004). The probability of conviction and of severe pecuniary fines, on the other hand, are statistically less significant and

have considerably lower deterrent impact. This contrasts with results obtained by Baltagi (2006) and Cornwell and Trumbull (1994) in general studies of crime in which similar components return significant estimation coefficients.

Third, political economy factors are statistically significant drivers of reported environmental crime rates. Greater environmental preferences of citizens lead to a more than proportional increase in reported crime. While the limitations of the data do not allow us to pinpoint the causal channels, I hypothesize on the basis of experimental evidence and empirical studies (Helland 1998) that citizens' preferences result in greater detection effort by both the public and enforcement agencies. By contrast, having a pro-industry party in government leads to a reduction in reported environmental crime. One explanation for this result rests on the presumed decrease in detection effort by government. Given the well-known feedback effects between greater enforcement and deterrence, these empirical results on the impact of changes in environmental preferences on environmental crime are arguably lower bounds on their total impact.

The remainder of part II is organized as follows. Section 7 sets out five hypothesis for understanding reported environmental crime. The aim is to state testable hypothesis about the relationship between components of the criminal sanctioning regime and the amount of reported environmental crime. Section 8 discusses the available data sources and section 9 develops an extended and tailored version of Becker's model of crime and employs it in a dynamic panel data estimation. Since the data constitute a small unbalanced panel with the plausible presence of simultaneity and nonstationarity in variables, my report of the main empirical results in section 10 includes a technical discussion on the suitable econometric techniques applied in order to generate reliable estimators (Alvarez and Arellano

2003). Finally, section 11 discusses a suite of robustness checks. Section 12 provides a discussion of the results in the light of the theoretical considerations of section 7 and the existing literature of part I. Section 13 concludes.

7 The Determinants of Reported Environmental Crime

Activities in the unofficial sector share the characteristic that their true volume is typically unknown. The starting point for most empirical analysis is therefore the reported volume of illegal activities. While a difficult proxy for the underlying true value, careful analysis nevertheless allows a number of ceteris paribus statements (Levitt and Miles 2006, McDonald 2001).

7.1 Deterrence

In line with the empirical literature examining other types of criminal activity in the white collar sector (e.g. Rickman and Witt 2007, Machin and Meghir 2004), potential environmental criminals are assumed to consider the net expected benefits of criminal activity as the primary decision criterion. An illustrative example is a decision regarding illegal waste disposal (Sigman 1998). Here, gross benefits consist of the avoided cost of proper disposal minus the cost of illegal disposal. The components of expected costs are the probability of being detected, 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. Variations in this expected cost give rise to the first two hypothesis.

Hypothesis 1. Reported crime responds to more severe criminal sanctions in that higher probabilities of their use lead - *ceteris paribus* - to a reduction in reported crime.

As environmental crime is primarily motivated by economic considerations, this hypothesis postulates that changes in sanctioning probabilities deter environmental criminal activity as predicted and observed in other contexts of enforcement and deterrence (Becker 1968, Cornwell and Trumbull 1994). Higher sanctioning probabilities raise the expected cost of criminal activity and should hence decrease net benefits of environmental crime, leading to less criminal activity being undertaken.

Hypothesis 1 is implemented using available data on the conditional probabilities of a case being subject to a court trial, a severe fine, and a prison sentence. The empirical strategy in this case is to exploit the inter-state and intertemporal variations in the sanctioning probabilities in order to extract their marginal impact on reported environmental crime. As in many studies, simultaneity between observed variables is a possible contaminating factor. While the first-order impact of tougher sanctioning is to reduce crime, less or more crime might in turn influence sanctioning practices. Estimated coefficients may therefore over- or understate the true magnitude of effects. My empirical strategy of controlling for simultaneity is explained in detail in section 4.

Hypothesis 2: A higher clearance rate implies a higher probability of being identified as an offender, thus raising the expected cost of crime and leading to a

reduction in reported crime.

Greater effort by police to identify the offenders responsible for a reported crime is the first key step for the prosecutorial process to commence. Clearance rates (or arrest rates) are therefore invariably included in empirical studies of enforcement (see Levitt and Miles 2006 for a survey). Since for a given amount of crime, a higher clearance rate implies greater probability of being subject to criminal investigation, there is a strong a priory intuition that reported crime should fall for higher clearance rates. Empirically, this conclusion is borne out by studies typically returning negative coefficient estimates on account of their deterrent effect on potential offenders (e.g. Baltagi 2006, Cherry and List 2002, Cornwell and Trumbull 1994). As in the previous hypothesis, increasing efforts to clear environmental crimes may plausibly interact with the composition of crime, leading to an endogeneity. I expand on the appropriate tests for endogeneity in section 4.

The prediction of negative coefficients attached to sanctioning variables is silent on the relative contribution of different components of the sanctioning regime to overall deterrence. The question of relative contributions is the subject of hypothesis 3.

Hypothesis 3: An increase in the probability of more severe sanctioning components will result in a greater deterrence effect relative to less severe sanctioning components. The order of deterrence effects should be the probability of (i) a prison sentence, (ii) a severe fine, (iii) a conviction, (iv) of having to stand trial, and (v) being identified as an offender.

Different sanctioning components imply different costs. Theory would dictate

that the marginal impact of a change in the different sanctioning probabilities should therefore correspond to these cost differences (Polinsky and Shavell 1984). Among the sanction considered in the German Penal Code, prison sentences are arguably the most severe form of punishment as they include time lost and the social stigma attached to prison sentences, followed by severe fines, standard fines, and finally the purely reputational losses of having to appear in court (Kahan and Posner 1999, Karpoff and Lott 1993).

While theoretically clear, the available empirical evidence is more equivocal on the issue: In a survey paper, Eide (2000) captures the prevailing view of the literature that a shift to harsher sanctions has a lower marginal impact than an increase in the probability of sanctions overall. In order to separate out the effects of overall deterrence and the contribution of individual components, the empirical analysis relies on conditional probabilities applied to the relevant subset of offenders (e.g. the probability of facing a severe fine given that one was convicted), which allows separating out the incremental contributions of each sanctioning component.

7.2 Political Factors

Hypotheses 4 and 5 examine political economy factors that conceivably influence environmental crime in specific ways. I examine two areas, namely the degree to which the public at large is concerned about environmental quality and the role of the ideological orientation of state-level administrations vis-à-vis the appropriate trade-off between environmental and business concerns.

Hypothesis 4: An increase in pro-environmental preferences among the public leads *ceteris paribus* to less reported crime.

Hypothesis 4 contains a prediction regarding the net effect of two different mechanisms, one direct, one indirect. The direct effect of a greater concern for environmental matters will increase the propensity by citizens to incur effort costs in order to detect and report crimes to the authorities. This leads - on average - to a greater proportion of violations being uncovered (Naysnerski and Tietenberg 1992, Langpap 2007). The indirect effect of greater environmental concern among the public is an increase in governmental efforts to detect and prosecute environmental violations. For the indirect effect to be operational requires a political system in which such environmental concerns have sufficient salience. In Germany, this salience is arguably provided through the country-wide presence of a well-organized Green Party such that state-level governments will find it in their interest to respond at the margin to changes in environmental preferences (Rose-Ackerman 1995).

The direct and indirect effect together provide a causal link from preferences to the aggregate detection and reporting effort. Linking these preferences to reported crime encounters a familiar feedback effect between changes in reporting effort and changes in reported crime (Levitt and Miles 2006). While a greater share of crimes may be reported, more crimes may be deterred to begin with, leading to a lower absolute number of reported violation. The number of reported cases will increase only if violations are inelastic with respect to being arrested. The elasticity of the supply of crime is a matter of great empirical uncertainty, however (Levitt and Miles 2006). Evidence from empirical research in college basketball refereeing seems to support that violations are highly elastic with respect to reporting effort (McCormick et al. 1984). In line with this evidence, hypothesis 4 assumes that the supply of environmental crimes is elastic with respect to detection and reporting

effort driven by environmental preferences. The extent to which this assumption is justified in the context of environmental crimes is subject to empirical examination. Given that the absolute risk of detection is comparatively low at 10 to 40 percent (Hoch 1994), environmental offenders are plausibly operating at a very different point on the supply curve from college basketball players. At a more general level, there is also a plausible link between a greater presence of environmental crimes and a greater share of citizens reporting strong environmental preferences. To check for the possible endogeneity between environmental consciousness and reported environmental crime, section 4 provides a suite of appropriate tests in order to rule out simultaneity.

The final hypothesis considers the inputs of governmental institutions on reported crime.

Hypothesis 5: Pro-industry governments lead *ceteris paribus* to a higher rate of reported environmental crime.

Hypothesis 5 considers the determinants of agency behavior in the context of environmental crime. Government has several channels of influence that determine detection and reporting effort since ministries of justice, the police force, and regulators are subject to political influence when deterring whether to devote effort to environmental crime at the margin. There is a small, but informative literature that has identified key political determinants of enforcement efforts. Helland (1998) demonstrates that local political preferences have identifiable impacts on the stringency and enforcement of state-level environmental regulations of federal statutes, with pro-industry preferences leading to less stringent implementation. Helland (2001) finds in a study of prosecutorial discretion at the EPA that regu-

lators' behavior is influenced by the nature of presidential administrations, with a shift from a pro-industry Republican to a less pro-industry Democratic administration being accompanied by a much more proactive approach by the EPA towards enforcement. A study by Hamilton (1996) examines EPA data on administrative fines levied in the context of hazardous waste violations.

As in the case of hypothesis 4, there are complicating feedback effects in operation between government orientation and reported environmental crime. Laxer enforcement by pro-industry governments will arguably lead to more environmental crime, but also less detection effort, leaving the net effect on reported crime ambiguous. Hypothesis 5 assumes that the supply of environmental offences is elastic with respect to detection effort. Again, this assumption is subject to empirical examination as well as further tests for endogeneity in section 4.

While the empirical exercise considers - in line with the established literature - additional explanatory variables such the level of economic activity and unemployment, the five hypotheses established in this section form the theoretical backbone of the following empirical investigation. They also reflect the econometric challenges that are inherent in the frequently ambiguous net effects of components of the enforcement environment on reported crime. In combination with additional endogeneity tests, however, this ambiguity has a silver lining in the form of allowing to anticipate a bias in the empirical estimation. Positive estimates of variable coefficients will tend to understate the size of the positive impact of variations in the variable since the results mask a simultaneous countervailing effect and vice versa.

The following section will implement the model with a view to returning empirical estimates for the differential effects of preference, enforcement variables,

and past reported crime rates.

8 Data

Data on environmental crime in Germany is collected at the level of 16 individual states to which enforcement is devolved and at various stages in the state-level enforcement process. Since one state has not released the relevant data, my sample comprises 15 of the 16 states and the years 1995 (1994 in case of reported cases) to 2005 with a small subset of states having incomplete reporting,[40] leading to an unbalanced panel. Data on reported environmental crime and the clearance rate are taken from the official police crime statistics (PKS) published by the German Federal Criminal Police Office (BKA). Data concerning juvenile offenders is excluded from the dataset due to the distinct sanctioning regime applicable to this subgroup. The necessary data for the explanatory variables of the sanctioning regime applied to environmental crime, such as the number of trials, convictions and length of imprisonment, is available from the official prosecution statistics (StVSt) of the Research Data Centre (FDZ) provided by the Federal Statistical Office and its state level counterparts. Data on structural variables that characterize individual states, such as population, size, political, and several socioeconomic variables, are taken from publications of the Federal Statistical Office.

Environmental preferences at the state level are not immediately observable. However, there is empirical confirmation of the intuitive argument that political preferences can proxy for environmental preferences. Witzke and Urfei (2001)

[40] No data is available for the state of Saxony-Anhalt. Saarland's date cover 1996-2005, Brandenburg 1995-2005 with the exception of 2002, Hamburg's data 1997-2005. Thuringia's data cover 1998-2005 and Mecklenburg-Vorpommern 2001-2005.

show that there is a significant positive and robust statistical relationship between higher political support for the Green Party and willingness to pay for environmental protection. Rather than using voting shares in elections, a better measure is therefore annual state-level survey data on people's stated sympathies for the German Green Party at the state level, available from the Central Archive for Empirical Social Research (ZA). Specifically, this variable tracks the share of people surveyed who describe themselves as 'strongly supporting positions of the Green Party'[41].

As an indicator of having a pro-industry government in power, I use the presence of the conservative party (CDU/CSU) as a proxy. The CDU (CSU in Bavaria) is the German party that is consistently most closely aligned with business and industry interests and least aligned with environmental policy preferences among the parties in German state parliaments (Budge et al. 2007).

Additional factors that are commonly included in these types of models include socioeconomic variables such as GDP per capita, unemployment rates, social transfers as well as enforcement resources such as the number of prosecutors and enforcement expenditures. Since most environmental crimes in Germany are illegal waste disposals, one fruitful approach would seem to include waste market variables in my empirical analysis. Data constraints preclude much of these extensions and limit the number of variables for which meaningful data at the appropriate level of specificity is available over the time period under consideration. I include variable covariates that report on those in appendix (table 25).

Tables 2 and 3 provide variable definitions and summary statistics for all vari-

[41] Although there exist data indicating environmental awareness for Germany as a whole, these are not available consistently on an annual and state-level basis.

ables included in the core econometric estimation.

Table 2: Variable Definitions

Variable	Definition
Environmental Crime Rate (CR)	Number of reported cases divided by population
Clearance Rate (cleared)	share of cases for which suspects are identified
Rate of tried suspects (tried)	share of identified suspects that are accused
Conviction Rate (convicted)	share of accused suspects that are convicted
Prison Rate (prison)	share of convicted offenders that are sent to prison
Rate of Severe Fines (fine)	share of convicted offenders that are fined heavily
Strong Green Support (green.supp)	share of survey respondents that see themselves as strong supporters of the German Green Party
Dummy Conservatives (cons)	takes on the value 1 if the conservative German party (CDU/CSU) is member of the state government

Table 3: Summary Statistics

Variables	Mean	Std. Dev.	Min	Max	Obs
CR	.0004379	.0003139	.0000818	.0014	163
cleared	.590	.126	.158	.806	152
tried	.263	.106	.060	.733	152
convicted	.762	.115	.333	1.00	152
prison	.035	.033	0.00	.200	152
fine	.064	.066	0.00	.600	152
green.supp	.047	.025	0.00	.113	152
cons	.572	.496	0	1	152

Given the limited sample size, this paper employs a two-step estimation approach. As a first step, the core of the model as set out in the analytical section is implemented and estimated. Subsequently, I carry out tests for additional variables that have been identified in the larger literature on crime to play a plausible role and check for robustness.

9 The Econometric Model of Environmental Crime

In this section, I implement the core of a simple model of reported environmental crime in line with the modern literature (Rickman and Witt 2007; Machin and Meghir 2004), augmented by variables capturing environmental preferences and governmental ideology. This model posits a relationship between annual reported crime in each state and state-level enforcement variables plus political economy variables. This leads to an estimation equation of the form:

$$\ln CR_{it} = A + \alpha \ln CR_{it-1} + \beta P_{it} + \gamma cons_{it} + \delta green.\sup p_{it} + F_i + T_t + \epsilon_{it} \quad (10)$$

where $\ln CR_{it}$ is the natural log of the reported environmental crime rate in state i in year t and A is an constant term. F_i (not included in pooled OLS) and T_i capture individual state 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 states. In my case this are clearance rates and clearance rate squared[42], the rate of tried offenders, conviction rates, prison rates and the rate of people sentenced to a severe pecuniary fine[43]. The indicator of environmental awareness employed in the estimation is captured in variable $green.\sup p_{it}$. $cons_{it}$ denotes a dummy variable that is set to unity for the conservative party in power in state i in year t and zero otherwise. Finally, $\alpha, \beta, \gamma, \delta$ and ϵ stand for the parameter (vectors) to be estimated and the disturbance term, respectively. As there is great support in general crime literature that different socioeconomic variables

[42] Further investigations pointed towards a nonlinear relationship between clearance rates and environmental crime.

[43] Usually, there is also a vector containing variables indicating the severity of punishment. However, since information about fines and prison sentences are not available in their true magnitude but only in intervals, it is not possible to construct plausible variables.

play an important role in explaining the amount of crime I additionally tested the following list of variables: Population Density, Housing Subsidies, Employees in Prosecution and Courts, Real Income per Capita, Real Gross Company Surplus, Portion of People Expecting Negative Future Economic Situation, Portion of People Being Afraid of Crime, Portion of People being Afraid of Loosing Job, Real Revenue of Manufacturing Sector, Real Revenue of Farming Sector, Number of Manufacturing Companies, Real Revenue of Recycling Sector, Degree of Modernity of Assets in Manufacturing Sector, Investments in Environmental Protection in Manufacturing Sector, Number of Manufacturing Companies Investing in Environmental Protection. However, none of these seem to have a significant influence on environmental crime in Germany. I will return to this in section 11.2 on omitted variables.

Table 4 presents the parameter estimates of the core model for different estimation procedures with different characteristics. Column (1) represents pooled OLS (POLS) with robust standard errors as it is the cases for the Fixed-Effects (FE) estimates in column (2). Columns (3) and (4) present parameter estimates for the Arellano and Bond (1991) difference GMM (AB) and the Blundell and Bond (1998) system GMM (BB)[44] estimators with robust standard errors and small sample corrections. Column (5) and (6) report the estimates obtained by following the Bias-Correction (BC) procedure as proposed by Bruno (2005a/b) for unbalanced panels, applying AB and BB in first stage[45].

[44] Implemented in Stata through the user written command xtabond2 by David Roodman, see Roodman et al. (2006).

[45] The BC is implemented in Stata using the the user written command xtlsdvc by Bruno (2005a). The variance-covariance matrix is a bootstrap-estimate based on 50 iterations.

Table 4: Estimation Results 1

Variable	POLS	FE	AB	BB	BC(AB)	BC(BB)
Regressors	1	2	3	4	5	6
lnCR, lag 1	.9983	.6757	.4917	.9945	.7601	.8426
	(0.0000)	(0.0000)	(0.0123)	(0.0000)	(0.0000)	(0.0000)
cleared	-1.9682	-3.5374	-2.3520	-2.4065	-3.4988	-3.4661
	(0.0015)	(0.0000)	(0.0006)	(0.0010)	(0.0021)	(0.0052)
cleared sq.	2.2718	3.4038	2.4589	2.7197	3.3739	3.3317
	(0.0001)	(0.0000)	(0.0009)	(0.0003)	(0.0006)	(0.0019)
tried	-.89062	-1.0474	-1.0524	-.91246	-1.0437	-1.0419
	(0.0000)	(0.0000)	(0.0003)	(0.0000)	(0.0000)	(0.0000)
convicted	-.1571	-.27678	-.2341	-.1442	-.2793	-.3030
	(0.2502)	(0.0856)	(0.3626)	(0.4017)	(0.1435)	(0.1391)
prison	-1.4634	-1.4393	-.5694	-1.263	-1.524	-1.541
	(0.0035)	(0.0025)	(0.3548)	(0.0247)	(0.0014)	(0.0026)
fine	-.1101	.0913	-.1599	-.1147	.1018	.0624
	(0.5632)	(0.5834)	(0.2608)	(0.5286)	(0.5801)	(0.7607)
green.supp	2.6980	1.7576	1.0610	2.6936	1.9258	2.2938
	(0.0000)	(0.0570)	(0.3204)	(0.0050)	(0.0560)	(0.0334)
cons	-.0235	-.0976	-.0500	-.0540	-.0988	-.0968
	(0.4993)	(0.0327)	(0.4371)	(0.3088)	(0.0181)	(0.0344)
N	152	152	136	152	152	152
instruments			73	84		
Sargan			69.9013	84.9307		
			(0.0715)	(0.0411)		
ar1			-2.7420	-2.7086		
			(0.0061)	(0.0067)		
ar2			1.2901	1.4829		
			(0.1970)	(0.1380)		

Note: Time dummies and a constant term have been included but omitted here. P-values in parenthesis. AB, BB and BC have been estimates via the user written command xtabond2 and xtlsdvc, respectively. Standard errors are robust and in case of BC obtained by bootstrapping with 50 repetitions. Small sample corrections were used in both GMM specifications.

There are various technical issues that are of relevance in comparing the results between the different estimation procedures and suggest the bias-corrected (BC) model as the most appropriate. It is well-known in literature (see e.g. Bond 2002) that OLS estimates for the lagged dependent variable will be upward and FE estimates will be downward biased. As columns (5) and (6) show, I confirm the prediction of the consistent BC estimate lying between the OLS and the FE estimates. Due to the large number of instruments relative to the small sample size, there is also a potential reliability problem associated with the estimators of both AB and BB. This is supported by the Sargan test which rejects the Null of validity of the instruments for the lagged dependent variable for AB and BB at the 10 and 5 percent level, respectively.[46] Another potential source of problems arises if the series are close to unit root (Bond 2002), in particular in the case of the estimators derived using AB difference-GMM. BB system-GMM is less vulnerable in case of unit roots (Bond 2002, Binder et al. 2005) but can suffer - like AB from a substantial bias in the case of small samples. Monte Carlo experiments (Kiviet 1995, Bun and Carree 2005) provide evidence that BC overcomes the results of difference and system GMM with respect to their bias even in small samples. The potential problems notwithstanding, parameter estimates are in fact robust across estimation procedures and, in most cases, highly significant.

10 Estimation Results

The estimation results comprise both results that are consistent with the existing literature and unexpected findings.

[46] For a more detailed discussion of the Sargan test of overidentifying restrictions in GMM, see Baum et. al. (2003) or Roodman (2006).

To begin, my results replicate in German data on environmental crime the common observation that there is strong intertemporal persistence in the dependent variable (e.g. Rickman and Witt 2007, Fajnzylber et al. 2002). Coefficient estimates for the lagged reported crime rate are at .84 for BC(BB). There are a number of explanation observations on this. One concerns the interplay between budget constraints and crime levels on available resources. Benson et al. (1995) and Cloninger and Sartorius (1979) identify past crime levels as a key driver of inputs available for crime detection and reporting. Cloninger and Sartorius (1979) demonstrate in a 16-year study of urban crime in Houston, Texas, that past crime levels are statistically significant in explaining future detection and reporting inputs. Benson et al. (1995) point to two factors that explain this observation, namely lagging budgetary allocations that are contingent on past crime rates and internal allocation processes that shift resources internally in response to changes in reported crime. Another explanation derives from the individual behavior of offenders who are likely to engage in repeat behavior (Fajnzylber et al. 2002a).

10.1 Deterrence

Table 4, upper middle section, reports the effects of the classic deterrence variables on reported environmental crime. With the exception of the rate of severe fines, these effects are consistently significant and have the predicted negative sign, leading to result 1.

Result 1: *Coefficient estimates lend strong support to the general deterrence conjecture contained in hypothesis 1. Particular support derives from the estimated elasticities of reported crime with respect to the rate of tried offenders and the*

incarceration rate.

The conviction rate has the predicted negative sign but is not significant for most relevant estimation procedures except FE. Of particular interest are the robust and substantial coefficients associated with the rate of tried offenders and the prison rate: Their estimates are statistically significant even at the 1% level across estimation procedures and their elasticities have magnitudes at around 1 for the rate of tried offenders and 1.5 for prison rates. This means that an increase in the rate of tried offenders of 1 percentage point will decrease environmental crime at about 0.9 to 1 percent. In case of the prison rate, the deterrence effect is even larger: An increase of the prison rate of one percentage point results in a decrease in reported environmental crime rate of 1.3 to 1.6 percent.

Clearance rates also show a clear deterrent effect on reported environmental crime, giving rise to result 2.

Result 2: *Parameter estimates for the clearance rate give support to the deterrence hypothesis 2. A higher clearance rate has an significant negative effect on reported crime with an elasticity of on average -.8.*

At the mean of clearance rates, the elasticity is at approximately -0.88, varying with one standard deviation of clearance rates between -0.77 and -0.89. Being subject to criminal investigation alone therefore deters potential offenders from committing an environmental crime.

While the deterrent effect of prison sentences provides a confirmation of the economic model of environmental crime, result 3 regarding clearance rates and the rate of tried offenders is less obvious.

Result 3: *Comparing coefficient estimates for different components of the sanctioning regime leads to a partial rejection of the hypothesis that deterrence effects of sanctioning devices are ordered by severity. While findings endorse the effect for prison rates, the rate of tried offenders and clearance rates, there is no evidence that severe fines and conviction rates fit into this frame.*

The least obvious finding are the magnitudes of the estimated coefficient for being identified as a suspect and for standing trial. These events in themselves do impose losses such as time and travel costs. These alone, however, would not seem sufficient to explain the scale of their deterrence effect. What is likely, therefore, is that unobserved reputational losses of being identified or standing trial are substantial. The public nature of criminal sanctioning is a plausible cause of such losses. Given the low level of pecuniary fines and the rarity of prison sentences, reputational effects remain as one of the main driving forces behind the deterrent effect of criminalizing environmental offences.

10.2 Political Factors

As Helland (1998, 2001), I find evidence for political factors being significant determinants of enforcement. The lower section of table 3 reports on the variables capturing the effect of detection and reporting effort on reported environmental crime. The effect of strong support for the Greens on reported environmental crime is compelling: The indicator for environmental preferences is statistically highly significant and positive, leading to result 4.

Results 4: *The positive and significant impact of environmental preferences on reported crime contradicts the conjecture that public environmental preferences*

decrease the supply of environmental crime. Hypothesis 4 is therefore rejected.

On the basis of the empirical evidence, the conclusion is justified that the elasticity of committing an environmental crime with respect to reporting behavior of society and agencies is low. The share of strong supporters of green issues in a state and year positively affect environmental crime by reducing the reporting bias.

Everything being equal, being governed by a pro-industry party reduces a state's reported environmental crime. Since enforcement variables are controlled for, this leaves a causal channel from administrative policies to detection and reporting effort as the most plausible explanation of the observed evidence.

Results 5: *There is no supporting evidence for the conjecture that pro-industry governments lead to an increase in environmental (hypothesis 5).*

The empirical results detect a small but negative and in most cases significant relationship between the CDU/CSU being in government and environmental crime rates. This pinpoints to a reduction of reporting efforts undertaken by agencies in response to a pro-industry government. I come back to this in the discussion on omitted variables.

11 Robustness of the Estimates

There are several technical issues involved in the econometric implementation of the economic model of environmental crime. First and foremost are issues of endogeneity whose presence may weaken the hypothesized causal relationship postulated in the simple model. As BC is only valid for strictly exogenous explanatory

Table 5: Difference-in-Sargan Test for AB and BB

explanatory variables	difference-in-Sargan (AB)	difference-in-Sargan (BB)
	P-values	P-values
cleared (level and squared)	0.137	0.885
tried	0.739	0.118
convicted	0.588	0.256
prison	0.056	0.008
fine	0.560	0.218
green.supp	0.725	0.396
cons	0.063	0.343

Note: Small sample corrections have been applied for AB and BB.

variables (except the lag of the dependent variable), I have to return to GMM to test for potential endogeneity issues.

11.1 Simultaneity

The empirical literature on the economics of crime is rich in exploring the problem of simultaneity, in particular for deterrent variables.[47] As suggested by Roodman (2006) and Baum et al. (2003), the difference-in-Sargan[48] test was used to examine possible endogeneity. The difference in Sargan tests are in most cases not able to reject the Null of exogeneity of the deterrence and political variables for AB and BB (table 5). Only the test for the CDU dummy in case of AB and prison rates for both AB and BB are significant.

However, as the Sargan test for the validity of the instruments for the lagged dependent variable causes some problems and there may be doubts about the

[47] See Ehrlich (1973), Cornell & Trumbull (1994), Corman and Mocan (2000) and many others; for an additional overview see Cameron (1988) or Levitt & Miles (2006).

[48] The test is automatically computed and diplayed in the output of xtabond2.

consistency of the test applying it to my data I reestimated my model with BB sequentially treating suspected variables as being endogenous. The reader finds the results in table 6. While it is possible to argue that under some circumstances regarding the data generating process the Sargan test statistic is invalid (see e.g. Roodman 2006 or Baum et al. 2003), parameter estimates and standard errors did not change substantially in comparison to the BB estimation in table 4 neither in significance nor in magnitude. There is therefore little reason to conclude that simultaneity plays an important role in my dataset. As this is not in line with previous findings the reader may be suspicious about theses results. However, in a workshop organized by the authors, members of police and prosecution mentioned that - in practice - environmental crime does not have priority inside enforcement institutions. Only environmental crimes with persistent media attention have anecdotally had significant influence on enforcement efforts at least in the short run.

11.2 Omitted Variables

In the interest of economical use of available data, the empirical strategy involves estimating the core of the economic model as a first step. However, this strategy runs the risk of omitting potentially important variables (see section 2.6.2). In order to check for robustness against omitted variables, other potentially relevant variables are subsequently introduced. The author is aware that this approach is not in line with usual 'General to Simple Strategy' (Greene 2003). However, having in mind that the data set is small, including too many variables at the same time reduces degrees of freedom dramatically and results would be questionable. To test

Table 6: Estimation Results 2

Variable	BB(cl)	BB(tr)	BB(conv)	BB(pr)	BB(sgs)
Regressors	1	2	3	4	5
lnCR, lag 1	.9983	.9950	.9967	.9977	.9983
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
cleared	-1.9682	-2.0206	-2.0267	-1.9511	-1.9682
	(0.0103)	(0.0071)	(0.0096)	(0.0088)	(0.0103)
cleared sq.	2.2718	2.3197	2.322	2.2551	2.2718
	(0.0032)	(0.0022)	(0.0033)	(0.002)6	(0.0032)
tried	-.8906	-.8757	-.8859	-.8943	-.8906
	(0.0000)	(0.0001)	(0.0000)	(0.0000)	(0.0000)
convicted	-.1571	-.1468	-.1462	-.1667	-.1571
	(0.3002)	(0.3422)	(0.3518)	(0.2669)	(0.3002)
prison	-1.4634	-1.4447	-1.5742	-1.5012	-1.4634
	(0.0099	(0.0095)	(0.0072)	(0.0058)	(0.0099)
fine	-.1101	-.0995	-.0748	-.1120	-.1101
	(0.5115)	(0.5441)	(0.6637)	(0.4995)	(0.5115)
green.supp	2.6980	2.6466	2.6023	2.7008	2.6980
	(0.0025)	(0.0025)	(0.0039)	(0.0027)	(0.0025)
cons	-.0235	-.0288	-.0285	-.0246	-.0235
	(0.6043)	(0.5219)	(0.5491)	(0.6018)	(0.6043)
N	152	152	152	152	152
instruments	152	144	144	144	152
Sargan	168.8952	161.2093	154.1789	165.3315	168.8952
	(.0166)	(.0138)	(.0342)	(.0077)	(.01665)
ar1	-2.7550	-2.7584	-2.7528	-2.7549	-2.7550
	(.0058)	(.0058)	(.0059)	(.0058)	(.0058)
ar2	1.6454	1.6221	1.6033	1.6443	1.6454
	(.0998)	(.1047)	(.1088)	(.1000)	(.0998)

Note: Time dummies and a constant term have been included but omitted here. P-values in parenthesis. Restricting lag length to 6 as I did implied a reduction of instruments to almost 1/2. BB(cl) indicates that both variables for clearance rate have been treated as endogenous. The same is true for the rate of tried offender, BB(tr), conviction rates, BB(conv), prison rates, BB(pr), and the support for the Greens, BB(sgs). Again, small sample corrections were used in all specifications.

whether my approach generates different outcomes I went through both procedures and ended up with the same core equation.

Typical examples for further explanatory variables are the competition for enforcement resources as indicated by the general crime rate, the level of enforcement inputs such as the number of employees in the prosecution service, expenditures for police, prosecution and courts. Structural variables are also potential candidates for omitted variables, such as GDP per capita, the revenue or value added for different sectors including recycling and farming, unemployment rates, and social transfers indicating a higher opportunity cost of compliance. Finally, socio-political variables that determine the governing party in individual states and a dummy for the eastern states would qualify *ex ante*. Table 25 (Appendix to part II) reports on the results for a roster of commonly used variables among those tested using the BC estimation procedure. None of the non-core variables had a robust effect on reported environmental crime across the different estimation procedures and remaining parameter estimates were unchanged. Differences in inputs into police forces or the prosecution system do not contribute to explaining the observed variation in reported environmental crime, nor do staple variables from the standard criminological literature such as unemployment. As environmental crime is a complement rather than a substitute to production activities, this is expected. Also, there is no evidence that other forms of reported crime crowd out reported environmental crime, for example through competition for scarce enforcement budgets.

As I used panel data and thus control for unobserved heterogeneity I can conclude that endogeneity issues as suggested in section 2.6.2 do not seem to be relevant for this dataset. However, few issues remain and will be subject to the

next section.

11.3 Additional Checks

The last concerns concern possible time lag structures, nonstationarity and aggregation bias in the data (see section 2.6.3 and 2.6.4). With respect to of I(1), it is evident that the dataset possesses a relatively large time dimension in comparison to the cross section. Although traditional approaches are consistent for $0 < T/N < 2$ (Alvarez and Arellano 2003) and thus appropriate in this case, the possibility of nonstationarity in the panel data with relatively large T is real (Pesaran et al. 1995, 1999). I apply the customary panel unit root test for unbalanced panel developed by Maddala and Wu (1999) to my environmental crime and deterrence variables. As it is evident in table 7, this test rejects the H_0 of integration and therefore points towards I(0) in my crime and deterrence variables.[49] Only the indicator for environmental preferences points towards I(1) in two of the three specifications. This provides an additional robustness check to the validity of the results.

In case of possible delayed updating of potential offenders resulting in time lags in the causal relationship between enforcement and crime (see section 2.6.4) it is recommended to estimate the crime equation with lags in all deterrence variables. However, as the sample is rather small and depends to a great extend on its time dimension, it makes only sense to include the variables with one lag. The reader finds the results in table 8. Although the amount of estimates being significant is reduced dramatically, the estimates especially for the preferred BC estimators

[49] Different specifications including trends and lags were applied, with the majority of tests rejecting unit roots.

Table 7: Maddala-Wu Test of I(0)

Variables	lag + trend	trend	lag
	P-values	P-values	P-values
CR	0.0098	0.0011	1.0000
cleared	0.0838	0.0041	0.0000
tried	0.0303	0.0000	0.1348
convicted	0.9724	0.0067	0.3419
prison	0.0000	0.0000	0.0000
fine	0.0000	0.0123	0.0010
green.supp	0.2784	0.3769	0.0173

Note: H_0 is I(1). The user written command xtfisher by Scott Merryman was used to implement this test in Stata.

have all the expected signs. The parameter estimates for the deterrence variables and the CDU dummy return to be negative and the estimate for the indicator for environmental preferences shows up to be positive. Moreover, the lagged dependent variable, conviction rates, prison rates, rate of severe fines and the CDU dummy also have the right order of magnitude. Only the estimates for clearances rates, rate of tried offender and environmental preferences decrease in comparison to the original results.

Although most of the variables become insignificant the signs and magnitudes of the parameter estimates stay almost the same especially for BC estimates. Usually the applied econometrician would apply several tests to find out the right lagging structure. This is not possible in my case as the sample size is too small.

Finally, table 9 shows results estimating the equation including only illegal waste disposal to circumvent the problem of an aggregation bias. I concentrated on illegal waste disposals as this is the major type of environmental crime in Germany (see section 1.3). Although the GMM estimators seem to deviate sometimes,

Table 8: Estimation Results for Lagged Deterrence Variables

Variable	POLS	FE	AB	BB	BC(AH)	BC(BB)
Regressors	1	2	3	4	5	6
lnCR, lag 1	.9656	.6856	.3879	.9459	.8856	.9094
	(0.0000)	(0.0000)	(0.0546)	(0.0000)	(0.0000)	(0.0000)
cleared, lag 1	.8134	-.9663	.2508	.8898	-.7585	-.6591
	(0.2735)	(0.3865)	(0.8694)	(0.4118)	(0.5889)	(0.5864)
cleared sq, lag 1	-.7787	.0642	-.8419	-.9256	-.2613	-.25128
	(0.2743)	(0.9496)	(0.5338)	(0.3901)	(0.8373)	(0.8212)
tried, lag 1	.0695	-.2358	-.0973	.1512	-.1277	-.1625
	(0.7533)	(0.2783)	(0.7430)	(0.6467)	(0.7131)	(0.5908)
convicted, lag 1	.0976	-.2056	-.4272	.0779	-.2906	-.2303
	(0.4856)	(0.3551)	(0.0402)	(0.5194)	(0.2660)	(0.2958)
prison, lag 1	-.3694	-.9517	-.7716	-.5232	-1.08968	-1.0445
	(0.5023)	(0.0645)	(0.0959)	(0.2752)	(0.1291)	(0.1216)
fine, lag 1	-.3644	-.2910	-.4206	-.3488	-.1923	-.2635
	(0.1271)	(0.2513)	(0.0439)	(0.0514)	(0.5643)	(0.3798)
green.supp	.9186	1.1283	.9394	.6942	1.1330	1.0991
	(0.2349)	(0.3323)	(0.4753)	(0.5363)	(0.4295)	(0.3974)
cons	.0258	-.0096	-.0253	.0090	-.0358	-.0062
	(0.5623)	(0.8568)	(0.7834)	(0.8970)	(0.5960)	(0.9116)
N	137	137	121	137	137	137
instruments			71	82		
Sargan			71.9726	87.3785		
			(.04245)	(.0227)		
ar1			-2.5466	-2.7042		
			(.01087)	(.0068)		
ar2			1.5667	1.9145		
			(.1171)	(.0555)		

Note: Time dummies and a constant term have been included but omitted here. P-values in parenthesis. AB, BB and BC have been estimated via the user written command xtabond2 and xtlsdvc, respectively. Standard errors are robust and in case of BC obtained by bootstrapping with 50 repetitions. Small sample corrections were used in both GMM specifications.

results for both BC and for OLS and FE are in line with previous findings. The only key difference is that or indicator for environmental preferences slightly fails significance at the 10% level for BC. The remaining results are almost the same as those for environmental crime in general both in magnitude and in statistical significance. To conclude, there seems to be no aggregation bias in my results derived so far.

To conclude the results for this section, there is great support that my original estimates are very robust with respect to all shortcomings mentioned in previous literature (see section 2.6). Neither endogeneity, aggregation bias, time lags nor nonstationarity give cause to doubt my initial findings. Additionally, a first try to capture variations in the dark figure showed up to be of great importance but have no effect on my deterrence variables.

12 Discussion

12.1 Interpreting the Results

The empirical results derived on the basis of the dynamic panel analysis add in significant ways to the existing literature. The first new insight is that while a substantial part of the legal literature characterizes criminal enforcement in case of environmental offences as ineffective and therefore redundant, the results of the paper indicate otherwise. While rarely used, enforcement instruments restricted to criminal sanctioning such as trial in a public court and prison rates have a substantial statistical effect on reported environmental crime rates. Most of the standard variables measuring the quality of enforcement come out as strongly

Table 9: Estimation Results for Illegal Waste Disposal

Variable	POLS	FE	AB	BB	BC(AH)	BC(BB)
Regressors	1	2	3	4	5	6
lnCR, lag 1	1.005	.6613	.6218	1.0246	.7425	.8230
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
cleared	-.7200	-3.3651	-1.7848	-.8789	-3.1783	-2.8139
	(0.3189)	(0.0000)	(0.2054)	(0.3943)	(0.0121)	(0.058)
cleared sq.	1.2176	3.3406	1.9444	1.4660	3.1733	2.8010
	(0.0682)	(0.0000)	(0.1339)	(0.1108)	(0.0042)	(0.0310)
tried	-.5895	-.8875	-.9542	-.6457	-.8663	-.8285
	(0.0000)	(0.0000)	(0.0000)	(0.0011)	(0.0003)	(0.0014)
convicted	.0946	.06346	-.0547	-.0136	.0545	.0359
	(0.6038)	(0.7734)	(0.8556)	(0.9516)	(0.8226)	(0.8963)
prison	-1.2365	-1.4149	-.2466	-.7717	-1.4304	-1.3764
	(0.1442)	(0.0533)	(0.6591)	(0.3361)	(0.0338)	(0.0795)
fine	.1034	.5580	.1320	-.0077	.5487	.5376
	(0.6664)	(0.0147)	(0.6379)	(0.9617)	(0.2464)	(0.3304)
green.supp	3.1917	2.0391	1.1277	3.0557	2.2580	2.5685
	(0.0001)	(0.0898)	(0.3150)	(0.0034)	(0.1044)	(0.1046)
cons	-.0129	-.0941	-.0667	-.0214	-.0876	-.0828
	(0.7765)	(0.0589)	(0.3556)	(0.6918)	(0.0623)	(0.1325)
N	151	151	134	151	151	151
instruments			73	84		
Sargan			54.8619	86.8262		
			(.4417)	(.0303)		
ar1			-2.6002	-2.4554		
			(.0093)	(.01407)		
ar2			1.4238	1.3791		
			(.1545)	(.1678)		

Note: Time dummies and a constant term have been included but omitted here. P-values in parenthesis. AB, BB and BC have been estimated via the user written command xtabond2 and xtlsdvc, respectively. Standard errors are robust and in case of BC obtained by bootstrapping with 50 repetitions. Small sample corrections were used in both GMM specifications.

significant and with a deterrent effect. With a view to validating the economic theory of crime, there is clear evidence that the "calculus of deterrence" is indeed operational in the domain of environmental crime. On the policy side, it should be pointed out that the results are not conclusive evidence that criminal sanctions are in any way superior to standard regulatory sanctioning mechanisms. At the same time, the results demonstrate that criminal sanctions can play an important role in deterring environmental crime.

The second new insight contained in the results is that the public nature of sanctioning by trial appears to be quantitatively much more important than the conviction rate and the magnitude of sanctions. The fact that the criminal process generates informational externalities that do not arise in the essentially bilateral relationship between regulators and offenders is an important feature of that regime. Its high deterrence effect suggests that policy-makers may find it worthwhile to consider adding a public component to regulatory processes in order to reap the benefits of this effect while avoiding incurring the high costs that beset prosecutions and trials under criminal law.

The third insight that my paper delivers is the importance of political factors to understand the variation in reported environmental crime. The positive contribution of citizens' environmental preferences to the explanation of reported crime has in my view not been empirically established so far. While the causal channels through which these preferences translate into greater reporting cannot be traced given the available data, intuitive explanations would center around the direct effects of more direct reports by citizens to enforcement authorities and the indirect effects of voter preferences leading to political pressure to increase detection and reporting efforts by the police and regulators. Empirical evidence on the effects of

which party governs individual states tends to lend support to this link that mediates voter preferences through the political process. The paper does not explicitly consider the longer–term effects of political preferences on the sanctioning regime (Helland 2001, Hamilton 1996). These will be the subject of a separate paper.

Focusing on the econometric aspects of the paper, particular attention has been paid to tackle the issue of possible simultaneity in connection with crime variables and the fact that the panel data set covers a long time period relative to the cross section, thus giving rise to the real possibility of unit roots in the data. Regarding simultaneity, the main problem arises in the joint determination of reported crime and enforcement variables. Here, the paper employs different validation strategies that universally fail to substantiate the presence of simultaneity in the data set. One explanation is that this is due to the small relative importance environmental crime has in comparison to serious and more frequent offences such as felonies. Overall, the estimation results are surprisingly robust and give grounds for cautious confidence in the results.

12.2 Confronting Results with the Existing Literature and Part III

It is the aim of this section to embed the new insights into the existing literature presented in part I and into the findings of part III. It will then become evident whether my results are supported by previous findings in the general law and the environmental regulation literature or not.

12.2.1 Deterrence

In the empirical analysis of part II I find strong evidence for the deterrence effect of clearance rates with the elasticity of around -.8 for the average clearance rate. Cornwell and Trumbull (1994) replicate studies using cross-sectional data with estimated elasticities for different types of crime being between -0.342 to -2.95 and almost all being statistically significant. Their own results regarding arrest rates are at around -.5 for their aggregate crime rate. Cherry and List (2001) reestimate the dataset analyzing different types of crime separately. Their elasticities range from -.167 (robbery) to -.557 (burglary). Baltagi (2006) gets similar results for his reestimation of the dataset. Cherry (1999), also using panel data, found results in similar magnitude. In his panel data analysis, Mustard (2003) found substantially lower deterrence effects of arrest rates with elasticities ranging from -0.0016 to -0.012 for different types of crime. Viren (2001) also included arrest/apprehension rates in his analysis finding very heterogenous results depending on the type of data. The elasticities range from -.003 (pooled cross country data) to -70.168 (pooled Finnish municipalities data). Gould et al. (2002) also found rather low elasticities of around -.001. In addition, Levitt (1998b) tries to separate measurement error, incapacitation and deterrence effects. The author finds strong support for the deterrence effect dominating the other with substantial effects especially for property crimes. In this analysis one additional burglar arrested deters two burglaries. Although previous literature found rather heterogenous results for clearance or arrest rates my findings are in a comparable order of magnitude. My results for clearance rates in part III confirm results in both part II and the general crime literature. At the level of counties of Baden-Württemberg, the estimated

elasticity is at around -.2 and therefore in line with previous findings.

Results are also in line with the findings of the literature on the compliance or noncompliance with environmental regulations. There the frequency of monitoring activities may reflect the probability of detection and thus the rate of violations being cleared. Almost all studies find significant positive effects of monitoring on compliance with different types of regulations (see section 3.3.1). The estimates are in a similar order of magnitude with -1.5 being the highest estimate.

As the rate of tried offender reflecting the probability of getting accused when identified is new in the law and economics literature it is not possible to compare my results to previous findings. However, the rate of tried offenders seems to be the most effective deterrence variable for Germany as results in part III broadly confirm the present findings. Although the estimated elasticity is smaller in part III (ca. -.5), it is again highly significant. Taken together, the fact of being tried seems with elasticities of around -1 (part II) and -.5 (part III) to be very effective in deterring people from committing environmental crimes.

The empirical analysis implemented in this part of the thesis returns an elasticity for the conviction rate of roughly -.3 but without significance at any common level. Cornwell and Trumbull (1994) also replicate two examples of cross sectional studies estimating the effects for conviction rate with elasticities of -.26 and -1.8, respectively. Depending on the model specification, their own analysis reveals effects ranging from -.282 to -.530 which are significant in most cases. Cherry and List (2001) estimate effects in similar size for different crime categories. The same is true for the reestimation by Baltagi (2006). Mustard (2003) also included conviction rate as a deterrence variable but got significant lower results with all elasticities being below -.001. Estimates in part III show even more ambiguous

results with varying signs and no significant effects.

Most comparable to conviction rates in the crime literature are the enforcement efforts in the environmental regulation literature. There, estimates are in a very similar range and do thus suggest a comparable level of deterrence (see section 3.3.2).

Prison Rates have in my analysis the biggest deterrence effect on criminal behavior with an elasticity of about -1.5. In literature, most results are of the same order of magnitude or smaller. Ehrlich (1973) analyses different dataset with different estimation approaches and gets estimates for the rate of apprehended and imprisoned ranging between -.275 to -1.3. The range of the results for Andreoni's (1995) reestimation is almost identical. The two papers replicated by Cornwell and Trumbull (1994) find effects of -.526 and -.991. Their own results do not show up to be significant and are relatively small (-.2). The reestimation by Cherry and List (2001) results in statistically significant effects for many types of crimes but with elasticities of again roughly -.2. This holds also for the reestimation of Baltagi (2006). My findings of part III are not able to confirm results of part II as the estimates are only significantly negative for the lagged effect (with elasticities of around -.9).

As there is little evidence for the impact of fines on deterrence in crime literature, I compare my results to the work by Bar-Ilan and Sacerdote (2004). In their study, the authors find elasticities of around -.2 and -.3, respectively. However, in case of German environmental crimes the rate of severe fines has ambiguous effects on crime and there is no specification for which it is significant. The reason for this may be that severe fines are seldom used and in contrast to prison sentences they may be of less interest to media coverage. However, estimates of part III

are negative throughout with elasticities of around -.5 and only slightly fail to be significant at the 10% level (see section 18.1).

In contrast, Stafford (2002) analyses the effect of a sudden increase of monetary sanctions for hazardous wastes caused by changing legal environments. Although this is not the same as a rate of severe fines it to some extent comparable to my analysis. Stafford (2002) finds that with this increased penalty the probability of a firm being in violations decreased by 3 percent.

12.2.2 Political Factors

The fact that political variables may affect the amount of crime or, to be more precise, the reported amount of crime is rather new in crime and environmental regulation literature. The only exception is, at least to my knowledge, Stafford (2002). The author included state environmental membership in her analysis finding a negative effect on non-compliance. However, as the targeted variables are different (see section 3.3.3), the results are not comparable. Although the empirical analysis of illegal waste disposals in Baden-Württemberg is not able to confirm the present results, there is evidence for variables being at the intersection between political and structural factors to influence illegal behavior (see section 18.3).

13 Conclusion to Part II

Environmental crime, despite sharing important features with the types of crime generally studied in 'economics of crime', has so far largely escaped the attention of scholars. This is in contrast with environmental policy-makers who have embraced and continue to embrace the sanctioning potential of criminal law, albeit

without clear empirical evidence regarding the ability of criminal sanctions to provide a deterrent effect. Instead, the absence of rigorous economic analysis has led to a proliferation of narratives with frequently irreconcilable characterizations of regulatory reality.

This paper attempts to close the evidence gap in the use of criminal sanctions in environmental policy making by specifying a theoretical model of reported crime and implementing it in the shape of a dynamic panel data analysis. In doing so, the paper not only confirms the operability of the "calculus of deterrence" in the context of environmental crime. It also challenges the notion now widespread in legal circles that German environmental criminal law is ineffective and - hence - redundant. This is important since although environmental agencies are able to impose fines, the essentially bilateral and confidential nature of standard regulatory practice denies regulators access to the reputational sanctions implicit in public trials.

To verify the result obtained so far, the next part of the thesis follows a similar strategy as this part does to analyzes illegal waste disposals on the more disaggregated level of Baden-Württemberg.

Part III

Illegal Waste Disposals and Punishment

14 Introduction to Part III

Part III of the thesis is dedicated to a specific analysis of the major type of environmental crime in Germany - illegal waste disposal - from a more regional perspective of the 44 counties (*Stadt- und Landkreise*) of the German state of Baden-Württemberg. This section therefore extends the analysis of part II in order to verify the results obtained on a more disaggregated level and to focus on further determining factors of environmental crime that may only be detectable at a finer level of analysis. Different aggregation levels imply different sets of available informations and it is therefore of huge importance to analyze environmental crime at the level of the German states and the counties of Baden-Württemberg. Congruence in the deterrence effects on both levels when including different sets of covariates would provide a strong argument for the reliability of the findings.

Due to data constraints the empirical analysis in part II only included informations for expected costs in terms of expected punishment and political economy factors. The economic approach to crime introduced by Becker (1968) claims, however, that potential criminals balance benefits and costs of crime. It is therefore also important to uncover the effects incorporated in the benefit side of illegal disposal. This will be the focus of this part of the thesis.

Focusing on illegal waste disposal has several advantages. First, it is the most common type of environmental crime in Germany and it has a similar weight in the U.S. (EPA 2006) and the rest of the European Union (EC 2007). Second, previous theoretical and empirical literature (Sullivan 1987, Fullerton and Kinnaman 1995, Sigman 1998 and Stafford 2002) suggest that illegal waste disposals should to a great extent be driven by economic incentives and thus constitute a good example to study Becker's (1968) model. Third, it is, in comparison to other types of environmental crime, rather easy to include data on the benefit side of the market as information for the amount of waste and for specific fees is contained in official statistics for Baden-Württemberg.

In line with my comments on the literature on environmental regulation in general, there is a small but informative literature on administrative sanctioning of illegal or hazardous waste for the case of the U.S. (Sigman 1998, Stafford 2002). However, at least to my knowledge, we do not know anything about criminal enforcement of illegal waste disposals so far. Sigman (1998) e.g. studies the effectiveness of administrative, civil and criminal enforcement under the Resource and Recovery Act (RCRA) together in one approach and thus is not able to reveal distinct effects for criminal enforcement. This lack of evidence is concerning, as there is an ongoing debate arguing in favor of a further strengthening of criminal enforcement in the context of environmental law for both the U.S. and EU (see section 1.2). For policy-making to be effective and consistent it is necessary to have information about all relevant ties in this context. It is therefore the aim of this part of the thesis to (i) validate the results for deterrence and political economy factors obtained through the state level analysis, to (ii) include specific information for the regional composition of each county and to (iii) incorporate

data for the markets of legal waste disposal. To be precise, it will be interesting to know whether results for deterrence for German states carry over to the counties of Baden-Württemberg. If this is the case it would provide a strong argument that criminal law is really effective in deterring environmental offences at least for the German case. The same is true for the results regarding the political economy drivers of reported environmental crime. Evidence for the composition of municipal councils (*Stadtrat* and *Kreistag*) having an impact on the amount of reported illegal waste disposals would definitely support findings of part II. However, one obvious drawback of more disaggregate data is that political variety is reduced significantly at this level. As the composition of municipal councils is rather stable over time and mostly in hand of the German conservatives (CDU)[50] in case of Baden-Württemberg, it will be hard to reveal important effects. Furthermore, there is no data available reflecting environmental preferences of county population. Additional waste market factors especially include a variety of informations for the sources of household and industrial waste and the quantities and prices relevant for legal disposal.

Although the data availability is much better for Baden-Württemberg than for most of the other German states, there are still some important drawbacks I will explain in section 16.

Results are fourfold. First and foremost, there is again strong support for a deterrence effect of criminal enforcement in the context of environmental crime. Especially the fact of being tried is again a key driver in the general deterrence framework. This finding is remarkable as the combination of part II and III give

[50] Other very important parties are local voters‘ associations only being active for a specific county.

rise to the result being consistent and reliable. The thesis is therefore in the position to add important informations to ongoing debates in Germany and to similar discussions elsewhere.

Secondly, and as it has been expected, the political economy factors reflecting the composition of municipal councils do not show up to be significant. This is not surprising as there is not much political heterogeneity in Baden-Württemberg. Both the state parliament and the municipal councils are dominated by the German conservatives for more than 50 years.

Third, as for the waste market data, it is not possible to reveal the causal channels. The quality of the informations available for the waste market give cause to concern. However, we will come to this issue in later sections.

Fourth, results suggest that structural variables indicating industrial activity in each county affect the amount of reported illegal disposals. Especially factors indicating the dependency a county faces with respect to the manufacturing industry in terms of employment or tax income seems to influence the amount of reported illegal waste disposals.

The remainder of part III is organized as follows. In section 15 I will present the theoretical hypothesis tested in later regression analysis. These include deterrence, political and structural effects potentially influencing the amount of illegal disposals. Section 16 introduces the data collected that builds the basis for the later econometric investigations. After that I will present the empirical model to be estimated and the corresponding results in section 17 and 18. Finally, there will be some robustness checks, a discussion and concluding remarks in sections 19 - 21, respectively.

15 The Determinants of Reported Illegal Waste Disposal

The theoretical hypothesis are based on three aspects. The first set of considerations stress the deterrence effects of criminal enforcement in the context of illegal waste disposals and is therefore in line with the analysis in part II. Deterrence should play a similar role at the county level and at the level of German states. I therefore briefly replicate the hypothesis on this issue stated in section 7.1. Secondly, and as it is well-known in environmental economics literature, the economic incentives inherent to the waste market will influence the amount of illegal waste disposal (Sullivan 1987, Fullerton and Kinnaman 1995, Sigman 1998 and Stafford 2002). Lastly, political and structural factors may influence illegal behavior.

15.1 Deterrence

In case of illegal waste disposals, gross benefits consist of the avoided cost of proper disposal minus the cost of illegal disposal. The components of expected costs are the probability of being detected, 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. Variations in this expected cost give rise to the first two hypothesis.

Hypothesis 1. Reported crime responds to more severe criminal sanctions in that higher probabilities of their use lead - *ceteris paribus* - to a reduction in reported crime.

As illegal waste disposals are primarily motivated by economic considerations, this hypothesis postulates that changes in sanctioning probabilities deter environmental criminal activity as predicted and observed in other contexts of enforcement and deterrence (Becker 1968, Cornwell and Trumbull 1994, Sullivan 1987, Fullerton and Kinnaman 1995, Sigman 1998 and Stafford 2002). Higher sanctioning probabilities raise the expected cost of criminal activity and should hence decrease net benefits of illegal disposals, leading to less criminal activity being undertaken.

Hypothesis 2: A higher clearance rate implies a higher probability of being identified as an offender, thus raising the expected cost of crime and leading to a reduction in reported crime.

Greater effort by police to identify the offenders responsible for a reported illegal disposal is the first key step for the prosecutorial process to commence. Since for a given amount of illegal disposals, a higher clearance rate implies greater probability of being subject to criminal investigation, there is a strong a priori intuition that reported cases of illegal disposals should fall for higher clearance rates. Empirically, this conclusion is borne out by studies typically returning negative coefficient estimates on account of their deterrent effect on potential offenders (e.g. Baltagi 2006, Cherry and List 2002, Cornwell and Trumbull 1994).

As stated in section 7.1, the prediction of negative coefficients attached to sanctioning variables is silent on the relative contribution of different components of the sanctioning regime to overall deterrence. The question of relative contributions is the subject of hypothesis 3.

Hypothesis 3: An increase in the probability of more severe sanctioning components will result in a greater deterrence effect relative to less severe sanctioning

components. The order of deterrence effects should be the probability of (i) a prison sentence, (ii) a severe fine, (iii) a conviction, (iv) of having to stand trial, and (v) being identified as a suspect.

Different sanctioning components imply different costs. Theory would dictate that the marginal impact of a change in the different sanctioning probabilities should therefore correspond to these cost differences (Polinsky and Shavell 1984). Among the sanction considered in the German Penal Code, prison sentences are arguably the most severe form of punishment as they include time lost and the social stigma attached to prison sentences, followed by severe fines, standard fines, and finally the purely reputational losses of having to appear in court (Kahan and Posner 1999, Karpoff and Lott 1993).

15.2 Waste Market Determinants

Although there is data available for the quantities of legal waste disposals and for local waste disposal fees for Baden-Württemberg, it is not quite clear in which way they affect the amount of illegal waste disposals. There are several reasons that give rise for ambiguous effects. The law on recycling and waste (*KrW-/AbfG*) implemented in October 1996 totally changed the situation for waste disposals. According to officials from local waste departments the new law had the same effect as a subsidy for all commercial operators producing waste. Prior to the law, the disposal of industrial waste had to be carried out by local authorized private firms or local waste disposal departments. With the law being in force, firms and plants are allowed to commission private companies without a local commitment and thus fewer regulatory control. Moreover, another effects is that companies

entered the market offering the professional disposal of industrial waste for a very low price and then dispose that waste illegally e.g. as household garbage. Although it would be very interesting to study the transition from one legal situation to the other in more detail, it is not possible to derive a clear-cut hypothesis whether the law leaded to more or less environmental crime.

Taken together, the law on recycling and waste decreased prices for industry waste disposal and increased at the same time the prices for household waste disposal. This is because local firms commission internationally operating companies to dispose their waste. In doing so, they cause a huge gap in the fill rate of local incinerating plants. The effect of this gap is that the price per kg of waste disposal rise which foremost affects the costs for private households as they are committed to the local supplier. On the other hand, rising fees also signal that less industrial waste is disposed locally. Although internationally operating firms may have incentives to dispose illegally, it is unlikely that this illegal disposal will happen at the place of origin. Furthermore, even on this disaggregate level, prices are very heterogenous and depend on the amount of services connected to the disposal. To summarize, one is not able to derive consistent and testable hypothesis for waste disposal fees.

Similar problems arise for the amount of waste appearing in official statistics. As data for the amount of waste is only collected recently and there have been several adjustments in official statistics, informations exhibit some inconsistencies over time.[51] It is therefore questionable if one finds definite effects when including data for the amount of different sorts of waste into an econometric specification.

[51] According to the ministry of environment of Baden-Württemberg, there have been several adjustments in recent years.

This suspicion is supported by later results (see section 19.2). None of the included waste market variables show up to be significant in any specification.

In contrast to waste market data, informations on the political and structural composition of each county are more reliable. It is therefore possible to derive consistent and testable hypothesis for these factors.

15.3 Structural and Political Factors

The key points regarding the impact of the structural and political composition of counties on illegal disposals are concentrated in 4 hypothesis. The first one considers the relationship between the amount of civil servants in a county and population. I assume that the higher the share of civil servants in comparison to county population, the higher the probability of a crime being detected and reported. However, as criminals may anticipate this, there may also be a deterrence effect of a higher share of civil servants. I assume the reporting effect to dominate the deterrence effect, leading to hypothesis 4.

Hypothesis 4: A higher share of civil servants in population will - *ceteris paribus* - lead to more reporting and thus increase the rate of reported illegal disposals.

On the other hand, illegal waste disposals may be more likely committed in a county with a lower population density (Eckert 2004). In a less dense populated county it should be fairly easy to dump waste without being caught red-handed. This leads to hypothesis 5.

Hypothesis 5: A more dense populated county is assumed to experience less

illegal waste disposals and thus a lower rate of illegal disposals.

In contrast to the analysis for German states, there is no data available reflecting environmental preferences of county population. In addition, although I have data on the political composition of municipal councils, there is not much variation as the conservatives are the dominating party in Baden-Württemberg (LPB 2008). Moreover, there are complicating feedback effects in operation between political orientation and reported illegal waste disposal. Laxer or a more stringent enforcement induced by politicians will arguably lead to more or less illegal disposals (Hamilton 1996, Helland 1998), but also less or more detection effort, leaving the net effect on reported cases ambiguous. However, I included several variables indicating how powerful the conservatives and the German green party are in local municipal councils. In contrast to part II, hypothesis 6 assumes that the supply of illegal disposals is inelastic with respect to detection effort. Again, this assumption is subject to empirical examination.

Hypothesis 6: Pro-industry councils lead *ceteris paribus* to a lower rate of reported illegal waste disposal. In contrast, a higher share of green politicians in municipal councils will *ceteris paribus* increase the rate of reported illegal waste disposal.

Typical structural factors like GDP per capita or indicators for industry activity like the total revenue of the manufacturing sector may also affect the amount of illegal disposals. I assume that both indicators for economic activity increase the amount of reported illegal disposals (Eckert 2004, Sigman 1998, Stafford 2002). According to Sigman (1998), counties with a higher income may care more about the environment and thus have higher reporting than counties with lower incomes.

Hypothesis 7: Increasing GDP per capita or total manufacturing revenue leads- *ceteris paribus* - to a increasing rate of reported illegal waste disposal.

Another potentially important determinant of reporting that is at the intersection between political and structural factors is the degree a county depends on the income generated by the manufacturing industry. Both the income of counties generated by corporate taxes and earnings of employees may affect the amount of reporting. I assume that in counties with a higher portion of people working in manufacturing industries there will be less reporting. In line with this, a higher relationship between county corporate tax income and total county income is assumed to reduce reported illegal disposals.

Hypothesis 8: Increasing the share of people working in the manufacturing industry or the weight corporate taxes have in comparison to county income leads *ceteris paribus* to a decreasing rate of reported illegal waste disposal.

The next section introduces the dataset used in the later econometric analysis in sections 17 - 19.

16 Data

Data on illegal waste disposals in Germany is collected at the level of 44 individual counties (*Stadt- und Landkreise*). As I employ panel data analysis, my sample comprises the years 1995 (1994 in case of reported cases and cleared cases) to 2005 with a small subset of states having incomplete reporting,[52] leading to an

[52] In 2001, there is no information on reported cases and clearance rates for Raststatt and Neckar-Odenwald-Kreis. In case of enforcement variables, data is missing for 17 observations.

incomplete panel. Data on reported illegal waste disposals and the clearance rate are taken from the official police crime statistics (PKS) published by the State Criminal Police Office (LKA) of Baden-Württemberg. Data concerning juvenile offenders is excluded from the dataset due to the distinct sanctioning regime applicable to this subgroup. The necessary data for the explanatory variables of the sanctioning regime applied to crime, such as the number of trials, convictions and imprisonments, is available from the official prosecution statistics (StVSt) of the Research Data Centre (FDZ) provided by the Federal Statistical Office and its state level counterparts. 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 municipal councils, data reflecting the waste market, county income and enforcement resources such as the number of civil servants, prosecutors and judges.

There are some important issues regarding data quality that have to be discussed in detail. First, an important characteristic of the enforcement process is that although there is data for cases and cleared cases of illegal waste disposals for every county and year, there does not exist data for the enforcement process on this disaggregated level. The reason for this is that local courts are in most cases responsible for several counties. In order to match every county with its corresponding court I mapped the enforcement variables of the 17 regional court districts (*Landgerichtsbezirke*) to their particular counties. That is, several counties will have the same rate of tried offender, conviction rates, etc..

As there may be some time lag between identifying a suspect and the criminal

proceeding and, in addition, the number of illegal waste disposal for each county sometimes is very low and varies significantly over time, there are 50 observations where the number of tried exceeds the number of identified suspects. This implies a rate of tried offenders which is greater than 1. Unfortunately, it is not possible to map the whole process of enforcement for each case separately as information stem from different sources. It is therefore not possible to identify the right time lag for every case separately. Applying some kind of average time lag or moving averages may worsen things as there is a significant amount of cases that are enforced in the year of detection. However, for the public and for potential offenders it is important to know the present amount of crime and the present amount of enforcement in order to generate the relevant probabilities of punishment that influence their decisions. In my point of view it is therefore most practical to use the original rates of tried offenders. In order to be able to interpret the estimates as elasticities and to ensure a similar range as the remaining enforcement variables I transformed the rate of tried offenders by adding 1 and taking the natural logarithm. This ensures that the variable is positive and in a similar range as the clearance rate, conviction rate, etc..

Tables 10 and 11 provide variable definitions and summary statistics for all variables included in the core econometric specification.

Table 10: Variable Definitions

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
ln(1+Rate of tried suspects) (tried)	natural log of 1 plus share of identified suspects that are brought to court
	(assures that variable is positive and can be interpreted as elasticity)
Conviction Rate (convicted)	share of accused suspects that are convicted
Prison Rate (prison)	share of convicted offenders that are sent to prison
Rate of Severe Fines (fine)	share of convicted offenders that are fined heavily
outliertrend	Interaction term: dummy indicating one of five outliers in sample
	(Biberach, Böblingen, Esslingen, Ludwigsburg, Stuttgart) multiplied by a year trend
population density (pop.den)	population divided by county size
share of greens (greens)	natural log of share of green politicians in local parliaments
share of conservatives (cons)	natural log of share of CDU politicians in local parliaments
dummy conservatives (dummy.cons)	dummy indicating whether CDU has majority in local parliaments
dummy conservatives and liberals (dummy.cons.lib)	dummy indicating whether CDU and FDP together have majority in local parliaments
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 civil servants (civil.servants)	nat. log of share of people working as civil servants
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 11: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
CR	505	.0000913	.0000839	0	.0006523
clear	526	.6736597	.2497356	0	1
tried	468	.3942176	.2131316	.0645385	1.540.445
convicted	470	.7392265	.1913142	0	1
prison	467	.0297241	.065799	0	.5
fine	467	.0508961	.1138831	0	1
outliertrend	528	2.272.159	6.351.823	0	2.005
pop.den	528	5.273.197	6.552.667	1.029.385	7.641.714
greens	528	.083408	.0446269	0	.2708333
cons	528	.4107641	.0741905	.2413793	.5652174
dummy.cons	528	.1609848	.3678655	0	1
dummy.cons.lib	528	.3522727	.4781314	0	1
civil.servants	440	.014436	.0058389	.005697	.0393293
gdp	440	72318.8	51729.69	19582.43	343650.1
rev.manu	484	54458.35	49372.29	7079.894	346632.7
emp.manu	440	.0906159	.1335163	.0079495	.6939474
corp.tax	350	.0004373	.0001312	.0001151	.0009186

Given that many of my political, structural and waste market variables are not available for the whole period under consideration this part of the thesis employs again a two-step estimation approach. As a first step, the core of the model as set out in the next section is implemented and estimated in order to use as many observations as possible. Subsequently, I carry out tests for additional variables that have been identified in the larger literature on crime and illegal waste disposals to play a plausible role and check for robustness.

17 The Econometric Model of Illegal Waste Disposal

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

$$\ln CR_{it} = A + \alpha \ln CR_{it-1} + \beta P_{it} + \gamma X_{it} + O_{it} + F_i + T_t + \epsilon_{it} \qquad (11)$$

where $\ln CR_{it}$ 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_i capture individual county and year effects, respectively. The variable O is an interaction term indicating whether the 5 counties that show an outlying behavior follow some distinct time trend. 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. In the present case this are clearance rates[53], the rate of tried offenders, conviction rates, prison rates and the rate of people sentenced to a severe fine.[54] X_{it} captures several aspects of political, structural and waste market specific factors that are added subsequently. Examples are the share of

[53] In contrast to the anaylsis in part II, clearance rates seem not to exhibit a nonlinear relationship with respect to illegal waste disposals.

[54] As on state level, information about fines and prison sentences are not available in their true magnitude but only in intervals. It is therefore not possible to construct plausible variables for the severity of punishment.

conservative politicians (CDU) and green politicians (Bündnis 90/Die Grünen) in the municipal councils (*Kreistag and Stadtrat*). In addition to using the share of conservatives I also generated a dummy variable indicating whether the conservatives hold the absolute majority in a county parliament. Furthermore, I generated a dummy variable indicating whether the conservatives and their usual coalition partner, the German liberals (FDP), have the absolute majority in local councils. Variables reflecting the structural composition are the share of civil servants and the share of employees in the manufacturing industry in the population, populations density, the total revenue of the manufacturing industry, GDP per capita and the share of county corporate taxes in total county income. Finally, $\alpha, \beta, \gamma, \delta$ and ϵ stand for the parameter (vectors) to be estimated and the disturbance term, respectively.

Table 12 presents the parameter estimates for the core model for different estimation procedures with different characteristics. BB stands for the Blundell and Bond (1998) one-step system GMM estimator with robust standard errors and small sample corrections. BC reports the estimates obtained by following the bias correction procedure as proposed by Bruno (2005a), applying BB in first stage.

After pinpointing the key results of this analysis there will a section checking the robustness with respect to endogeneity issues and time lags.

18 Estimation Results

The results for the core model are presented in table 12. Although many of the mentioned shortcomings of GMM are not as demanding in this dataset as they have been in part II, bias correction will serve as a benchmark to contrast esti-

mation results. Very similar to my estimates on state level, illegal waste disposals again show a significant degree of persistency. However, parameter estimates are significantly lower and do not point towards I(1). The panel unit root test as proposed by Maddala and Wu (1999)[55] rejects the Null of nonstationarity for all specifications even at the 10% level.

There is some evidence that the 5 counties with outlying behavior follow a distinct development as the estimates are significant and positive for the GMM specifications. The behavior of the Sargan test of overidentifying restrictions gives again some reason for cautiousness. With a p-value of .044 for BB, the test questions whether levels and differences of the lagged dependent variable serve as good instruments to correct for the Nickell (1981) bias. However, the Arellano and Bond (1991) tests for first and second order autocorrelation do provide evidence against the model fit. There is evidence for ar(1) and for ar(2) at the 10% level and no evidence for ar(3) (column1). I therefore only used lags 2-4 of the dependent variable to serve as instruments in later GMM regressions. In doing so, there is evidence that both the Sargan and the Hansen test are not able to reject the Null of validity of the instruments at common significance levels for the core equation in table 12.

Table 13 and 14 display results for additionally included structural effects. Although tests for ar(2) now behave as requested, the Sargan statistic again points against the validity of the instruments. Altering the number of instruments or the range of lags did not change results. It is therefore most practical to stick to bias correction especially as there is no evidence that endogeneity plays a role in this setting (see section 19.1).

[55] Again, the xtfisher command in Stata by Scott Merryman has been used.

Table 12: Estimation Results 1

Variable	BB	BB	BC	BB	BC
	1	2	3	4	5
waste, lag	.46434	.7649	.4316	.4471	.4462
	(0.0000)	(0.0000)	(0.0000)	(0.0023)	(0.0000)
clear	-.3528	-.4156	-.2293	-.2246	-.2464
	(0.0738)	(0.0975)	(0.2660)	(0.2750)	(0.2643)
tried	-.5917	-.6482	-.4672	-.4988	-.4837
	(0.0036)	(0.0044)	(0.0224)	(0.0166)	(0.0219)
convicted	.0528	-.0638	-.1950	.0495	-.2105
	(0.7844)	(0.7933)	(0.4166)	(0.7922)	(0.3971)
prison	.5255	.2880	.2039	.4561	.2208
	(0.1301)	(0.4746)	(0.6914)	(0.1374)	(0.6879)
fine	-.4427	-.3464	-.2085	-.4387	-.2059
	(0.1370)	(0.2816)	(0.5392)	(0.1511)	(0.5608)
outliertrend	.0004	.0002	-.0056	.0003	-.0131
	(0.0000)	(0.0007)	(0.8663)	(0.0001)	(0.6902)
pop.den	-.0936	-.0662	5.5790	-.0887	5.3349
	(0.1063)	(0.1044)	(0.2245)	(0.1310)	(0.2476)
greens	.0172	.0230	.0315	-.0283	.0357
	(0.8888)	(0.7730)	(0.9286)	(0.8213)	(0.9197)
cons	.2870	.0479	-.2157		
	(0.3308)	(0.8021)	(0.7969)		
dummy.cons				.0442	-.0571
				(0.6183)	(0.7351)
N	407	407	407	407	407
instruments	57	53		53	
Sargan	76.6833	25.5897		98.1410	
	(.0000)	(.7814)		(0.0000)	
ar1	-4,63E+07	-4.168.601		-4,12E+07	
	(.0000)	(.0000)		(.0000)	
ar2	1.7961	1.8135		1.6915	
	(.0724)	(.0697)		(.0907)	
ar3	.3179	.4150		.4317	
	(.7505)	(.6781)		(.6659)	

Note: Time dummies and a constant have been included but omitted here. P-values in parenthesis. All GMM specifications have been applied using one-step system GMM with small sample corrections and robust standard errors. In case of bias correction standard errors have been estimated using bootstrapping with 50 repetitions.

Table 13: Estimation Results 2

Variable	BB	BC	BB	BC	BB	BC
	1	2	3	4	5	6
waste, lag	.6180	.4344	.4576	.3572	.7295	.3572
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0001)	(0.0000)
clear	-.2243	-.3115	-.0683	-.0383	-.1013	-.0383
	(0.2394)	(0.1633)	(0.7631)	(0.8942)	(0.7081)	(0.8942)
tried	-.6291	-.5079	-.6742	-.4406	-.7396	-.4406
	(0.0075)	(0.0310)	(0.0068)	(0.1311)	(0.0159)	(0.1311)
convicted	-.0311	-.2520	.1092	-.1416	-.0436	-.1416
	(0.8858)	(0.3585)	(0.6315)	(0.6334)	(0.8807)	(0.6334)
prison	.4258	.2188	.6908	.2638	.3789	.2638
	(0.2693)	(0.6378)	(0.0909)	(0.6372)	(0.3853)	(0.6372)
fine	-.4217	-.2008	-.8873	-.1006	-.8903	-.1006
	(0.3022)	(0.6228)	(0.1152)	(0.8057)	(0.1190)	(0.8057)
outliertrend	.0002	.0088	.0004	.0131	.0002	.0131
	(0.0000)	(0.8111)	(0.0016)	(0.7890)	(0.0316)	(0.7890)
greens	.0335	.0182	.0079	.0400	-.0621	.0400
	(0.7523)	(0.9505)	(0.9636)	(0.9234)	(0.5199)	(0.9234)
rev.manu	.0438	.6408	.0296	1.2438	.1138	1.2438
	(0.5361)	(0.1479)	(0.8288)	(0.0892)	(0.4124)	(0.0892)
gdp	.6034	-.6748	1.2037	1.4656	1.0113	1.4656
	(0.0175)	(0.6174)	(0.1427)	(0.4760)	(0.1456)	(0.4760)
pop.den	-.2050	2.8624	-.2399	.1231	-.2087	.1231
	(0.0223)	(0.5504)	(0.3037)	(0.9890)	(0.2551)	(0.9890)
dummy.cons.lib	.0642	-.0833				
	(0.6073)	(0.6519)				
cons			.3276	.6561	.1321	.6561
			(0.4365)	(0.5875)	(0.7146)	(0.5875)
civil.servants			.3015	-.8222	.0564	-.8222
			(0.3268)	(0.1987)	(0.8188)	(0.1987)

Note: Time dummies and a constant have been included but omitted here. P-values in parenthesis. All GMM specifications have been applied using one-step system GMM with small sample corrections and robust standard errors. In case of bias correction standard errors have been estimated using bootstrapping with 50 repetitions. Again, lags 2-4 of the dependent variable serve as instruments in GMM

Table 14: Estimation Results 2, continued

Variable	BB	BC	BB	BC	BB	BC
	1	2	3	4	5	6
corp.tax			-.3684	-.2600	-.4314	-.2600
			(0.0207)	(0.2450)	(0.0039)	(0.2450)
emp.manu			-.0885	-3.374	-.1589	-3.3744
			(0.8130)	(0.0737)	(0.5141)	(0.0737)
N	369	369	282	282	282	282
instruments	56		55		52	
Sargan	37.0253		59.9053		58.4586	
	(.0000)		(.0013)		(.0006)	
ar1	-4.4423		-4.3438		-3.9577	
	(.0000)		(.0000)		(.0000)	
ar2	.7449		1.1125		1.2019	
	(.4563)		(.2658)		(.2293)	

18.1 Deterrence

The result confirm most of the findings of part II. The effect for the rate of tried offenders is again remarkable. The elasticities range from -.44 to -.67 and are highly significant in all specifications. In contrast to part II, there is no evidence that the prison rate provides significant deterrence for the present data. Estimates are positive throughout and in one case significant (column 3 in table 13). However, including prison rates with one lag reveals a negative and significant effect (see section 19.3). The results for conviction rates and the rate of severe fines are in line with the previous analysis. Both show negative parameter estimates for almost all specifications but are not significant at the 10% level.

Result 1: *There is evidence for a deterrence effect of the rate of tried offenders. Parameter estimates for conviction rates and the rate of severe fines are also negative but not significant. Prison rates do not seem to deter illegal waste disposals as estimates are positive in all specifications. However, including prison rates*

with one lag reveals a significantly negative effect on illegal disposals.

Hypothesis 2 focused on the effect of police effort in clearing illegal waste disposals. Estimates for clearance rates do show the intended negative sign and are significant at the 10% level for some of the core specifications (columns 1 and 2 in table 12) with values of around -.2 to -.4.

Result 2: *Clearance rates do show up to have the intended negative effect on illegal waste disposals.*

Another important issue within the deterrence framework stresses the relative contribution of the different enforcement components. As different stages in the enforcement process imply different costs it is interesting to compare their effectiveness. Similar to results of part II, there is again some support for hypothesis 3.

Result 3: *For the relative contribution to the deterrence effect it is possible to partly confirm hypothesis 3. Within the significant estimates, clearance rates do show a smaller effect than the rate of tried offender. The remaining deterrence variables, however, are not in line with the initial hypothesis.*

To sum up, there is again evidence for a deterrence effect especially for the first two enforcement stages.

18.2 Waste Market Variables

Although data quality for prices and quantities of waste disposal seems to be rather low, I do provide estimates including specific variables in section 19.2. This is to

test whether it is possible to confirm results obtained by Stafford (2002). The author showed that especially higher prices of legal disposal have the expected effect of increasing the amount of illegal disposal. However, and as it has been expected, none of the included variables show up to be significant. Since it is unlikely the case that the market for waste disposal does not affect the amount of illegal disposals at all, the most obvious reason is that data quality is not sufficient enough to enlighten the relevant information. Data for quantities and prices of waste are collected only recently and there have been several adjustments such that it is likely the case that the relevant information is blurred.

18.3 Political and Structural Factors

This part of the thesis summarizes the results for the political and structural factors. As criminal enforcement is rather expensive, it may be interesting to learn more about further determinants of illegal waste disposals. However, looking at table 13, there is no confirmation for hypothesis 4. The estimates for the share of civil servants do not reveal significant effects in any specification.

Result 4: *Results do not support the hypothesis that the share of county population working as civil servants affects the amount of reporting and thus the amount of reported illegal waste disposals.*

However, I do find some support for hypothesis 5 as estimates for population density are relatively robust. Estimates are almost always negative and significant for one specification[56] (column 1 of table 13) with an elasticity of around -.2.

[56] Estimates slightly fail significance at the 10% level for many other specifications (see table 13).

Result 5: *Results give cautious support for a higher population density leading to a lower rate of reported illegal disposals.*

Regarding the political suggestions subsumed in hypothesis 6, I do find positive parameter estimates for the share of conservatives in municipal councils and varying signs for both dummies. Results for the German green party show ambiguous signs. It is therefore not possible to verify hypothesis 6.

Result 6: *Contrasting results in part II, there is some evidence for a positive relationship between the conservatives and illegal waste disposals. However, estimates are not significant for any common significance level and it is therefore not possible to draw clear-cut conclusions. Estimates for the share of greens in municipal councils is even more ambiguous.*

The results for the structural factors are totally in line with the initial expectations. Revenue generated in the manufacturing industry shows positive parameter estimates with elasticities ranging between .04 and 1.2 and estimates are significant for some BC specifications. The results for GDP per capita are not as clear-cut. Estimates are positive in most cases but only once significant with elasticities ranging from -.6 to 1.4.

Result 7: *There is evidence that the revenue of the manufacturing sector has a positive impact on illegal disposals. The results for GDP per capita point towards the same direction but are less definite.*

Hypothesis 8 focused on the dependency of a county on the manufacturing industry. Both indicators for the degree of dependency show the expected negative

sign and are significant for some specifications (table 14). Elasticities range from -.26 to -.43 for the share of county corporate tax revenue in county total income and from -.08 to -.3.37 for the share of county population working in the manufacturing industry.

Result 8: *Both the share of county populations working in the manufacturing industry and the share of county corporate tax income in total county income influence the amount of reported illegal disposals negatively.*

19 Robustness

As already discussed in part II, there are some technical issues connected to the empirical estimation of the economic model of crime. First, simultaneity may lead to biased estimates as discussed in section 11.1 of part II. It may always be the case that both potential criminals reacting on changing enforcement efforts and enforcement institutions reacting on the behavior of criminals. With 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. Further biases arise when omitting important variables. Section 19.2 therefore focuses on this issue. The last subsection is dedicated to a specific analysis of potential time lags in the deterrence framework. Since the present part of the thesis analyzes illegal waste disposals there is no danger of facing an aggregation bias as proposed by Cherry and List (2002). Furthermore, panel unit root tests did reject the hypothesis of nonstationarity in the series of illegal disposals (see section 18).

Table 15: Difference-in-Sargan Test

Deterrence Variable	Test Statistic: Chi2(1)	P-Value
Clearance Rate	0.96	0.328
Rate of Tried	0.06	0.809
Conviction Rate	0.14	0.71
Prison Rate	1.58	0.208
Rate of Severe Fines	1.94	0.163

Note: The difference-in-Sargan tests follow a chi2 distribution with one degree of freedom (Roodman 2006). The test was obtained using the estimation specification in column 2 of table 12 with non-robust standard errors.

19.1 Simultaneity

Simultaneity is of special interest for the included enforcement variables. It is unlikely that the amount of illegal waste disposals affects the political or structural composition of a county. In testing for simultaneity I follow a similar strategy as I did in part II. Testing for simultaneity implies using GMM as the bias-corrected estimators are only valid for strictly exogenous variables.

The difference in Sargan test[57] is not able to reject the Null of exogeneity for any of the deterrence variables. I present the p-values in table 15. As the Sargan and Hansen test work well for the core specification[58] results seem to be trustworthy.

However, as one might question the reliability of the Sargan and Hansen test (Baum et al. 2003, Roodman 2006) in general, I also estimated the core model (column 2 in table 12) sequentially treating the different enforcement variables as being endogenous in GMM.

Column 1 of table 16 presents estimates with endogenous treatment of clearance

[57] Automatically computed with xtabond2 in Stata.

[58] I used the specification displayed in column 2 of table 12 where the Sargan test was not able to reject the validity of the instruments.

Table 16: Estimation Results for Endogenous Treatment

Variable	BB	BB	BB	BB	BB
	Clearance	Tried	Convicted	Imprisoned	Sev. fines
waste, lag	.6001	.6519	.6476	.7106	.7405
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
clear	-.5091	-.2918	-.3405	-.33611	-.2689
	(0.0804)	(0.1534)	(0.1314)	(0.1267)	(0.2008)
tried	-.5869	-.6824	-.6314	-.5838	-.5392
	(0.0015)	(0.0121)	(0.0029)	(0.0040)	(0.0056)
convicted	-.0388	-.0108	-.0819	.0281	.0290
	(0.8516)	(0.9610)	(0.7588)	(0.8932)	(0.8921)
prison	.4208	.2727	.3515	.1799	.2780
	(0.2606)	(0.4312)	(0.3392)	(0.5679)	(0.4821)
fine	-.4548	-.2825	-.4062	-.3570	-.4402
	(0.1252)	(0.3341)	(0.1751)	(0.2203)	(0.1672)
outliertrend	.0003	.0003	.0003	.0002	.0002
	(0.0001)	(0.0001)	(0.0001)	(0.0003)	(0.0009)
greens	.0415	.0257	.0147	.0073	.0053
	(0.6911)	(0.7788)	(0.8763)	(0.9289)	(0.9455)
pop.den	-.0969	-.0715	-.0739	-.06117	-.0490
	(0.0610)	(0.0914)	(0.1049)	(0.1279)	(0.2036)
cons	.1735	.1560	.1174	.0794	.0521
	(0.4864)	(0.4815)	(0.5930)	(0.6894)	(0.7980)
N	407	407	407	407	407
instruments	92	89	89	89	89
sargan	109.1096	81.4183	75.7144	65.3194	84.9833
	(.0024)	(.1273)	(.2436)	(.5696)	(.0798)
ar1	-4.4129	-4.3852	-4.3529	-4.3477	-4.5117
	(.0000)	(.0000)	(.0000)	(.0000)	(.0000)
ar2	1.8087	1.8154	1.8278	1.8195	1.8572
	(.0704)	(.0694)	(.0675)	(.0688)	(.0632)
ar3	.3145	.4608	.4294	.4479	.4884
	(.7531)	(.6448)	(.6676)	(.6541)	(.6252)

Note: All specifications have been estimates via xtabond2 applying one-step system GMM with small sample corrections and robust standard errors. P-values in parenthesis. Time dummies and a constant have been included but omitted here.

rates, column 2 with rate of tried, column 3 with conviction rates, column 4 with prison rates and column 5 with the rate of severe fines, respectively. Similar to my analysis in section 11.1, I do not find evidence for simultaneity to play an important role. None of the estimated parameter values changes significantly in comparison to the estimates in table 12. From a theoretical point of view it is therefore appropriate to use both bias correction and GMM as valid estimators.

19.2 Omitted variables

The most obvious candidates for causing an omitted variable bias when excluded from the estimation equation are informations regarding the potential gains of illegal waste disposals. However, as stated in sections 15.2 and 18.2, data for quantities and prices of local waste is not of particularly high quality. The reader finds estimation results with several additional variables reflecting waste market factors in table 17.

None of the additional variables changes results for my initial estimates in tables 12 and 13 except for the specifications including waste fees. However, in this case the sample size is reduced by almost 2/3. Estimating the core equation in table 12 with the sample of columns 5 and 6 in table 17 leads to almost identical results. That is, the different results are due to the sample reduction and not due to the additional variables.

Furthermore, there may be selection bias when using subsamples as done in tables 13 and 17. In this dataset there are different numbers of observations available for different variables. I therefore first of all estimated a core equation as explained in section 18 to include as many observations as possible and then added

Table 17: Estimation Results including Additional Variables

Variable	BB	BC	BB	BC	BB	BC
	1	2	3	4	5	6
waste, lag	.4550***	.3986***	.7428***	.3544***	-.0219	.1903
clear	-.1223	-.2115	-.1091	-.0276	.3410	-.4654
tried	-.5129**	-.4605**	-.7528**	-.4406	.4457	.3355
convicted	.0974	-.1100	-.0167	-.1453	.07468	-.3027
prison	.5189	.1245	.3427	.2716	1.4850	1.2896
fine	-.4044	-.0084	-.9293	-.1085	.00188	.7088
outliertrend	.0004***	-.0126	.0002**	.0073	.0005**	-.0669
pop.den	-.0949	6.330	-.2468	.1625	-.1228	3.0481**
greens	.0297	.1502	-.0638	.0488	.0891	.0630
cons	.2723	.3040	.0275	.7006	.3446	1.5177
household waste	-.0496	-.1435	.1072	-.0017	-.2927	.9965
bulky waste	-.0461	.0288	-.0612	.0165	.0896	.2592
industry waste	-.0105	.0143	-.0055	.0523	.0623	.0574
hazardous waste	.0694	-.0125	.0563	.0115	.1708	.0941
rev.manu			.0903	1.2746**		
gdp			.8646	1.1515		
civil.servants			.0455	-.8698		
corp.tax			-.4794***	-.2605		
emp.manu			-.0419	-3.5274*		
industry waste fees					-.5732	.1382
household waste fees					.2211	.0787
N	369	369	281	281	140	140
instruments	56		56		37	
sargan	95.5370		57.8585		63.0967	
	(.0000)		(.0007)		(.0000)	
ar1	-3.9438		-3.7643		-2.6820	
	(.0000)		(.0001)		(.0073)	
ar2	1.9242		1.1860		1.8335	
	(.0543)		(.2355)		(.0667)	

Note: All GMM specifications have been estimates via xtabond2 applying one-step system GMM with small sample corrections and robust standard errors. Bias correction has been implemented using xtlsdvc by Bruno (2005) with BB as initial estimator and bootstrapping with 50 repetitions. Time dummies and a constant have been included but omitted here. *, **, *** indicating significance at the 10, 5 and 1% level, respectively. P-values in parenthesis.

further variables resulting in a steadily decreasing sample size. Results might be biased (Heckman 1979), if the availability of the information for a specific variable would be correlated to the error term. In this context the sample size depends on the decision of statistical offices when to start collecting specific data and should therefore not depend on any of the other included variables. However, reducing the sample size by introducing further variables provides a robustness check. The result is that none of the estimates for the variables in the core equation change significantly (comparing estimates in tables 12, 13 and 17, except columns 5 and 6).

19.3 Time Lags

The last concern I want to stress is the possibility of time lags. Although empirical work suggests that potential criminals update their beliefs within a few month (see section 2.6.4), I will estimate the core equation including time lags of the enforcement variables. I will include the variables with one year lag, as it is unlikely the case that updating takes more than one year. Table 18 shows results for the core equation.

There are two interesting findings. First, the lag for clearance rates is positive and highly significant. This effect may be due to a lagged effect of police reaction on the amount of crime that first influences clearing and then reporting behavior. However, it is not easy to interpret. Remarkable are the results for the lagged prison rate. Estimates are negative throughout all specifications and in case of BC also significant with an elasticity of -.92. One might suggest that this is evidence for delayed updating and therefore a confirmation for a deterrence effect for prison

sentences in case of illegal waste disposals. However, as the prison rate is 0 for 72% of the observations in the sample, the reliability of the estimates may be questionable.

The lags for the remaining deterrence variables neither seem to have an impact on illegal disposals nor on the remaining estimates.

20 Discussion

20.1 Interpreting the Results

The findings in this part of the thesis support in a significant way results of part II. First, clearance rates and the rate of tried offenders seem to deter potential environmental offenders from committing crimes. This findings perfectly fit to both the analysis at the level of the German states (see section 10.1) and the general crime literature (see section 2.3.1). A new insight is that there is cautious evidence for the rate of severe fines additionally providing some deterrence at least at the county level. Taken together, results of parts II and III explicitly support the hypothesis that criminal law is a very effective tool in enforcing environmental regulations. The thesis findings contribute in a substantial way to a better understanding of the effectiveness of criminal enforcement in the context of environmental law.

Secondly, it is not possible to confirm results of part II for the German conservatives. However, this has been expected as counties are far more conditioned by the decisions of the state government than states are by the decisions of the federal government. The federal system in Germany implies a huge degree of in-

Table 18: Estimation Results Including Time Lags

Variable	BB	BC	Variable	BB	BC
	1	2		1	2
waste, lag	.4612	.4390	outliertrend	.0003	-.0253
	0.0008	0.0000		0.0013	0.5089
cleared	-.2244	-.3342	greens	-.0035	.1207
	0.3825	0.1363		0.9782	0.7047
cleared, lag	.6935	.6413	pop.den	-.0542	6.7188
	0.0114	0.0041		0.3932	0.1568
tried	-.5371	-.4200	cons	.3740	.4265
	0.0011	0.0523		0.2460	0.6474
tried, lag	.0239	.1279	N	363	363
	0.8965	0.5868	instruments	57	
convicted	.0747	-.1090	sargan	87.2260	
	0.7105	0.5209		.0000	
convicted, lag	.1508	-.0749	ar1	-3.9387	
	0.5225	0.7191		.0000	
prison	.0982	-.2237	ar2	2.0239	
	0.7135	0.6655		.0429	
prison, lag	-.7129	-.9213	ar3	-.6059	
	0.1774	0.0421		.5445	
fine	-.5269	-.2279			
	0.1101	0.5694			
fine, lag	-.0965	.2926			
	0.8095	0.4595			

Note: All GMM specifications have been estimated via xtabond2 applying one-step system GMM with small sample corrections and robust standard errors. Bias correction has been implemented using xtlsdvc with BB as initial estimator and bootstrapping with 50 repetitions. P-values in parenthesis. Time dummies and a constant have been included but omitted here.

dependency for the single states. In contrast, counties are very much constrained by the decisions of the state government. As the state government of Baden-Württemberg is dominated by the German conservatives (CDU) for more than 50 years, it is implausible to expect a huge degree of political heterogeneity for the single counties.

Third, there is evidence that counties that are highly dependent on a prospering industry show a lower reporting behavior. 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).

In line with the existing literature (Eckert 2004), there is evidence for the population density to negatively affect the amount of reported illegal disposals. Counties that are more dense populated seem to deter illegal disposals probably because the probability of detection is higher there. Another structural factor determining the amount of reported illegal disposals is the revenue generated in the manufacturing sector. There is evidence that total revenue has a positive impact on reported illegal waste disposals. Although not as definite, results for GDP per capita support this findings.

With respect to the econometric analysis, I focused on system GMM and bias correction to estimate the economic model of illegal waste disposals. Similar to the analysis in part II, I applied different robustness checks to test whether results are reliable. First and foremost one has to control for potential endogeneity issues

that are typically apparent in the economic model of crime (Ehrlich 1973, Cornwell and Trumbull 1994, Baltagi 2006, etc.). In line with findings of part II, there is no evidence that endogeneity plays a crucial role in this setting. Environmental crime in Germany is probably of minor importance in comparison to capital crimes and may therefore imply a rather weak reaction of enforcement institutions to changing criminal behavior.

20.2 Confronting Results with Part II and the Existing Literature

It is the aim of this section to contrast the new insights to the findings of part II and the existing literature. This will be another proof for the reliability of the findings obtained so far.

20.2.1 Deterrence

Although elasticities for clearance rates and the rate of tried offender are significantly lower in this part than in the previous one, they are still in a range that is in line with the existing literature. Elasticities for clearance rates range between -.2 and -.4 and therefore totally fit into previous findings ranging between 0 and -3 (see section 2.3.1). As there is, at least to my knowledge, no other study using the rate of tried offender in the deterrence framework, I compare the findings to those of part II. With estimates ranging from -.48 to -.64 the results are lower than those of part II (ca. -1) However, they are still highly significant and fit into the estimates usually obtained for enforcement probabilities in the deterrence literature (see section 2.3.1). Contrasting the results of part II and the major

part of the general crime literature (see section 2.3.1), there is no evidence that imprisonment deters people from disposing waste illegally in Baden-Württemberg. Significant effects appear only when including lags of prison rates. Estimates for conviction rates contradict the results of the general crime literature but are in line with findings of part II. A new insight is that severe fines show negative estimates at the county level that only slightly fail significance at the 10% level.

To compare both enforcement mechanisms it is important to also look at the effectiveness of administrative law. Although Stafford (2002) finds no deterrence effect of past inspections on the compliance of plants with hazardous waste regulations, Sigman (1998) does find an effect of state enforcement activities[59] under the Resource Conservation and Recovery Act (RCRA). The author estimates an elasticity of -.18 being significant at the 10% level. This is in a similar range as my findings on clearance rates are and lower than the estimates for the rate of tried offenders. In general, both administrative law and criminal law seem to be effective instruments to prevent violations of environmental laws.

20.2.2 Political and Structural Factors

Although there is no clear-cut evidence for GDP per capita affecting the amount of crime in existing literature (see section 2.5), there is a tendency pointing towards a positive effect different income measures have on crime (Ehrlich 1973, Andreoni 1995, Cherry 1999, Viren 2001, etc.). My own results confirm previous findings in that the effects are not clear-cut but there is some support for GDP per capita and manufacturing revenue to affect illegal disposals. In line with the results of Eckert

[59] Total acitivities including administrative actions, civil referrals and criminal referrals (Stafford 2002).

(2004) I do also find a negative effect of population density on illegal disposals.

I do also find evidence for variables being at the intersection between the structural and political compositions of counties to influence the amount of reporting. One possible explanation for this is that the degree of dependency a county faces with respect to the manufacturing sector influences political decision-makers deciding on the amount of efforts put into the enforcement of environmental laws. This is in line with results obtained by Helland (1998) that both estimated profits and number of manufacturing plants in a state have negative and significant effect on inspections. It will be subject to further investigations to analyze this in more detail.

21 Conclusion to Part III

The deterrence effects estimated in the present part confirm to a huge extent findings of part III. There is again evidence that especially the first stages of enforcement - to be identified as a suspect and to be brought to court - deter people from committing environmental crimes in general and illegal waste disposals in particular. Combining the insights of both parts reveals important policy-implications.

In line with the existing literature there is evidence that structural factors affect the amount of reported illegal disposals. Results suggest that the structural composition of counties like population density, GDP per capita and revenue in the manufacturing sector have an impact on illegal disposals. Moreover, new insights suggest that informations being at the intersection between political and structural factors influence the amount of reported illegal disposals. Variables like the share

of people working in the manufacturing sector and the relation between corporate tax revenues and total county income seem to affect the amount of reported crimes.

With this results at hand, policy-makers are able to base their decisions on reasonable informations when deciding which enforcement mechanism to use and how much resources to put into specific components.

The last part of the thesis provides information on the determinants of police, prosecution and courts in enforcing environmental crimes. To get a complete picture of the effectiveness of criminal enforcement it is important to analyze both the determinants of crime and the determinants of enforcement.

Part IV

The Political Economy of Criminal Enforcement in Environmental Law

22 Introduction to Part IV

Every legislature interested in effective, coherent, and consistent policy implementation has to confront the agency problem of how to organize its regulatory activities. Key dimensions of the solution to the agency problem are the extent of delegation from the legislature to the regulatory institutions and the degree of independence of the institutions from the legislature (Horn 1995). One important area in which the agency problem is particularly palpable is in the case of the criminal justice system (Becker and Stigler 1974). The criminal justice system ensures compliance with key regulations and is therefore arguably as important for determining policy outcomes as the regulations themselves (Polinsky and Shavell 2006).

Agency problems in the criminal justice system have attracted attention since the system typically consists not of a single agency, but of several regulatory institutions arranged sequentially. At the base, there is a police force that monitors and investigates, followed by a prosecution service that decides on the basis of police reports and own investigations on the merits of an offence, and, finally, courts

that decide on cases brought before their judges by prosecutors. The combined activities of all of these institutions together jointly determine the effectiveness of the enforcement regime.

Despite their joint objective and their procedural inter-connectedness, the institutions of the criminal justice system vary considerably in terms of their independence. Some, such as the police force, are - as part of the executive branch of government - relatively dependent. Others, such as courts, are deliberately set up to operate at arm's length from other branches of government. This institutional heterogeneity can be understood to mirror two countervailing arguments about the merits of independence within the criminal justice system: One the one hand, there are the well rehearsed arguments of constitutional checks-and-balances and of interest group theory for granting some of the decision-makers in the system a relatively high degree of independence (Landes and Posner 1975). On the other, the independence of decision-makers in the criminal justice system from the legislature should be limited in order to resolve the agency problem that has decision-makers deviate systematically from the intentions of the legislature (Becker and Stigler 1974). This would suggest employing various incentive mechanisms in the form of budgets or personal rewards in order to align the interests of police officers, prosecutors, and judges with that of the public.

Conceptually, therefore, the trade-off between the arguments of checks-and-balances and agency problems seems clear. Empirically, however, there is a lack of evidence on whether and how this trade-off works in practice. Given the institutional structure, observed enforcement outcomes should reflect the different degrees of independence and therefore different incentives that agents face at different stages of the sequential enforcement process, taking into account the dif-

ferent resource constraints at each level. The empirical question is whether this conjecture is borne out by reality. This leads to three sub-questions. The first is what determines enforcement decisions by the police force, prosecutors, and judges within the criminal justice system. The second is whether and if yes, to what degree, decision-makers are responsive to the preferences of voters and politicians. The third is how the influence differs between agents at different stages. Is the conjecture correct that those institutions of enforcement that enjoy greater independence by design are indeed less responsive to the political factors that drive the legislature and executive?

The core of the present paper consists of an empirical approach to answering these questions in a particular context. This context is the enforcement of environmental criminal law. This highly specific area of criminal law lends itself for an empirical investigation of this type for two reasons. One is that it is an area of criminal law that - because of the complexity of its nature - requires non-trivial amounts of resources to be spent at every level in order to push cases through the enforcement process (Lutterer and Hoch 1997, Cohen 1999). This offers an opportunity to recover from empirical data the economic determinants of enforcement decisions at the level of the police force, prosecution service, and courts because pursuing environmental crimes imposes non-negligible opportunity costs. The other reason is that the public and politicians have preferences regarding the public good to be protected that are easily observable. Resource and political economy factors should therefore be empirically salient.

How does this paper add to the literature? The political economy of regulatory enforcement has attracted a good deal of scholarly attention, resulting in an impressive body of empirical evidence on what determines regulatory action.

The typical case considered in the literature studies the behavior of one particular regulator enforcing one regulation. Examples are studies on the enforcement by a regulatory agency such as the Food and Drugs Administration (FDA, Shipan 2004), the Internal Revenue Service (IRS, Mete 2002) and the Environmental Protection Agency (EPA, Nadeau 1997; Deily and Gray 1991) as well as monitoring under the Occupational Safety and Health Act (OSHA, Headrick et al. 2002). Other studies examine the behavior of prosecutors (Ramseyer et al. 2008; Boylan 2005) or of judges (Salzberger and Fenn 1999, Ashenfelter et al. 1995). Across the studies, there is evidence that the political economy factors are allocatively relevant. My enforcement context also focuses on a single regulation, i.e. the German Penal Code, but differs in that it studies the behavior not of a single regulator but several different institutions at once. This multitude of institutions offers the opportunity of comparing the determinants of enforcement decisions of different institutions along a single enforcement chain with each other and against widely held assumptions about how this system works. Methodologically, I add to the literature by demonstrating the usefulness of approaches to dynamic production function estimation (Blundell and Bond 2000) and to cross country studies (Kiviet 1995, Bruno 2005a/b) to bear on the problem of the political economy of regulatory enforcement.

My key results are threefold. The first is that economic factors matter at all stages of the enforcement process. This implies that - very much in line with the economic theory of enforcement - institutions deliberately direct resources away from the enforcement of environmental law as its opportunity cost increases. This responsiveness with respect to costs is evident at all levels, including criminal courts, which enjoy the greatest degree of independence. It also lends credibility

to using a production function approach as a methodological starting point. The second result is that political economy factors influence enforcement decisions at a statistically significant level at all stages of the process. This demonstrates that even in the ostensibly most independent parts of the criminal justice system, there is evidence of political reach-through. The third result is that the relative weight of political economy factors is not fully in line with the declared degree of independence: Prosecutors' and judges' decisions seem to be as responsive to political economy variables as the police force.

The paper proceeds as follows: In the following section, I summarize the main features of environmental crime and its prosecution in Germany, emphasizing the three institutions of police, prosecution service, and courts involved in criminal enforcement. I then develop a set of testable hypotheses on the determinants of enforcement decisions at each of the institutions in section 23. Section 24 explains the data sources, followed by a presentation of the empirical strategy and key results. Section 26 discusses the results and section 27 concludes.

23 Hypotheses on the Determinants of Enforcement Decisions

In this section I develop the arguments that give rise to four testable hypotheses regarding the extent to which political economy factors help explain enforcement decisions of different institutions involved in the compliance assurance process.

23.1 Police

As the first of three institutions involved in enforcing the German Penal Code against environmental offenders, decisions of police force determine the influx of cases into the system by passing 'cleared 'cases, that is cases for which suspects are identified, on to the prosecution office. The 'production' of cleared cases is determined by the number of cases on the one hand and the effort dedicated to linking individuals to an illegality on the other. I proceed in two steps, first focusing on the economic determinants of the production of cleared cases by the police, then discussing the role of political economy factors.

From an economic point of view, the production of cleared cases depends on inputs and opportunity costs of effort dedicated to environmental crimes. Growth in cleared cases of environmental crime will depend positively on the growth in cases to be investigated. This scale effect leads us to predict a positive coefficient (Ehrlich 1973). Higher opportunity costs of investigation, on the other hand, shift resource away from investigating environmental crime. Such opportunity costs are an increased number of overall cases to be investigated and - finally - a higher number of cases of environmental crime proceeding to trial and therefore requiring additional police resources dedicated to preparing evidence to a higher standard of proof. The opposite effect, driven by decreases in opportunity cost, is known to be generated by changes in enforcement priorities towards environmental crime as a result of a growing environmental crime rate. Benson et al. (1995) and Cloninger and Sartorius (1979) identify increases in crime levels as a key driver of inputs available for crime detection and reporting, leading us to predict a positive coefficient. In addition to the scale and opportunity cost effects, the final economic

consideration in the production of cleared cases is the question of economies of scope in efforts dedicated to clearing up environmental crime. Two countervailing effects exist: A higher production of cleared cases in other areas will take resources away from environmental crime, leading to a negative scope effect. On the other hand, offenders booked for environmental crime will - at the same time - have typically committed other punishable offences (Hoch 1994). The possibility of both negative and positive spillovers is therefore present, with the net effect an empirical matter.

Turning to political economy considerations, political factors also impacts on the opportunity costs of effort. Pro-environmental parties in the administration would be predicted to give higher priority to enforcement resources being shifted towards environmental offences while pro-industry parties would be predicted to have a lower priority. Likewise, the executive administration may want to respond to a higher 'green' sentiment among the population by directing the police force to prioritize environmental offences relative to other areas of crime. Stronger 'green' preferences in the population would therefore be predicted to be associated with a higher volume of cleared cases produced by the police.

The predictions on how the volume of cleared cases responds to exogenous variables are summarized in the following hypothesis.

Conjecture 1 *For reasons of economic constraints, the output of cleared cases of environmental crime by police will (a) increase in the amount of cases to be investigated, (b) increase in the growth rate of environmental crime, and (c) decrease in the number of environmental crime cases tried and in the number of general crime case to be investigated. The effects of (d) the total volume of cleared cases*

is ambiguous. For reasons of political economy, the effect of (e) variables capturing 'green' preferences and the effect of a pro-envionmental party in government is predicted to be positive, that of (f) a pro-industry party in government to be negative.

23.2 Prosecutors

There is a small, but rich literature on prosecutor behavior, starting with Forst and Brosi (1977). Most of these studies focus on the case-specific determinants of prosecutorial activity and productivity within the model of a self-interested prosecutor (e.g. Myers and Hagan 1979, Albonetti 1986, Boylan 2005). The empirical results bear out the concept of the prosecutor as a rational decision-maker, balancing expected benefits in the form of successful convictions against opportunity costs of time and resources.

In terms of economic determinants, prosecutors are predicted to respond to more prosecution opportunities in environmental crimes (that is cleared cases forwarded by the police) with raising the volume of associated suspects accused on account of higher expected benefits and to an increase in the number of overall identified suspects in the Penal Code by bringing fewer environmental offenders to trial on account of higher opportunity cost of prosecuting environmental offences. Since prosecutors cannot be expected to care about deterrence to the same extent as politicians (Miceli 1996), an increase in the growth rate of environmental crime would be predicted to have a smaller effect on the decision on whether to bring case to trial at the margin.

Political economy considerations have only recently been studied in the con-

text of prosecutor behavior. An approach close to ours in spirit is by Ramseyer et al. (2008). There, two models of prosecutor behavior are developed, a functionalist variety in which the prosecutor is an extended hand of the social planner and a political variety in which the prosecutor's payoff is modeled as dependent on achieving a mix of objectives, in part set by the public and in part set by the prosecutor themselves. The functionalist version is rejected by the empirical evidence while the evidence support the political model. The empirical analysis by Ramseyer et al. (2008) builds on the specifics of the US context that do not carry over easily to the German setting on account of important institutional differences. However, like Ramseyer et al., I include political economy factors as explanatory variables in the empirical model, predicting that the dependence of prosecutors on the Ministry in terms of resources will make their prosecution decisions responsive to political circumstances such as the identity of the political party in power and the strength of 'green' preferences among the population.

Together, these factors give rise to the following predictions on how the number of cases brought to trial will respond to different variables.

Conjecture 2 *The number of offenders of environmental crime brought to trial by public prosecutors will (a) increase in the amount of identified suspects, (b) weakly increase in a growth in environmental crime, and (c) decrease in the number of general suspects to be investigated on account of an opportunity cost effect. The effects of (d) a higher number of overall tried suspects is ambiguous. The effect of (e) political economy variables capturing 'green' preferences and the effect of a pro-envionmental party in government is predicted to be positive, that of (f) a pro-industry party in government to be negative.*

23.3 Courts

The output of courts in context of environmental enforcement is the production of convicts out of an input of defendants, with the balance constituting the released. There is a strong expectation that the decisions of courts should - in the words of Landes and Posner (1975) - be independent of "the sorts of political factors [...] that would influence and in most cases control the decision were it to be made by a legislative body". Empirical tests of the resulting prediction of judicial independence demonstrate that the empirical record does not unequivocally support the prediction of judicial independence. While some studies find that variables capturing the political environment of current court cases and the judge's own political background do not explain court decisions (Ashenfelter et al. 1995), the balance of the literature tends to emphasize the importance of political economy variables in explaining court behavior (Cohen 1987, Anderson et al. 1989, Salzberger and Fenn 1999). In other words, the interests of voting public and politicians as well as the ideological convictions of the judges themselves are - more often than not - found to influence judicial decisions at the margin.

The economic factors that are candidates for explaining the behavior of courts in my sample center - again - on inputs and opportunity costs. I predict - on account of a scale effect - that a greater volume of suspects being brought to trial by prosecutors will lead to an increase in the volume of convicts. However, an increase in overall trials will raise the cost of time and effort to argue environmental cases to the required standard of proof. As a result, I predict a negative relationship between the aggregate volume of trials and convictions for environmental crimes. The impact of a growing rate of environmental crime on convictions should be

weak, as argued before in the case of prosecutors (Miceli 1996), and if not zero, then positive. As at the level of prosecution, the presence of economies of scope between convictions for environmental and other crimes is an empirical question with little prior evidence as guidance.

In the light of the preceding empirical literature on courts, I predict factors of political economy to have the same effect as at the previous two levels: A 'greener' population should - at the margin - lead to more convictions. So should the presence of a green party in government. The presence of a pro-industry party in government, on the other hand, should lead to a decrease in the conviction rate.

Hypothesis 3 summarizes these prediction regarding the decision of judges thus:

Conjecture 3 *The number of offenders of environmental crimes ending in a conviction by a judge will (a) increase in the amount of tried suspects (b) be unaffected by a growth in environmental crime, and (c) decrease in the number of general crime suspects to be tried on account of an opportunity cost effect. The effects of (d) a higher number of convictions for other crimes is ambiguous. The effect of (e) political economy variables capturing 'green' preferences and the effect of a pro-envionmental party in government is predicted to be positive, that of (f) a pro-industry party in government to be negative.*

23.4 Synopsis of Economic and Political Variable Predictions

Before turning to my last testable hypothesis, table 19 summarizes the predictions on the determinants of enforcement decisions. The left-hand column lists explanatory variables for the enforcement outputs of the police force (cleared cases),

prosecutors (tried offenders) and courts (convicted offenders). Different symbols summarize the predicted effects of a change in the explanatory variable on the enforcement output, with a plus sign signaling a predicted positive relationship and a minus sign a predicted negative relationship. The sign '$\varnothing$' implies a prediction of no influence of the variable and a question mark denoting an ambiguous influence.

For police success in clearing environmental crimes, I predict a positive relationship vis-a-vis reported cases. In addition, theoretical considerations suggest police to be negatively affected by the amount of tried environmental offenders and the amount of aggregate crime cases through a opportunity cost argument. The influence of an increase in the amount of aggregate cleared cases is unclear ex ante.

The decision of prosecutors whether to bring an environmental suspect to court is predicted to positively depend on the number of identified suspects. In contrast, an increase in the amount of aggregate suspects is expected to raise opportunity costs and thus reduce the number of environmental offenders brought to court. There is again no clear-cut prediction for the scope effect of the number of aggregate tried suspects.

For the last stage of enforcement, theory suggests that an increase in the number of tried environmental offenders will increase, and an increase in the number of overall offenders brought to court will decrease the number of convicted environmental offenders. The effect on overall convictions is ambiguous.

With respect to political factors the literature leads us to predict that the effect of a pro-industry party in state government is negative throughout. In contrast, green preferences and the German greens in state government will have a negative effect on all stages of enforcement.

Table 19: Summary of Predictions

	Police force	Prosecution	Courts
Explanatory variables	Cleared cases	Tried offenders	Convicted offenders
No. of EC cases	+		
EC suspects		+	
EC offenders tried	-		+
Change in EC rate	+	∅	∅
Aggr. crime vol.	-		
Aggr. cleared cases	?		
Aggr. suspects		-	
Aggr. offenders tried		?	-
Aggr. offenders convicted			?
Pro-industry party in gvmt.	-	-	-
Greens in gvmt.	+	+	+
Green preferences	+	+	+

Taken together, theory and previous empirical evidence provide a basis for predicting the coefficient sign of most of the variables. One exception are economic variables whose effect depends on the presence or absence of economies of scope at each level: Dedicating effort to cases in other areas of crime competes with resources for environmental crime. On the other hand, environmental crime is frequently connected with other offences such that economies of scope are a plausible outcome at every stage of the enforcement chain.

The final testable hypothesis concerns the relative strengths of coefficients for variables capturing political economy factors. Different institutions ostensibly enjoy different degrees of independence from the legislature, from the police force with the lowest degree to the courts with the highest degree of autonomy in decision-making. I would therefore expect that the relative responsiveness of these three institutions vis-à-vis the identity of the governing party and the preferences of vot-

ers should reflect this. The police force would therefore be predicted to be most responsive, courts the least, and prosecutors somewhere in between. This idea is captured in hypothesis 4.

Conjecture 4 *The absolute value of coefficients for political economy variables capturing 'green' preferences and the identity of the party in government should be highest at the level of the police, lowest at the level of courts, and between police and courts at the level of the prosecution service.*

With my set of three testable hypotheses complete, I now turn to the data used in the econometric specifications.

24 Data

Data on crime in Germany is collected at the level of 16 individual states to which enforcement is devolved and at various stages in the state-level enforcement process. Since one state has not released the relevant data, my sample comprises 15 of the 16 states and the years 1995 (1994 in case of reported cases) to 2005 with a small subset of states having incomplete reporting,[60] leading to an unbalanced panel. Data on reported and cleared cases of environmental and aggregate crime are taken from the official police crime statistics (PKS) published by the German Federal Criminal Police Office (BKA). Further necessary data of the sanctioning regime applied to crime, such as the number of trials, convictions and imprisonment, is available from the official prosecution statistics (StVSt) of the Research

[60] No data is available for the state of Saxony-Anhalt. Saarland's date cover 1996-2005, Brandenburg 1995-2005 with the exception of 2002, Hamburg's data 1997-2005. Thuringia's data cover 1998-2005 and Mecklenburg-Vorpommern 2001-2005.

Data Centre (FDZ) provided by the Federal Statistical Office and its state level counterparts. Data concerning juvenile offenders is included in cleared cases but excluded from the remaining analysis due to the distinct sanctioning regime applicable to this subgroup. However, on average 93 percent of all identified suspects for environmental crimes are adults. Data on structural variables that characterize individual states, such as population, size, political, and several socioeconomic variables, are taken from publications of the Federal Statistical Office.

Voting shares and information on the support for the German Green Party at the state level are available from the Central Archive for Empirical Social Research (ZA). Specifically, voting shares track the share of people surveyed who would vote for the German green party if there had been elections at the time of the interview. The supporters of the German Green Party indicate the share of respondents that identify themselves as strong supporters for the German Greens (1 on a scale of 1-5).

As an indicator of having a pro-industry government in power, I use the presence of the conservative party (CDU/CSU) as a proxy. The CDU (CSU in Bavaria) is the German party that is consistently most closely aligned with business and industry interests and least aligned with environmental policy preferences among the parties in German state parliaments (Budge et al. 2007). I also included a dummy for the presence of the German greens in state governments to validate their impact on prosecution.

Another important factor determining the success of institutions in enforcing environmental criminal law is the endowment of police, prosecution, and courts with manpower and equipment. I therefore included information for budgets and number of employees in my analysis. However, I will explain in preceding sections

Table 20: Variable Definitions

Variable	Definition
cleared env. crimes (cleared)	number of cases for which suspects are identified
tried suspects (tried)	number of identified suspects that are accused
convicted offenders (convicted)	number of accused suspects that are convicted
environmental crime (cases)	reported cases of environmental crime
identified suspects (suspects)	number of identified environmental offenders
Environmental Crime Rate (CR)	Number of reported cases divided by population
aggr. crime cases (agg.cases)	total amount of reported crimes
aggr. cleared cases (agg.cleared)	number of cases cleared overall
aggr. identified suspects (agg.suspects)	number of identified overall offenders
aggr. tried offender (agg.tried)	total number of accused offender
aggr. convicted offender (agg.conv)	total number of convicted offender
dummy conservatives (cons)	indicating whether CDU/CSU is in state government
dummy greens (greens)	indicating whether green party is in state government
green voters (green.pref1)	share of people intending to vote for greens
green supporters (green.pref2)	share of people with strong support for greens

why I did not include information for this in my core estimations. Tables 20 and 21 provide variable definitions and summary statistics for all variables included in the core econometric estimation.

25 Econometrics

In this section I analyze the 3 successive stages of the enforcement process in Germany empirically. Thereby I assume that the enforcement production of police, prosecution and courts depend on economic and political economy factors. As there are different institutions responsible for different stages of the enforcement process I split my analysis according to these responsibilities. Going with the natural way first of all a crime has to be detected and recorded to police. Police then has to identify suspects. This is the first step of the enforcement process and the

Table 21: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
cleared	176	1.192.114	9.377.375	24	4258
tried	152	3.265.461	3.031.189	6	1497
convicted	152	2.493.487	2.366.307	4	1156
cases	176	1.986.028	1.452.868	58	5848
suspects	274	1261.825	939.9252	31	4211
CR	176	5.196.115	3.715.087	8.733.851	1.796.139
agg.cases	176	405652.2	317165	60651	1531647
agg.cleared	176	210833.5	163082.7	30861	741607
agg.suspects	274	137536.8	104779.7	21368	485859
agg.tried	154	76661.32	65145.82	10784	254178
agg.conv	155	62018.07	52157.22	8006	195050
cons	176	.5568182	.4981785	0	1
greens	176	.1818182	.386795	0	1
green.pref1	176	.0986038	.0520535	0	.3037975
green.pref2	176	.0440468	.026972	0	.1736111

only stage police is involved directly.[61] After the police having identified a probable offender prosecution decides whether there is enough evidence to accuse the suspect and thus bring the incidence to court. When brought to court the judge has to decide whether a potential offender is guilty and thus will be convicted to a fine or even sent to prison. One important issue is whether these different punishment rates are persistent - leading to a dynamic production function (Blundell and Bond 2000) - or not. As I will show in the next few paragraphs there is evidence for persistency for most punishment rates but not for all. Another important task is to deal with the small sample size in an appropriate manner. As the number of observations is limited and the amount of potential explanatory factors is rather large I followed two different strategies. I first estimated a core equation and added in a second step subsequently further variables figuring out whether they have an

[61] However, the quality of evidence the police secures will be important for all following stages.

influence or whether they change results. The second approach was to include all potential explanatory variables and then subsequently skip those which do not seem to influence the dependent variable. In this context I also included variables indicating the number of employees and the expenditures for police, prosecution and courts as obvious input to the enforcement process. However, none of these variables turned out to be significant (see table 26 provided in the appendix). This is not very surprising considering the fact that overall employment or overall budget probably does not reveal the resources dedicated to the prosecution of environmental offences. I therefore think that the opportunity costs faced by everyone enforcing environmental offences may be a far better indicator of the available resources.

25.1 Police

The basis for all later enforcement activities for the major fraction of all reported environmental crimes in Germany[62] is the initial work of police.

The equation I am going to estimate for the production of cleared cases is the following:

$$\begin{aligned} \log cleared_{it} &= \alpha + \beta_1 \log cleared_{it-1} + \beta_2 \log cases_{it-1} + \beta_3 \Delta CR_{it} + \\ &+ \beta_4 \log tried_{it} + \beta_5 \log agg.cases_{it} + \beta_6 \log agg.cleared_{it} + \\ &\beta_7 cons_{it} + \beta_8 greens_{it} + \beta_9 green.pref_{it} \\ &+ f_i + t_t + \epsilon_{it} \end{aligned} \tag{12}$$

[62] In 2004, 76% of all cases handled by prosecution were forwarded by police, 20% were initiated by the prosecution itself and 3.2% were reported by environmental agencies.

where α, β_{1-9} are the parameters to be estimated, f_i *and* t_t are state and time dummies. Furthermore, i and t being the subscripts for states and time periods, respectively, and ϵ is the error term.

Table 22 displays the results. As suggested by Blundell and Bond (2000) for dynamic production function estimation I used system GMM (BB) rather than Arellano and Bond (1991) difference GMM to estimate dynamic production functions.[63] However, simulations show (Bond 2002) that GMM is vulnerable in case of very small samples and may perform badly in case of persistency for the dependent variable. There is evidence (Bruno 2005a/b) that bias correction as proposed by Bruno (2005a/b)[64] or similarly by Kiviet (1995), Bun and Kiviet (2003) and Bun and Carree (2005) outperforms GMM in terms of biases especially in case of persistency of the dependent variable and small sample size. In addition, the Sargan statistic of overidentifying restrictions points against the validity of the instruments. I would therefore in principle prefer the BC estimates. Unfortunately, bias correction is only valid for strictly exogenous variables. One has therefore to make sure that there exist no further endogeneity problem besides the Nickell (1981) bias. The only suspected variables for potential endogeneity or simultaneity issues are the growth in environmental crime and number of tried offenders. As the amount of identified offenders are the key input to the amount of tried offender there is obviously an effect in this direction as well. However, I applied different strategies[65] to control for this and results remained fairly constant. On

[63] All GMM estimations have been carried out with the user written xtabond2 command in Stata, see Roodman (2006). To keep the number of instruments for the lagged dependent variable tractable we only used lags 1 to 4.

[64] All bias-corrected estimations have been carried out with the user written xtlsdvc command in Stata, see Bruno (2006). Another feature of xtlsdvc is that it has been tailored for unbalanced panels.

[65] A difference-in-Sargan test was not able to reject the Null of exogeneity (p-value: 0.647).

the other hand a rising amount of cleared cases increases expected punishment and my therefore reduce that growth in environmental crime. Again, I applied various tests[66] and did not find evidence for the growth of the environmental crime rate to distort results.

Besides this the Arellano and Bond test for first and second order autocorrelation works as suggested. There is evidence for first order autocorrelation (ar1) and no evidence for second order autocorrelation (ar2). To capture the environmental preferences of state populations I included the share of green voters (green.pref1) or the share of strong supporters for the German green party (green.pref2).

Comparing the different specifications does not reveal significantly differences for most of my variables. There is huge evidence that the number of cleared cases (cleared) occupy some time dependency as the lagged variable is highly significant in all specifications with values between .57 and .75. My input variable for the production process of cleared cases, the number of environmental crimes (cases), has a positive and with elasticities of around .4 for BC significant influence on the production of cleared cases by police. Overall crime cases (agg.cases) indicate the opportunity costs and overall cases cleared (agg.cleared) point towards a general scope effect. In my case, parameter estimates for aggregate cases and aggregate cleared cases show up to be highly significant for BB and slightly fail significance at the 10% level for BC. Aggregate cases show with estimates of around -.3 for BB a negative and significant relationship to cleared environmental crimes. There

Furthermore, we treated the number of tried as being endogenous in BB and results remained unchanged. Another strategy was to use the lag or to skip the variable from the estimation equation. However, none of the applied methods revealed further problems.

[66] The difference-in-Sargan test was again not able to reject the Null of exogeneity (p-value: 0.310). Furthermore, we treated the number of tried as being endogenous in BB and results remained unchanged. However, none of the applied methods revealed further problems.

Table 22: Estimation Results for Police Production of Cleared Cases

	BB	BC	BB	BC	BB	BC
Exp. variables	1	2	3	4	5	6
cleared, lag	.7545	.5868	.7466	.5739	.7110	.5766
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
cases	.1740	.3754	.1718	.3873	.2034	.3902
	(0.2132	(0.0021	(0.1872	(0.0013	(0.1438	(0.0012
CR growth	.8551	.6388	.8605	.6247	.8256	.6250
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
agg.cases	-.3727	-.5312	-.3208	-.5403	-.3809	-.5324
	(0.0321	(0.1331	(0.0517	(0.1248	(0.0294	(0.1330
agg.cleared	.3735	.4777	.3265	.4903	.3840	.4822
	(0.0318	(0.0550	(0.0471	(0.0477	(0.0268	(0.0517
tried	.0378	.0458	.0439	.0503	.0498	.0453
	(0.3263)	(0.2095)	(0.2579)	(0.1620)	(0.2634)	(0.2118)
cons	-.0447	-.1399	-.0438	-.1349	-.0438	-.1371
	(0.3028)	(0.0002)	(0.3202)	(0.0004)	(0.3339)	(0.0003)
greens	.0315	-.0541	.0322	-.0494	.0302	-.0499
	(0.3110)	(0.2678)	(0.2890)	(0.3072)	(0.3213)	(0.3002)
green.pref1			-.2649	.1792		
			(0.3072)	(0.5862)		
green.pref2					-.2136	.1991
					(0.6784)	(0.7815)
N	152	152	152	152	152	152
instruments	69		70		70	
F	1808.8973		2480.3867		4046.8116	
Sargan	70.1179		69.6997		73.9341	
	(.0316)		(.0341)		(.0155)	
ar1	-2.5958		-2.6591		-2.6566	
	(.0094)		(.0078)		(.0078)	
ar2	.7591		.5501		.6391	
	(.4477)		(.5822)		(.5227)	

Note: time dummies and a constant have been included but omitted here. P-values in parenthesis. All GMM specifications have been estimated with robust standard errors and BC standard errors via bootstrapping with 50 repetitions.

is thus strong support for the opportunity cost hypothesis. The estimates for the aggregate cleared cases, however, are positive and give with a value of .53 support for my scope effect hypothesis.

The estimates for the growth rate for environmental crime (ΔCR) are highly significant and positive and reveal elasticities ranging from .62 to .86. I therefore find clear evidence for the police reacting on criminal behavior. Another possible determinant of cleared cases is the amount of suspects brought to court as this may imply further investigations. However, my estimates for the number of tried suspects (tried) do not seem to have a negative impact on the amount of cleared cases.

The remaining explanatory variables represent my political hypothesis. The share of green voters (green.pref1), the share of supporters of the greens (green. pref2) and the greens dummy (greens) do not seem to influence police behavior in clearing environmental crimes. However, my dummy for the conservatives (cons) reveals a negative and for BC significant connection to cleared cases. The parameter estimate is throughout negative with a semi-elasticity of -.13 for BC.

The next section analyzes the behavior of prosecution as this is the next institution involved in the enforcement of environmental crimes.

25.2 Prosecution

It is probably not possible to underrate the role of prosecutors in the context of enforcement of crimes. Prosecutors decide on behalf of society whether a suspect will be brought to trial - or not. This decision being very important as if a prosecutor decides not to accuse a potential offender there will be no further opportunity

for a criminal sanction.[67]

Having my theoretical predictions in mind I am going to estimate the following equation:

$$\begin{aligned} \log tried_{it} &= \alpha + \beta_1 \log tried_{it-1} + \beta_2 \log suspects_{it} + \beta_3 \Delta CR_{it-1} + \\ &\beta_4 \log agg.suspects_{it} + \beta_5 \log agg.tried_{it} + \beta_6 cons_{it} + \\ &\beta_7 greens_{it} + \beta_8 green.pref_{it} + f_i + t_t + \epsilon_{it} \end{aligned} \tag{13}$$

where again the greek letters represent the parameters to be estimated, f and t indicate state and time effects and in case of ϵ the error term. In contrast to the specification for police production of cleared cases I included the growth rate for environmental crime with one lag. The reason for this is that I belief prosecutors and also judges not to have immediate information on the crime rate as it is the case for police. I think that prosecution and judges may get the information out of official statistics published at the end of each year. Table 23 presents the estimation results.

Similarly to cleared cases there is evidence that the amount of tried suspects exhibits some degree of persistency. Problems arise when looking at the Sargan test statistics. Whereas the Arellano and Bond tests for autocorrelation behave as requested the Sargan test needs some further attention. The Sargan test is for both AB and BB significant rejecting the Null of validity of the instruments even at the 1% level for BB. I therefore again prefer bias correction as the most reliable estimator.

The results reveal a throughout positive and highly significant relationship for

[67] There will be exceptions only if the prosecutor made a serious mistake.

Table 23: Estimation Results for Production of Suspects Prosecuted

	BB	BC	BB	BC	BB	BC
Exp. variables	1	2	3	4	5	6
tried, lag	.6879	.5651	.7338	.5760	.6606	.5619
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
offender	.3273	.2688	.2647	.2652	.3640	.2612
	(0.0110)	(0.0690)	(0.0286)	(0.0706)	(0.0013)	(0.0748)
CR growth, lag	.4395	.3857	.4564	.3439	.4338	.3865
	(0.0095)	(0.0119)	(0.0129)	(0.0250)	(0.0126)	(0.0101)
agg.offender	-.3589	-.1883	-.2809	-.0631	-.4083	-.1817
	(0.2479)	(0.7470)	(0.3036)	(0.9123)	(0.1638)	(0.7561)
agg.tried	.3435	.3210	.2763	.2369	.3806	.3900
	(0.1842)	(0.5594)	(0.2176)	(0.6613)	(0.1230)	(0.4822)
cons	-.0520	-.1614	-.0455	-.1913	-.0656	-.1664
	(0.3041)	(0.1496)	(0.3755)	(0.0887)	(0.1818)	(0.1284)
greens	-.0334	-.0643	-.0246	-.0941	-.0522	-.0512
	(0.4016)	(0.6515)	(0.6289)	(0.5056)	(0.2645)	(0.7128)
green.pref1			-.4710	-3.553		
			(0.7347)	(0.0006)		
green.pref2					2.6105	2.4377
					(0.0323)	(0.2010)
N	136	136	136	136	136	136
instruments	55		56		56	
F	91.5133		42.2263		1126.0095	
Sargan	63.863.609		62.572.573		64.039.004	
	(.0053)		(.0072)		(.0051)	
ar1	-2.4597		-2.4052		-2.4304	
	(.0139)		(.0161)		(.0150)	
ar2	.4177		.7968		.2855	
	(.6761)		(.4255)		(.7752)	

Note: time dummies and a constant have been included but omitted here. P-values in parenthesis. All GMM specifications have been estimated with robust standard errors and BC standard errors via bootstrapping with 50 repetitions.

the lagged number of tried suspects. The magnitude of the effect is with estimates of .56 to .73 in the same range as for the number of cleared cases. Again, the production input in form of the amount of identified suspects reveals with elasticities ranging from .26 to .36 a highly significant influence on the amount of tried offender. Contrary to my initial suggestions the growth of environmental crime shows up to be a significant and positive driver of the amount of tried suspects (.34 to .45). My variables indicating the aggregate amount of identified and tried suspects have the expected signs but seem to have no influence on the amount of tried environmental offenders. A bit curious are the findings for public environmental preferences. The share of green voters (green.pref1) seem to have a negative and in case of BC significant effect on the amount of tried environmental offenders. On the other hand, the parameter estimate for share of strong supporters for the German green party (green.pref2) has in case of BB a positive and significant influence on the amount of tried offenders. It is therefore not quite clear if one can rely on one of these outcomes. The dummy for the greens in state parliament is not significant in any specification. My dummy for the conservatives, however, reveals a throughout negative parameter estimate which is significant once[68] and gives thus cautious support for the pro-industry assumption.

In the next subsection I now analyze the behavior of courts. After a prosecutor deciding whether to accuse a potential offender the lawsuit comes to court and judges have to decide whether to convict the offender.

[68] cons slightly fails significance at the 10% level for the other BC estimates.

25.3 Courts

As already stated in my theoretical part I assume that the political influence is reduced significantly for this last stage of enforcement. However, as this is just a hypothesis in a first stage I estimated the following estimation equation:

$$\begin{aligned} \log convicted_{it} &= \alpha + \beta_1 \log convicted_{it-1} + \beta_2 \log tried_{it} + \beta_3 \Delta CR_{it-1} + \quad (14) \\ & \beta_4 \log agg.tried_{it} + \beta_5 \log agg.convicted_{it} + \\ & \beta_6 cons_{it} + \beta_7 greens_{it} + \beta_8 green.pref_{it} + f_i + t_t + \epsilon_{it} \end{aligned}$$

In line with the production function for prosecutors I assume that judges take their information about the environmental crime rate out of official statistics published at the end of the previous year. The growth rate of environmental crime appears therefore with one lag. Table 24 reveals that the series of convicted environmental offenders does not exhibit persistency as found in earlier stages of the enforcement process. I therefore stick to static Fixed Effects (FE) as the most appropriate estimator. Moreover, further investigations revealed that there is serial correlation[69] in the errors such that I estimated the model with AR(1) disturbances.[70]

It is interesting to see that the persistency of judges behavior is relatively small in comparison to previous results.

Besides this, the input measure for the production of convicted environmental offenders, the amount of tried suspects has the intended effect. The amount of tried suspects (tried) shows up to be highly significant with an elasticity of around 1. The estimates for the growth in environmental crimes do provide some evidence

[69] We applied a test suggested by Wooldridge (2002) and implemented in Stata through the user written command xtserial by Drukker (2003).

[70] Implemented with xtregar in Stata.

Table 24: Estimation Results for Judges Production of Convicts

	BB	BC	FE	FE	FE
Exp. variables	1	2	3	4	5
convicted, lag	-.0155	-.0071			
	(0.7500)	(0.8504)			
tried	1.0173	.9757	.9710	1.0276	.9702
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
CR growth, lag	-.1325	-.1443	-.1090	-.1153	-.1082
	(0.3168)	(0.0328)	(0.0656)	(0.0402)	(0.0687)
agg.tried	-1.3584	-1.8491	-2.4771	-2.2343	-2.4698
	(0.0400)	(0.0219)	(0.0049)	(0.0070)	(0.0052)
agg.conv	1.3396	1.7964	2.3021	2.0703	2.3078
	(0.0474)	(0.0144)	(0.0019)	(0.0030)	(0.0020)
cons	-.0255	.0329	.0365	.0656	.0341
	(0.4938)	(0.4711)	(0.4996)	(0.2025)	(0.5329)
greens	-.0354	.0389	.0511	.0581	.0506
	(0.4758)	(0.5631)	(0.4601)	(0.3726)	(0.4668)
green.pref1				1.6152	
				(0.0004)	
green.pref2					.2697
					(0.7372)
N	136	136	135	135	135
j	55				
F	3890.9901		59.4512	64.0705	55.4288
Sargan	112.9140				
	(0.0000)				
ar1	-1.5625				
	(.1181)				
ar2	1.0813				
	(.2795)				

Note: time dummies and a constant have been included but omitted here. P-values in parenthesis. All GMM specifications have been estimated with robust standard errors and BC standard errors via bootstrapping with 50 repetitions.

for influencing the amount of convicted offender negatively with an elasticity of roughly -.1 for static FE. This is not in line with my initial expectations and difficult to interpret.

The variables reflecting the amount of overall tried and convicted offender follow my previous suggestions. The number of tried (agg.tried) have negative elasticities ranging from -1.3 to -2.4 and the number of convicted (agg.conv) a positive one with values of 1.3 to 2.6. Both elasticities are highly significant throughout all specifications.

The political variables included in my regressions show in most cases no effects on the amount of convicted environmental offenders. The share of green voters (green.pref1) being the only exception indicating a significant and positive influence with an elasticity of around 1.6. The estimates for strong green support are positive but not significant. The dummy for the greens is negative but insignificant in case of static FE and the dummy for the conservatives has also no definite effect on convicted offenders.

26 Discussion

In this section I contrast previously stated conjectures with my empirical findings. The first conjecture stressed the possible determinants of police clearing behavior regarding environmental crime.

Result 1 *I find evidence for (a) the amount of reported cases of environmental crime to increase with the amount of cleared cases. Moreover, there is also evidence that (b) the growth rate of environmental crime has the intended shift effects as parameter estimates are positive, significant and robust. There is no support*

for the hypothesis that the amount of tried environmental offenders decreases the amount of cleared cases (c) through a opportunity cost effect. The effects of my aggregate crime variables (d), however, are very definite. The amount of aggregate crime points towards a significantly negative effect on the clearing of environmental offences through a opportunity cost effect. In contrast, the aggregate amount of cleared cases is a positive driver of the amount of cleared environmental crimes. For my political variables there is only evidence for the conservative dummy to negatively affect police success in clearing environmental crimes. The remaining variables do not show up to have a significant influence on police behavior.

My results for the opportunity cost arguments confirm the findings of Helland (1998) in the context of EPA enforcement of pollution control laws. The author finds that increasing the number of targeted companies by one standard deviation significantly reduces the probability of being inspected by the EPA by around -.5. Moreover, I do also find evidence for the argument that police may react to changing crime rates as proposed by Miceli (1996). With respect to the political factors, estimates support findings in the existing literature that politicians may have a significant impact on enforcement decisions (Mete 2002, Shipan 2004, etc.).

The behavior of prosecution is the next key institution when stepping up the enforcement process. Their key input in the production of tried suspects is identified suspects resulting trough the clearing of a crime cases. I summarize my empirical findings in the following paragraph.

Result 2 *There is clear-cut evidence that the amount of suspects brought to court increases with the number of identified suspects (a). Surprisingly, the growth in environmental crime (b) again has a highly significant and positive effect on the*

amount of prosecuted suspects. I also find support for my next hypothesis (c) that a higher amount of aggregate suspects decreases the amount of tried environmental offenders through a opportunity cost effect. There is also evidence for the scope effect. The amount of aggregate suspects tried increases the amount of tried environmental offenders. A bit surprising and counterintuitive are the negative and in some cases significant estimates for the share of green votes. In contrast, the share of green supporters point towards a positive and significant effect on tried offender. It is therefore not possible to draw clear-cut conclusions with respect to environmental preferences. Being in line with this, the dummy variable for the greens does not show up to have any effect. However, there is again some evidence that the conservatives have a negative influence on enforcement of environmental crimes.

In contrast to the theoretical considerations by Miceli (1996), I do find evidence that prosecutors react to changing criminal threat in the context of environmental crimes. A higher growth in environmental crimes leads to a significantly higher amount of tried environmental offenders. In contrast to Ramseyer et al. (2008), I do find evidence for both political and production-based factors to influence the behavior of prosecutors.

The final institution involved in the enforcement of crimes are courts represented by judges. Judges finally decide whether to convict a suspect and which kind of sanction to impose.

Result 3 *The input of tried offenders has the suggested effect (a) of increasing the number of convicted suspects. Contrary to initial suggestions and results for previous enforcement stages there is evidence that the growth in environmental*

crime affects the amount of convicted offender in a negative fashion (b). Similar to previous stages, however, the overall amount of tried suspects has a negative and the overall amount of convicted criminals a positive effect on convicted environmental offender (c) and thus supporting my opportunity cost and scope effect hypothesis. Contrary to my initial expectations I find cautious support for public environmental preferences to positively influence judges decisions to convict offender (d). Both the share of green supporters and the share of green voters show positive estimates which are in case of the share of green voters also significant. The dummies do not show up to be significant in any specification.

Surprisingly, the growth in environmental crimes seem to negatively affect the amount of convicted offenders. As the results for previous stages were positive it is not quite clear how to interpret this. However, there is again evidence for political considerations to influence judges decisions as the variables indicating public environmental preferences seem to have a positive influence. Although my approach is rather novel, there is support in the literature that political factors have an influence on courts (Cohen 1987, Anderson et al. 1989, Salzberger and Fenn 1999) or bureaucrats enforcement decisions (Headrick et al. 2002).

My last hypothesis focuses on the degree of political influence at different stages of the enforcement process. Although my empirical findings do show evidence for political economy factors being important determinants of agency behavior, the degree of political influence contradicts initial predictions.

Result 4 *Except for the dummy for the German Green Party being in state government, all political economy variables seem to influence enforcement of environmental crimes. Especially the dummy for the conservatives meant to reflect a*

pro-industry policy has a negative and significant impact on police and prosecution in enforcing the German Environmental Penal Code. Moreover, there seems to be at least slight evidence for the share of green voters to positively influencing the amount of convicted environmental offenders. However, as the degree of control does not decrease but remains fairly constant while stepping up the enforcement process, I do not find support for my fourth hypothesis.

27 Conclusion to Part IV

The starting point of this paper was that the criminal justice system combines at least three distinct institutions, police, prosecution service, and courts, in order to enforce key regulations. This proliferation of agencies for a single public task - while grounded in sound constitutional arguments - raises questions about the scale of agency problems in criminal enforcement. These questions have not been adequately examined from an empirical perspective and I believe that this paper is one first step in this direction.

The findings of this paper add in a significant way to existing literature. Firstly, I reaffirm the usefulness of the production function approach as a powerful tool for analyzing behavior of law enforcement institutions as pioneered by (Becker and Stigler 1974). On its basis, the paper provides new evidence on the role of economic and political factors for explaining the behavior of the criminal justice system. Secondly, it is the first paper to my knowledge to provide this evidence not only at the level of one institution involved in criminal enforcement, but at all three key stages of police, prosecution, and courts. This allows us to compare the empirical record with institutional design choices. These choices would suggest

that while the police and - to a lesser extent - the prosecution service can be expected to be responsive to public preferences, the decisions of courts should be independent of political factors. The empirical analysis, on the other hand, finds evidence that both economic and political factors are present at all levels. This means that - faced with scarce resources - police, prosecutors and judges are forced to consider opportunity cost arguments when deciding how much effort to put into enforcement and that political factors influence this decision at the margin. It also means that political economy factors influence agency decision making in significant ways. In line with previous results (Ramseyer et al. 2008), there is evidence that pro-industry parties tend to decrease the enforcement of environmental crimes while public environmental preferences have a positive effect. In addition, there is evidence that police and prosecutors respond to a growth of environmental crime with increased effort in order to provide further deterrence, an empirical finding that contrasts with Miceli (1996).

Finally, on a geographical note, this is to my knowledge the first paper to do so for the context of Germany, thus demonstrating the applicability of the methods in new legal contexts.

28 Final Conclusions

The present thesis extends both the economic literature on the enforcement of environmental regulations and the general economic of crime literature by empirically analyzing the effectiveness of environmental criminal law. In addition, it provides evidence for the determinants of police, prosecution, and courts in enforcing environmental laws. In line with the initial predictions, the empirical results show that economic theory is a very powerful tool in explaining the behavior of both environmental offenders and enforcement institutions.

28.1 The Contributions

The contributions of the thesis are manyfold. At first, the thesis makes a first step to fill an important gap in the existing literature. It has been a shortcoming of the discussion on the merits of criminal sanctions for environmental offences that the empirical evidence on their effectiveness had so far not been systematically examined. This contrasts with the case of administrative sanctions for which a rich literature is available. Furthermore, and despite the obvious parallels with the types of criminal behavior studied using the so-called 'economic model of crime', the theoretical and empirical economic literature on crime had also largely by-passed the area of environmental crime. Little was therefore known regarding the extent to which the 'calculus of deterrence' postulated by Becker (1968) is operational in the context of environmental sanctions. The present thesis provides important new insights in the peculiarities of criminal enforcement in the context of environmental crime. It adds a sound empirical analysis to the literature that is able to uncover important new aspects in this context.

The second contribution is that the new insights obtained in the present thesis have important implications for the ongoing policy debates in the US (HoC 2003), the EU (EC 2007) and several other countries. Findings support the beliefs of many policy-makers that criminal enforcement is effective in the context of environmental law.

Third, the thesis provides clarification for the German case. Germany extended its Penal Code in 1980 to include important environmental laws and there has been no verification of this decision until now. While a substantial part of the German legal literature characterizes the German environmental criminal code as ineffective and therefore redundant, the results obtained in part II and III indicate otherwise. While rarely used, enforcement instruments restricted to criminal sanctioning such as being identified as a suspect and being brought to a public court have a substantial statistical effect on reported environmental crime rates.

Fourth, the thesis adds a new geographical focus to the literature as most of the surrounding literature relies heavily on data from the U.S. or UK.

Lastly, the results of the present thesis emphasize that criminal law is a powerful tool for reducing the damages to society caused by environmental crime. The results on the effectiveness of criminal sanctioning suggest that enforcement significantly reduces the amount of crimes and therefore the amount of damages.

28.2 The Results

On the basis of the present thesis one can derive five results that are of huge importance for the general discussion.

First, with a view to validating the economic theory of crime, there is clear

evidence that the 'calculus of deterrence' is indeed operational in the domain of environmental crime. Especially the fact of being identified as a suspect and being tried in a public court deters people from committing environmental crimes in Germany. For the level of the German states there is also evidence that prison sentences are effective in the enforcement of environmental law. With respect to their relative contribution to the deterrence effect one can conclude that estimates are mostly in line with economic theory. Clearance rates have the smallest effect followed by the rate of tried offenders and prison rates. However, conviction rates and the rate of severe fines do not fit into this frame as the estimates do not show up to be significant.

The second insight is the importance of the detection and reporting effort for understanding the variation in reported environmental crime. The positive and negative contribution of citizens' environmental awareness and pro-industry parties, respectively, to the explanation of reported crime has in my view not been empirically established so far. In contrast to felonies like murder, rape, etc. the dark figure for environmental crimes is assumed to be rather high at least for Germany. Although it is not possible to pinpoint the causal channels, the thesis findings in part II point towards environmental preferences of society and the political orientation of parties in power to affect the amount of reporting and detection efforts in each state. This is a very important finding as enforcement in either way first of all requires that a crime is reported to police and thus finds its way into official statistics.

Third, the results for the analysis of the counties of Baden-Württemberg additionally suggest that structural factors and community characteristics do have an impact on the amount of reported environmental crime. Especially the manufac-

turing sector being one important source of waste seems to influence the amount of reported illegal waste disposals through various channels. I assume that these factors do have an impact on reporting rather than on the actual amount of illegal disposals. However, it will be subject to further investigations to identify this relationship in more detail.

Fourth, according to the results obtained in part IV, an important finding is that the behavior of institutions involved in the enforcement process can be described by a production function approach. For example, the success of police in clearing environmental crimes depends on the amount of reported cases and on opportunity costs like the amount of overall crimes reported to police. Furthermore, institutional behavior also reveals scope effects as police behavior in clearing environmental crime depends on the amount of overall cleared crimes. The same arguments hold for the behavior of prosecutors and judges. In line with the existing literature, there is also evidence for the growth rate of environmental crime to affect the behavior of involved institutions.

The final result of the present thesis is that the outcomes of different enforcement stages not only depend on input factors and opportunity costs as suggested by production theory but also on political factors similar to the analysis in previous parts. Although the degree of independence increases with enforcement stages, it seems like the influence of political factors remains fairly constant.

Taken together, the thesis contributes in a significant way to a better understanding of the functioning of criminal law in the context of environmental regulation. For this reason the thesis builds an important basis for several ongoing debates discussing whether to strengthen or weaken criminal enforcement of environmental laws. Although the analysis concentrates on German data, the thesis

provides consistent results that allow decision makers to base their arguments on reliable information.

28.3 Future Research

In order to provide additional verifications for the results of the present thesis, it would be of interest to compare the findings to other empirical studies with a similar research focus. Moreover, as the policy debates are not limited to Germany or the EU, it will be of importance to have further evidence for different legal environments and different geographical focuses. Especially the importance of reporting and political determinants should attract more attention in future research on the determinants of crimes in general and environmental offences in particular.

Another important area of further research is to examine whether criminal or administrative enforcement is more efficient in this context. It will therefore be important to provide additional evidence for the effectiveness of administrative sanctions in enforcing environmental regulations in Germany. Finally, one would have to analyze the efficiency of both enforcement mechanisms. This would allow decision makers to compare both enforcement mechanisms for the same legal environment.

Although the present thesis concentrated on empirical strategies, there is of course need for theoretical analysis. Theoretical considerations in the context of environmental crimes received an as low attention as the empirical counterpart. Similar to the empirical findings, further research questions include e.g. efficiency aspects of criminal enforcement or the importance of reporting. As shown in

the present thesis, reporting may play a key role in the context of environmental crimes. However, detecting and reporting environmental crimes is costly as it requires a significant amount of informations. Without having detailed knowledge of a specific law or the relevant technical tools, it is in many cases impossible to decide wether a specific emission or waste disposal is illegal or not.

It would be also interesting to analyze wether the more or less static setting of criminal enforcement applied in most countries including Germany exhibits disadvantages in contrast to dynamic aspects like bargaining, warnings or other types of reciprocal interactions commonly used for administrative enforcement. In order to establish the optimal amount of deterrence it may be efficient to use customized enforcement strategies preceding the criminal enforcement as this is very costly.

Moreover, some peculiarities of the German environmental law like the administrative accessoriness should be analyzed in more detail. It is not clear *ex ante* what the effects are on offenders and on enforcement institutions. The fact that bureaucrats decide on both what is legal and what has to be punished may have distorting effects on the enforcement of environmental laws.

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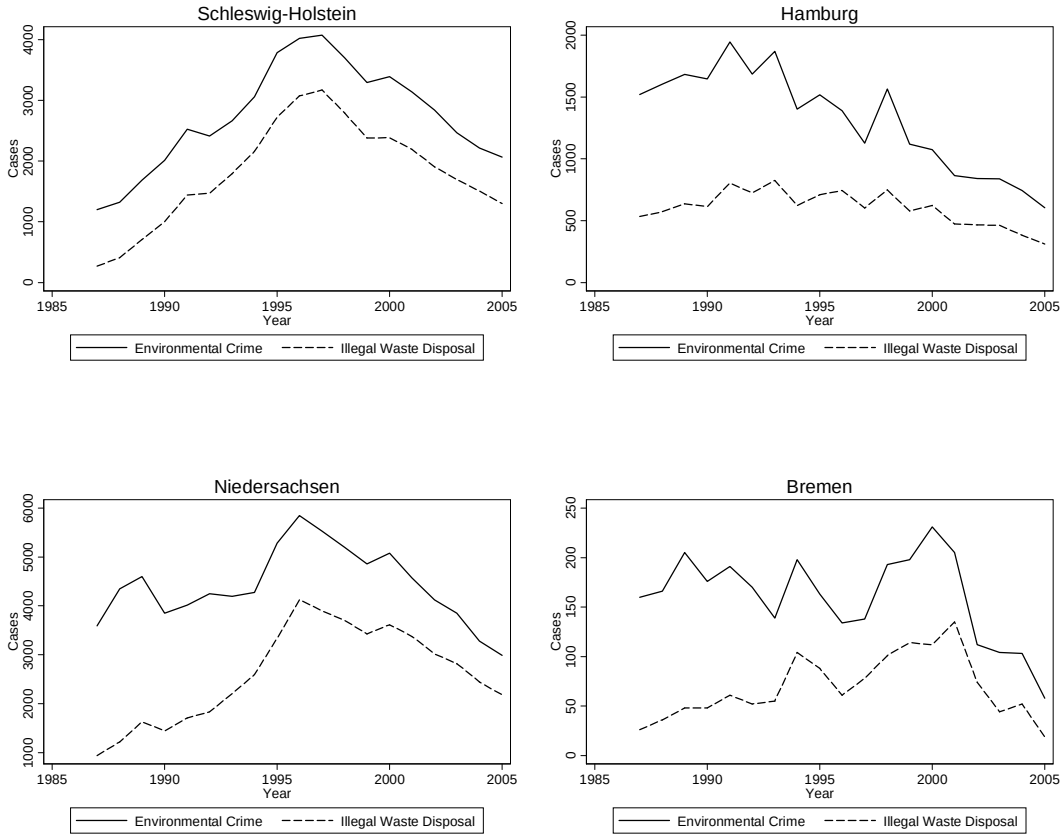
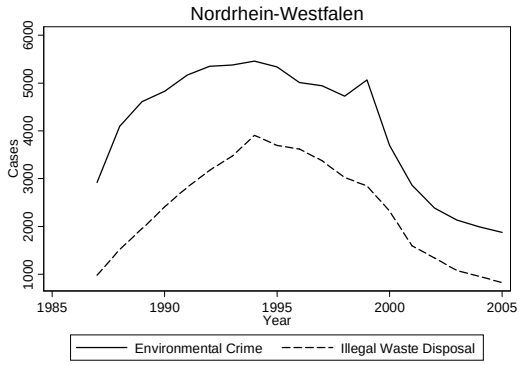
Part V

Appendix

A Appendix to section 1.3

Figure 6: The Development of Environmental Crimes in German States (1987/1993 - 2005

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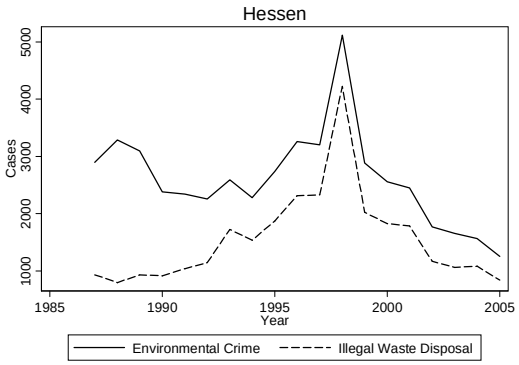
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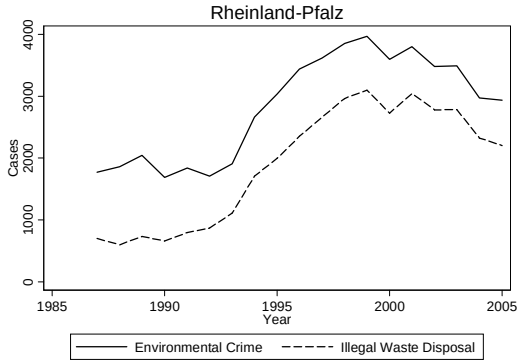
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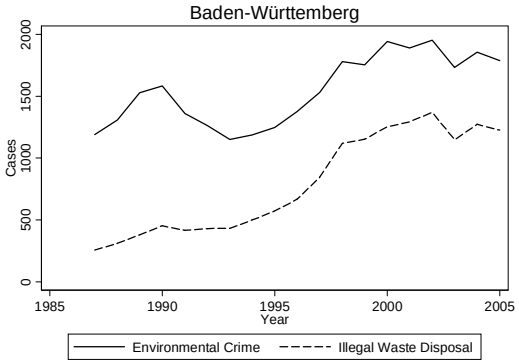
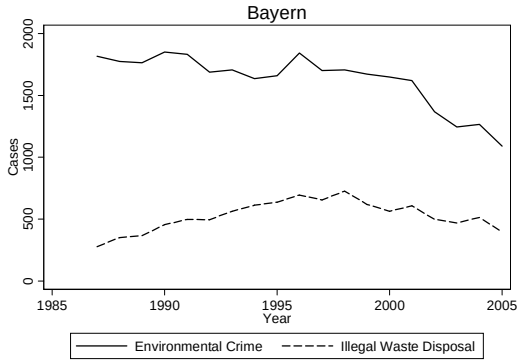
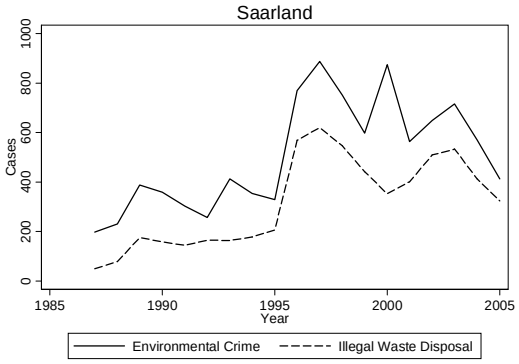
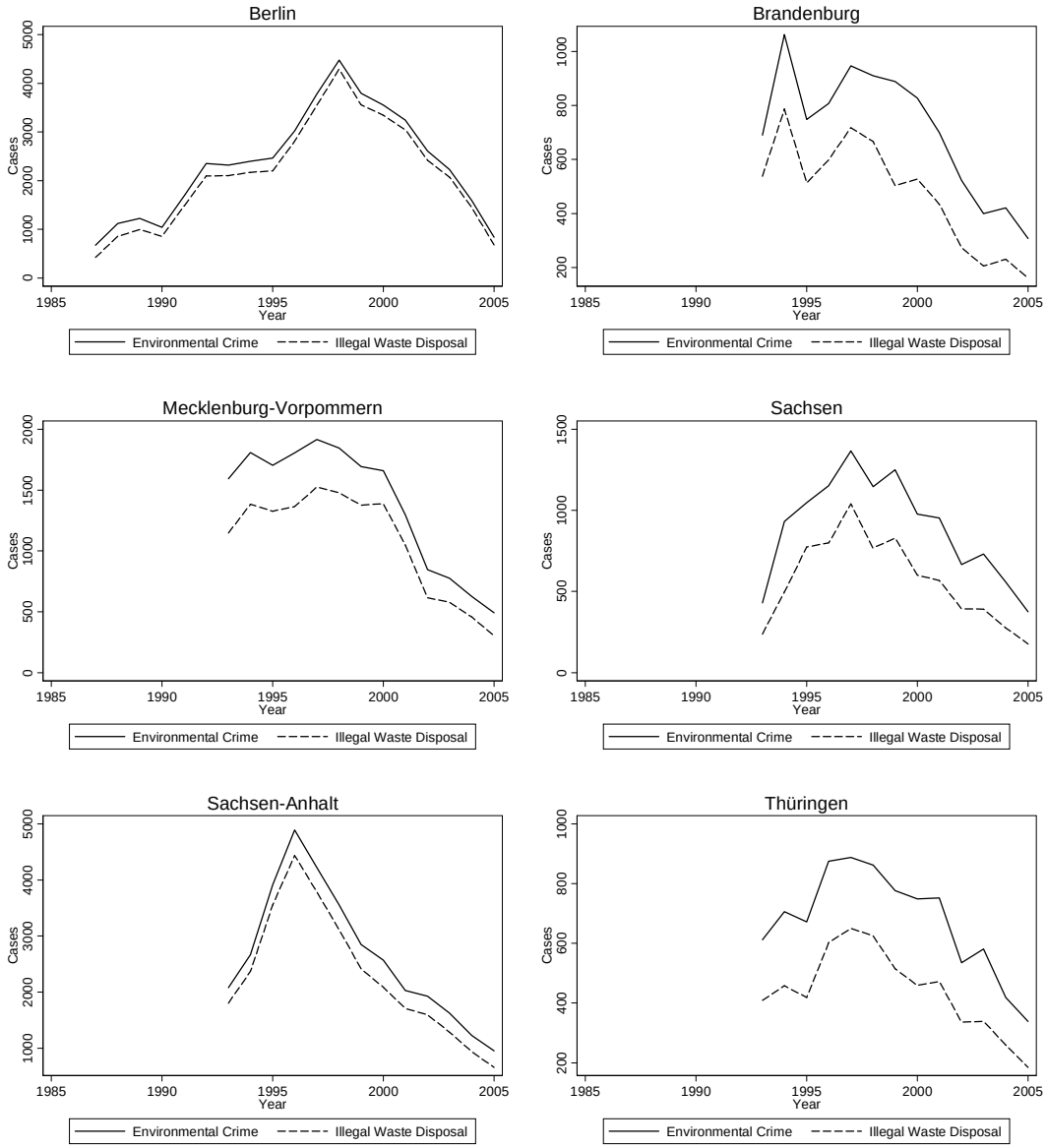
Environmental Crime
Illegal Waste Disposal


Baden-Württemberg
Cases
0
500
1000
1500
2000
1985
1990
1995
2000
2005
Year
Environmental Crime
Illegal Waste Disposal


Bayern
Cases
0
500
1000
1500
2000
1985
1990
1995
2000
2005
Year
Environmental Crime
Illegal Waste Disposal

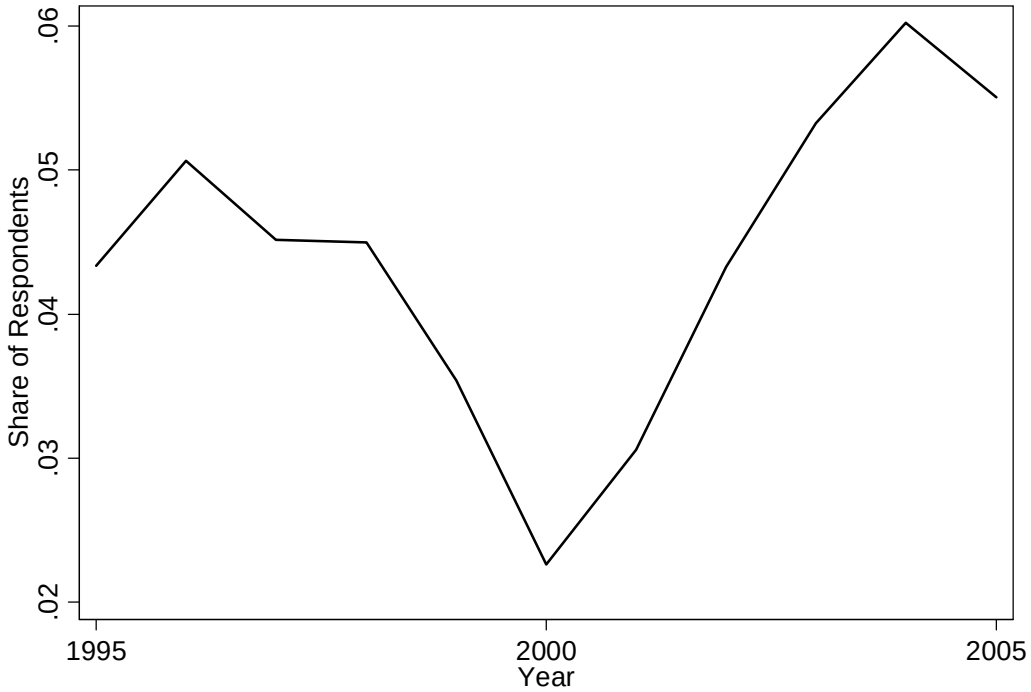

Saarland
Cases
0
200
400
600
800
1000
1985
1990
1995
2000
2005
Year
Environmental Crime
Illegal Waste Disposal


Berlin
Brandenburg
Mecklenburg-Vorpommern
Sachsen
Sachsen-Anhalt
Thüringen
Cases
Year
1985
1990
1995
2000
2005
Environmental Crime
Illegal Waste Disposal

B Appendix to Part II

B.1 The Development of Strong Green Support

Figure 7: Share of Strong Supporters for the German Green Party (Bündnis 90/Die Grünen, 1995 - 2005)



Note: Data from the Politbarometer survey provided by the ZA of the University of Cologne was used to generate this variable consisting of two survey questions. The first questions is: "Do you tend to sympathize with a special party? When, which one is it?". The second one is: "How strong is your sympathy for this party on a scale from 1 to 5?". I generated a variable indicating the portion of people who denounced the green German party to the first question and one (very strong) to the second. This variable is denoted as the portion of people who are "Strong Supporter of Greens". The present graph displays averages over all states.

B.2 Estimates for Different Covariates

Table 25: BC Estimates for Different Covariates (Part II)

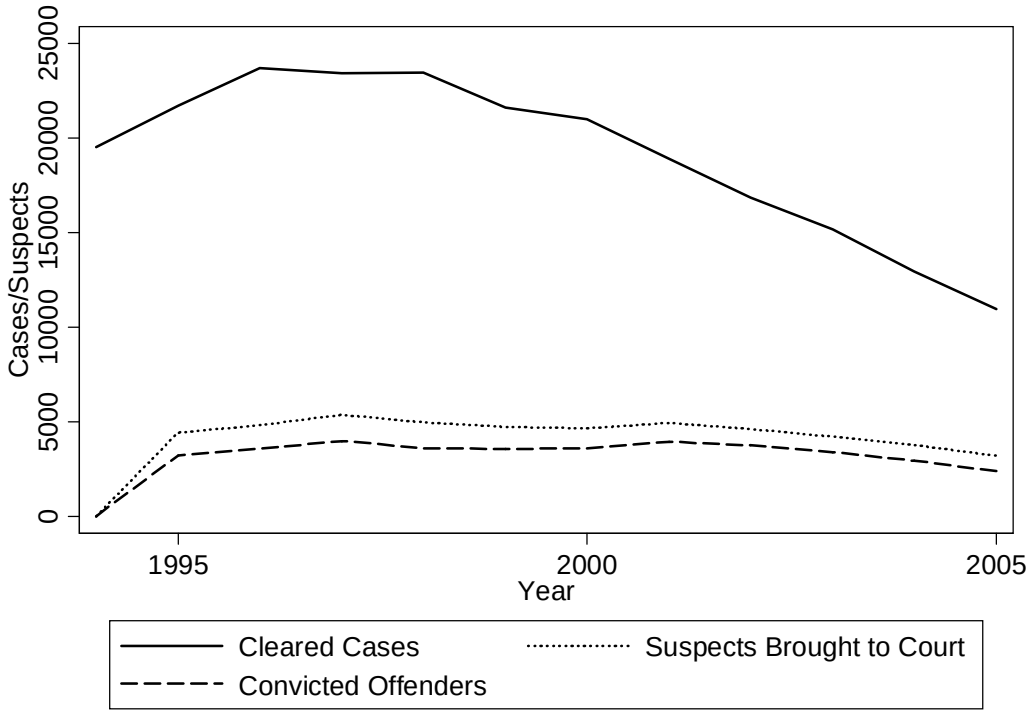
Regressors	1	2	3	4	5	6	7
Env. Crime Rate (Ln/Lag1)	.7561***	.7624***	.8488***	.8462***	.8354***	.8422***	.8548***
Clearance Rate	-3.711***	-3.719***	-3.329***	-3.469***	-3.389**	-3.451***	-3.484***
Clearance Rate Squared	3.671***	3.680***	3.216***	3.325***	3.250***	3.330***	3.329***
Rate of Tried Offenders	-.7618***	-.7879***	-1.045***	-1.052***	-1.042***	-1.038***	-1.054***
Conviction Rate	-.2087	-.2276	-.3009	-.2763	-.2918	-.3092	-.2849
Prison Rate	-1.507**	-1.500**	-1.528***	-1.549***	-1.544***	-1.570***	-1.525***
Rate of Severe Fines	.1896	.1157	.0420	.0910	.0682	.0592	.0762
Strong Green Support	1.993*	1.974*	2.317**	2.260**	2.288**	2.268**	2.295**
Dummy Cons	-.1249**	-.1238**	-.0993**	-.0928**	-.0901	-.1021	-.1023
Real Police Exp (Ln)	.1426						
Real Exp Pro./Courts (Ln)		-.0674					
Real GDP per Capita (Ln)			-.2298				
Unemployment Rate				.0060			
Dummy Greens					.0178		
Dummy SD						-.0091	
Agg. Crime Rate (Ln/Lag1)							-.1898
Observations	152	152	152	152	152	152	152

Note: All estimates are produced with Bias-correction and standard errors through bootstrapping with 50 repetitions. ***, ** and * indicating significance at the 1, 5 and 10 percent level, respectively. Time dummies have been included but omitted here. 'Real Police Exp (Ln)' and 'Real Exp Pro./Courts (Ln)' indicate the natural logarithm of real expenditures for police and for prosecution and courts, respectively. The dummies for conservatives, greens and social democrats indicate whether the specific party was in the state government. The last variable indicates the Ln of the overall crime rate with lag 1.

C Appendix to Part IV

C.1 The Development of Enforcement for Environmental Crimes in Germany

Figure 8: Proceedings of Environmental Crimes in Germany (1995 - 2005)



Source: Federal Criminal Police Office/Research Data Centre (FDZ)

C.2 Estimates for Different Covariates

Table 26: BC Estimates for Different Covariates (Part IV)

Exp. variables	BC(cleared)	Exp. variables	BC(tried)	Exp. variables	FE(convicted)
cleared, lag	.5527	tried, lag	.5416		
	(0.0000)		(0.0000)		
cases	.4279	offenders	.3809	tried	1.0354
	(0.0000)		(0.0160)		(0.0000)
CR growth	.6257	CR growth	.3029	CR growth	-.1325
	(0.0000)		(0.0404)		(0.0256)
agg.cases	-.7469	agg.offenders	-.5793	agg.tried	-2.7638
	(0.1379)		(0.3998)		(0.0066)
agg.cleared	.5845	agg.tried	-.0091	agg.conv	2.8395
	(0.0732)		(0.9887)		(0.0017)
tried	.0489				
	(0.2972)				
cons	-.1110	cons	-.1520	cons	.0172
	(0.0181)		(0.2125)		(0.7728)
greens	-.0240	greens	-.0240	greens	.0054
	(0.6569)		(0.8689)		(0.9398)
green.pref1	.0581	green.pref1	-3.4383	green.pref1	1.7102
	(0.8933)		(0.0068)		(0.0006)
exp.police	.1221	exp.enf	-1.0494	exp.enf	.1454
	(0.7571)		(0.1410)		(0.7056)
GDP	-.6967	GDP	-.6254	GDP	.8631
	(0.3050)		(0.6319)		(0.2182)
unemp	-.0031	unemp	-.0377	unemp	-.0122
	(0.8830)		(0.2899)		(0.5133)
N	137	N	121	N	120

Note: P-values in parenthesis. Time dummies have been included but omitted here. 'exp.police' and 'exp.enf' indicate the log of real expenditures for police, and for prosecution and courts, respectively. 'GDP' and 'unemp' stand for real GDP per capita and the unemployment rate in either state and year.