CORRUPTION, RULE OF LAW AND INTERNATIONAL INTERACTION IN ENVIRONMENTAL POLLUTION AND CBRN TERRORISM

by

Kate Ivanova

A Dissertation Presented to the
FACULTY OF THE GRADUATE SCHOOL
UNIVERSITY OF SOUTHERN CALIFORNIA
In Partial Fulfillment of the
Requirements for the Degree
DOCTOR OF PHILOSOPHY
(INTERNATIONAL RELATIONS)

August 2006

Acknowledgements

I would like to express my appreciation to all the people who supported me during the preparation of this thesis. First, I would like to express my deepest gratitude to my advisor, Professor Todd Sandler, for his excellent guidance, unparalleled enthusiasm, and encouragement in writing this dissertation. He was the first to introduce me to the ideas of public goods theory and innovative ways of applying them to the study of international relations and has inspired my interest in the interdisciplinary research. I have always admired his ability to give timely and constructive feedback on my drafts that helped me crystallize my thoughts and get to the root of the problem I was exploring. By coauthoring one chapter of the dissertation, he has provided me with an invaluable learning experience and insights into the preparation of manuscripts for publication. I will always be indebted to him for the knowledge he has passed on to me and the faith that he has placed in me.

I am also very grateful for having an exceptional doctoral committee and wish to thank Professor John Odell and Professor Steven Lamy for their support and advice first in their classes and then in doing dissertation research and Professor Cheng Hsiao for his willingness to share his expertise on the technical issues. Professor John Odell raised important conceptual questions and suggested helpful revisions that have improved the final presentation. His insightful comments and generous attitude have helped me broaden my perspective and cast new light upon approaches to my work. Professor Steven Lamy's dedication and interest has been a source of inspiration throughout my graduate study. His supervision as the director

of the USC School of International Relations, his thought-provoking lectures and talks and valuable suggestions on my dissertation have impacted my views on the study of international relations in a distinctive way. My discussions of econometric techniques with Professor Cheng Hsiao have facilitated my empirical work and provided me with confidence. I thank him for his encouragement and good will to come to help in critical moments.

I would like to extend my special thanks to Professor Peter Rosendorff whose optimism and rigorous reasoning have always fueled my interest in the subject of international political economy. I have profited a lot from taking his course and the opportunity to present and discuss my work at the Center for International Studies at USC that he has directed. I am also very thankful to Professor Isabelle Perrigne whose course in econometrics has laid the foundation for my dissertation research. I appreciate the advice she has continued to give me after joining the Pennsylvania State University.

I wish to express my appreciation to Luda Spilewsky and Linda Cole for all their help, patience and personal support in all times. By coordinating and overseeing the administrative concerns, they have always provided me with the resources I needed to accomplish my studies and research.

I am particularly grateful to my sister Anna Ivanova whose determination and knowledge of economics have sometimes been crucial to my work.

My thanks also go to the School of International Relations for the several grants for travel, data acquisition and the overall financial support.

Table of Contents

List of Tables

Abstract

The dissertation consists of three separate projects. The first project studies illegal trade in chlorofluorocarbons (CFCs) controlled by the Montreal Protocol. Since data on illegal trade is not available, the analysis starts with a model of illegal trade in CFCs that derives predictions about the effect of corruption, the rule of law and environmental tariffs on both legal and illegal imports of CFCs. The theoretical predictions concerning legal imports are tested using panel data on CFC consumption. Although both corrupt and honest regimes with weak and strong rule of law, respectively, have relatively high legal imports, illegal and total imports in the former are much higher than in the latter, indicating lower environmental performance.

The second project examines transboundary air pollution in Europe where the focus is on a corruptible environmental inspector and a firm who collude to underreport pollution levels. Since part of the emissions from one nation falls on the territory of neighboring countries, transboundary spillovers are taken into account. The theoretical model derives predictions about the effect of corruption, the rule of law and transbpundary spillovers on both actual and reported emissions. The hypothesized relationships regarding reported emissions are tested using spatial econometric techniques and the EMEP data on sulphur pollution. Both corrupt and honest regimes with weak and strong legal systems, respectively, have relatively low

emission reports, however, actual emissions and consequently pollution are much higher in the former than in the latter.

The third project investigates the influence of democratic principles, the rule of law and corruption on the likelihood of chemical, biological, radiological, and nuclear (CBRN) terrorist incidents. Odds ratios establish that democratic rule, strong rule of law, and noncorrupt regimes are associated with more CBRN incidents. Failed states may be where some terrorist groups form or take refuge, but these states have not been the venue of choice for CBRN incidents. Religious (cults and fundamentalists) and nationalist/separatist groups are not more likely than others to engage in CBRN attacks. The results of negative binomial regressions support the conjecture that democratic rule and strong rule of law are positive determinants of CBRN incidents.

Chapter 1. Introduction

It has become common to link corruption and weak rule of law to environmental degradation. When countries enact laws to protect the environment and create special agencies to enforce these laws, complying with environmental regulations imposes costs on firms that can be avoided by bribery. As a result, there is often a gap between policy and its implementation which is particularly characteristic of the developing world. Thus, corruption and inadequate penalties may be central to explaining low environmental performance in some countries (Pargal et al. 1997; Desai 1998).

The connection between corruption, weak rule of law and international terrorism, however, only became clear recently when the international community realized that the fight against terrorism cannot be separated from the fight against corruption. Commenting on the September 11 terrorist acts in his address to the 10th International Anti-Corruption Conference, Interpol's chief Ronald Noble (2001) emphasized that "the most sophisticated security systems, the best structures, or trained and dedicated security personnel are useless, if they are undermined from the inside - by a simple act of corruption". By forming "pacts" with corrupt government officials, terrorist groups create "states of convenience" from which to commit conspiracies on a global scale (Thachuk 2005). These pacts not only finance and facilitate operation, but also provide safe heaven.

The study of corruption has a long history in both political science and economics. The political science literature has shown that the mechanisms constraining political and bureaucratic corruption such as merit-based bureaucratic values, established transparent government processes and an informed civil society develop over a long period of time emphasizing the historical underpinnings of corruption (Johnston 1997). The economics literature has focused on the economic costs of corruption examining its detrimental effect on investment and growth (Mauro 1995; Wei 1997). However, like most of illegal activities, corruption is clandestine and consequently, very hard to measure so that empirical research on the subject has remained quite limited.

In recent years, private rating agencies have begun to produce so–called corruption indices based on replies by consultants living in the countries to standardized questions. Although the rankings are subjective, there is a very high correlation between indices produced by different agencies, pointing to the consistency of the results (Mauro 1997). The objective of this dissertation is to use data on corruption and the rule of law provided by the International Country Risk Guide to examine the links between weak public institutions and 1) compliance with environmental regulations as well as 2) the incidence of the chemical, biological, radiological and nuclear (CBRN) terrorism. In the case of environmental regulations, the project identifies important mechanisms through which corruption and weak rule of law affect performance in different countries and distort data on compliance submitted to international environmental agencies. The study of CBRN incidents

shows that although corruption and weak rule of law may attract terrorists in terms of where to form and take refuge, they are not the characteristics of the regimes that they choose for CBRN incidents.

Apart from using perception indices to measure the quality of public sector institutions, the research project also investigates ways to circumvent the problem of incomplete data that results from illegal transactions in an environment characterized by corruption and weak rule of law. For example, when the imposition of quantitative restrictions on the use of ozone-depleting substances (ODS) required by the Montreal Protocol leads to a widespread illegal trade across borders, the data provided by countries to the relevant monitoring agency reflect the legal part of the transactions while the data on the ODS shipments secretly transported from one country to another never get into any of the official records. Similarly, when an environmental inspector accepts a bribe from a polluting firm to underreport its true level of emissions, the data on polluting substances submitted to the government authorities do not include the part that the inspector and the firm deliberately omit from the reports. If compliance with international environmental regulations is based on the examination of officially reported data on polluting economic activities, this divergence in data has to be taken into account or else misleading conclusions about the level of compliance will be drawn: some countries may report lower production of polluting substances, but at the same time be responsible for higher levels of actual pollution due to their inability to control illegal transactions.

Literature Review

The contemporary international relations literature draws a distinction between compliance and two other concepts that are often invoked in the study of regime theories: implementation and effectiveness. A high level of compliance, which is often defined as "a state of conformity or identity between actor's behavior and a specified rule" (Raustiala and Slaughter, 2002: 539), does not necessarily presuppose any action by a government or regulated entity (implementation) or any changes in behavior caused by the introduction of the new rule (effectiveness). Although national implementation is often critical, it is neither necessary nor sufficient to ensure compliance with international regimes. For example, a large drop in pollution in Russia and hence a high rate of compliance with many environmental agreements is not the result of the implementation of international commitments but rather an unintentional consequence of a dramatic economic decline (Raustiala and Victor, 1998). Similarly, there is no clear-cut connection between compliance and effectiveness. If the legal standards are set low and commitments codify the changes that governments would be willing to make in the absence of an international agreement, regulatory regimes may have high compliance levels without exerting any significant influence on behavior (Levy, 1993).

While this distinction is important theoretically, in practice it may not always be possible to draw a line between the three conceptual variables. Although mere existence (or lack) of compliance in terms of conformity of behavior to rules does not always indicate the effectiveness (or ineffectiveness) of legal standards, studying

compliance often implies examining the operation of international institutions which may lead to policy prescriptions about their design. Focus on behavioral impacts of regimes, in its turn, may produce evidence of the importance of noncompliance as part of an effective regulatory strategy (Levy, 1993). Giving a broader definition of the effectiveness of international regimes than merely legal compliance or economic efficiency, Young (1999) suggests to focus on any changes in the behavior of actors, in the interests of actors and in the polices and performance of institutions caused by a regime that lead to an improvement in the environment. This definition does not grant compliance a privileged position, but it does not exclude consideration whether compliance is high or low, highlighting the importance of the interaction between legal compliance and political effectiveness.

Much of the recent compliance debate in the rationalist tradition has been centered on identifying regime characteristics that are most conducive to eliciting compliance. According to the enforcement approach based on game theory and collective action theory, compliance decisions of states result from the calculation of costs and benefits of alternative behavioral choices (Olson, 1965; Axelrod, 1984; Downs, Rocke and Barsoom, 1996). Violations occur whenever the net benefits from defection exceed the net benefits from compliance. A regime will be successful if it changes the incentive structure of the problem and increases the costs of noncompliance making it a less attractive option. Coercion in the form of monitoring and sanctions is thus imperative for securing compliance from this point of view.

The alternative management approach to compliance, however, emphasizes that states have a general propensity to comply with international rules. Noncompliance results rather unintentionally from capacity limitations and rule ambiguity (Mitchell, 1994; Chayes and Chayes, 1995). Capacity limitations may be political (the inability of the government to secure ratification or illicit compliance from subnational actors) or economic (lack of financial resources). Rule ambiguity arises from the unclear and imprecise treaty language that allows for different interpretations by the parties. Managerial theorists believe that rather than providing enforcement, international efforts should focus on the problem solving through capacity building, rule interpretation and transparency.

Both these approaches present important insights on the effective strategies to address noncompliance in international cooperation. However, when considered in isolation, they oversimplify the real-life cooperation processes and overlook the interaction between the distinct behavioral mechanisms. Tallberg (2002) argues that compliance systems that combine the enforcement and management mechanisms are most effective in securing rule conformance. Examining the EU compliance system, the author finds that noncompliance in the EU stems from both relative incentives and capacity limitations of states and that monitoring, sanctions, capacity building, rule interpretation and social pressure can coexist and reinforce each other as instruments to induce compliance. These findings indicate the importance of considering the interplay between the two compliance strategies in further research.

Both the enforcement and management schools are primarily static approaches. They assume that once an agreement has been reached, the positions of the actors do no change and there is litte interaction between the actors. At the same time, evidence suggests that bargaining characteristic of the pre-negotiation stage does not end with the conclusion of a treaty. Some scholars view post-agreement bargaining as a mechanism for enforcing compliance and managing problems and thus consider it central to the propositions of both the enforcement and management approaches (Jonsson and Tallberg, 1998). As labeled by Jonsson and Tallberg (1998), compliance bargaining can change the level of compliance, redefine what constitutes compliance and noncompliance and redistribute gains in future bargaining. Studying the effects of compliance bargaining can thus help account for the dynamic elements of enforcement and management and bridge the gap between the two approaches.

A somewhat different perspective on the reasons for compliance has been suggested by constructivist scholars, who invoke theories of legal process and obligation rather than rationalist-instrumentalist explanations. Constructivists believe that compliance is motivated by the internalization of international rules and norms and their incorporation into the actor's value system (Koh, 1997, 1998). State behavior in this view should be understood as interpreted by other states and as intended by the actors themselves so that international obligations are regarded as social constructs which are best analyzed through an intersubjective framework of meaning (Kratochwil and Ruggie, 1986). One of the central concepts in this

approach is the legitimacy of a legal rule or authority. As Hurd (1999) points out, the study of compliance with rules or norms has most often been limited to two of the three devices for social control, i.e. coercion and self-interest, while it has ignored the third mechanism, i.e. legitimacy, without which any analysis of the international system will be incomplete. The perceived legitimacy of a rule provides an actor with an internal reason to comply and because the legitimation occurs through the internalization by the actor of an external standard, it helps to define how the actor sees its interests. One of the criticisms of these approaches is, however, that it is easy to conflate the dependent and independent variables because internalization may be viewed as both a reason for and a constitutive feature of compliance.

Some attempts have been made to reconcile the rationalist and constructivist approaches. These works stress that the logic of consequences where decisions are based on self-centered calculations and the logic of appropriateness where behavior is shaped by social constraints are not mutually exclusive (Finnemore and Sikkink, 1998). Shanon (2000) shows that from the political psychology point of view, violations can be explained by a conflict between personal desires of the actors and normative constraints imposed on them by the prevailing social structure. The focus here is thus on the process of interaction between the agent and the structure. Violations are then possible only if leaders can interpret norms and situations in a manner that justifies noncompliance in particular situations as socially acceptable. In a similar line of research, other authors emphasize the deliberative aspects of social learning and argumentative persuasion that lead to compliance as a result of

preference change (Checkel, 2001), the role of discourses based on interests, science and ethics in encouraging change in behavior (Mitchell, 1998) and the impact of speech acts and condemnatory language on the responsiveness of states to regime allegations of noncompliance (Weisband, 2000). Although intuitively plausible, the challenge with these approaches is to apply their theoretical insights to empirical research.

Another strand of compliance literature deals with the interrelationships between compliance and the nature of the domestic regimes. The dominant view in this approach is that democratic states are more likely to comply with international obligations because norms regarding respect for judicial processes and regard for constitutional constraints carry over into the realm of international politics. Compliance results from the incorporation of international law into the domestic political system and from the replication of international rules in the domestic regulation (Fisher, 1981). Although this approach has some affinity with rationalism where international institutions are believed to have an important influence on the domestic political life, Simmons (1998) insists that "democratic legalism" makes a distinctive contribution by assuming systematic differences between liberal democracies and nondemocracies. Because political constraints are much stronger in the former, liberal states will be more willing to depend on the rule of law in their external behavior as well. The research in this field has, however, paid little attention to the linkages between compliance with international obligations and deviations from liberal institutional norms such as political corruption and weak rule of law.

Plan of Dissertation

The dissertation consists of three separate projects and is organized as follows. Chapter 2 examines the implications of illegal trade in ozone-depleting substances for compliance with the Montreal Protocol (project 1). Since data on illegal trade is not available, the chapter begins with a theoretical model that explains the effect of corruption, the rule of law and environmental tariffs on both legal and illegal imports. The theoretical predictions concerning legal imports are then tested using panel data on CFC consumption reported by the UNEP. Based on the empirical estimates and the model, inferences about illegal trade are made. The basic findings indicate that legal imports are higher in both corrupt countries with weak legal systems and honest regimes with strong judicial institutions in comparison to countries were either corruption is high or the rule of law is weak. However, illegal and total imports are much higher in corrupt countries with weak rule of law and much lower in honest countries with strong legal systems. Thus, higher legal imports in the former signal deterioration in environmental performance, while higher legal imports in the latter indicate better observance of environmental laws.

Chapter 3 deals with controlling transboundary air pollution in Europe (project 2). The analysis focuses on collusion between an environmental inspector and a polluting firm. If the inspector accepts a bribe offered by the firm to misreport sulphur emissions, the level of reported emissions will be lower than the actual level. Since the damage from pollution in a given country depends on both the share of its own emissions that falls within its borders and the spillovers from neighboring

countries, the theoretical model derives predictions about the effect of corruption, the rule of law, the share of own depositions and transboundary spillovers on both reported and actual emissions. The hypothesized relationships regarding reported emissions are tested using spatial econometric techniques and the EMEP data on sulphur pollution. The results suggest that reported emissions are lower in both corrupt regimes with weak rule of law and honest regimes with strong legal system in comparison to countries where either corruption is high or rule of law is weak. Actual emissions and consequently the level of pollution are, however, much higher in corrupt countries with weak judicial institutions than in honest countries with strong legal systems. Thus, lower emission reports in the former imply higher pollution levels while lower emission reports in the latter suggest lower environmental degradation.

Chapter 4 investigates whether regime characteristics such as democratic practices, rule of law and noncorruption are related to past CBRN incidents (project 3). Democratic values and institutions are believed to support and encourage terrorist attacks owing to freedom of association, protection of civil liberties, media coverage of events, and an ability to acquire weapons, funding, and information. Based on data on CBRN incidents, collected by the Monterey Institute of International Studies, odds ratios establish that democratic rights and principles are positively associated with CBRN incidents. Weak rule of law, as characterizing failed states, may be conducive to terrorist groups getting organized, but strong rule of law presents an ideal venue for CBRN incidents. The data also suggest that religious cults,

fundamentalist groups, and nationalist/separatist groups are not more likely than others to engage in CBRN attacks. Moreover, the odds of religious cults and fundamentalists being involved in CBRN events are generally greater where governments are noncorrupt or there is strong rule of law. In addition, transnational terrorist groups are shown to be less likely to conceal their acquisition of CBRN weapons and indiscriminate CBRN attacks are shown to be as likely as discriminate attacks to result in casualties. Negative binomial regressions provide additional evidence for the positive effect of democratic rule and strong rule of law on the number of CBRN incidents.

Chapter 5 concludes and highlights policy recommendations regarding the correct interpretation of data on environmental compliance reported to international monitoring agencies and the potential WMD threat inherent in CBRN terrorism.

Chapter 1 References

Axelrod, Robert (1984), *The Evolution of Cooperation*, London: Penguin.

Chayes, Abram and Antonia H. Chayes (1995), *The New Sovereignty: Compliance with International Regulatory Agreements*, Harvard University Press: Cambridge, Massachusetts.

Checkel, Jeffrey T. (2001), "Why Comply? Social Learning and European Identity Change," *International Organization* 55 (3), 553-588.

Desai, Uday (1998) *Ecological Policy and Politics in Developing Countries: Economic Growth, Democracy and Environment*, Albany, New York: State University of New York Press.

Downs, George W., David M. Rocke and Peter N. Barsoom (1996), "Is the Good News about Compliance Good News about Cooperation?" *International Organization* 50 (3), 379-406.

Finnemore, Martha, and Kathryn Sikkink (1998), "International Norm Dynamics and Political Change," *International Organization* 52, 887-918.

Fisher, Roger (1981), "Improving Compliance with International Law," Charlottesville, VA: University of Virginia Press.

Hurd, Ian (1999), "Legitimacy and Authority in International Politics," *International Organization* 53 (2), 379-408.

Johnston, Michael (1997) "What Can Be Done About Entrenched Corruption?" Paper presented at the Annual World Bank Conference on Development Economics, Washington, D.C., April 30 – May 1.

Jonsson, Christer and Jonas Tallberg (1998), "Compliance and Post-Agreement Bargaining," *European Journal of International Relations* 4 (4), 371-408.

Koh, Harold H. (1998), "Bringing International Law Home," *Houston Law Review* 35 (3), 181-207.

Koh, Harold H. (1997), "Why Do Nations Obey International Law?" *Yale Law Journal* 106, 2598-2659.

Kratochwil FriedrichV., and John G. Ruggie (1986), "International organization: a state of the art on an art of the state," *International Organization* 40 (4), 753-775.

Levy, Marc A. (1993), "European Acid Rain: The Power of Tote-Board Diplomacy," in P.M. Haas, R.O. Keohane, and M.A. Levy (eds), *Institutions for the Earth: Sources of Effective International Environmental Protection*, Cambridge, MA: MIT Press, 75-132.

Mauro, Paolo (1995) "Corruption and Growth," *The Quarterly Journal of Economics* 110 (3), 681-712.

Mauro, Paolo (1997) "Why Worry About Corruption?" *Economic Issues* 6, International Monetary Fund, Washington, D.C.

Mitchell, Ronald B. (1998), "Discourse and Sovereignty: Interests, Science, and Morality in the Regulation of Whaling," *Global Governance* 4, 275-294.

Mitchell, Ronald B. (1994), "Regime Design Matters: International Oil Pollution and Treaty Compliance," *International Organization* 48 (3), 425-458.

Noble, Ronald (2001) "The Role of the Police in Fostering Political Commitment: Remarks by Ronald K. Noble, Interpol Secretary General," 10th International Anti-Corruption Conference, Prague, Czech Republic, October 8, 2001 [http://www.interpol.org/Public/ICPO/speeches/20011008.asp], accessed on May 15th, 2006.

Olson, Mancur (1965), *The Logic of Collective Action: Public Goods and the Theory of Groups*, Cambridge, MA: Harvard University Press.

Pargal, Sheoli., Muthukumara Mani and Mainul Huq (1996), "Inspections and emissions: puzzling survey evidence on industrial water pollution," *Policy Working Paper* No. 1810, World Bank.

Raustiala, Kal and Anne-Marie Slaughter (2002), "International Law, International Relations and Compliance," in Walter Carlsnaes, Thomas Risse and Beth A. Simmons (eds) *Handbook of International Relations*, London: Sage Publications, 538-558.

Shanon, Vaughn P. (2000), "Norms Are What States Make of Them: The Political Psychology of Norm Violation," *International Studies Quarterly* 44, 293-316.

Simmons, Beth A. (1998), "Compliance with International Agreements," *Annual Review of Political Science* 1, 75-93.

Tallberg, Jonas (2002), "Paths to Compliance: Enforcement, Management, and the European Un ion," *International Organization* 56 (3), 609-643.

Thachuk, Kimberley (2005) "Corruption and International Security," *SAIS Review*, vol. XXV no 1.

Victor, David G., and Kal Raustiala (1998), "Conclusions," in David G. Victor, Kal Raustiala and Eugene B. Skolnikoff (eds) *The Implementation and Effectiveness of International Environmental Commitments: Theory and Practice*, Cambridge, MA: The MIT Press, 659-708.

Wei, Shang-Jin (2000) "Local Corruption and Global Capital Flows," *Brookings Papers on Economic Activity* 2000 (2), 303-354.

Weisband, Edward (2000), "Discursive Multilateralism: Global Benchmarks, Shame, and Learning in the ILO Labor Standards Monitoring Regime," *International Studies Quarterly* 44, 643-666.

Young, Oran B. and Marc A. Levy (1999), "The Effectiveness of International Environmental Regimes," in Oran B. Young (ed) *The Effectiveness of International Environmental Regimes: Causal Connections and Behavioral Mechanisms*, Cambridge, MA: The MIT Press.

Chapter 2. Corruption, Illegal Trade and Compliance with the Montreal Protocol

This chapter studies the effect of corruption, the rule of law and environmental tariffs on illegal trade in chlorofluorocarbons (CFCs) controlled by the Montreal Protocol. Since data on illegal trade is not available, it is not possible to test any theoretical conclusions about smuggling. The paper, however, attempts to circumvent the problem by developing a model of illegal trade in CFCs that derives predictions about the effects of corruption, rule of law and environmental tariffs on both legal and illegal imports of CFCs. Then the theoretical predictions concerning legal imports are tested using panel data on CFC consumption. Using the estimates of legal imports, inferences about illegal trade are made. The basic findings indicate that knowledge about the degree of rule of law, corruption and the level of environmental tariffs is needed for the correct interpretation of the data on environmental performance reported to international monitoring agencies.

The Montreal Protocol on Substances that Deplete the Ozone Layer is considered one of the most successful international agreements to-date. It was ratified by over 180 countries and the phase-out of ozone-depleting substances (ODS) detailed in the Protocol is reported to proceed according to schedule. However, unforeseen at the stage of negotiations and first detected in the mid 1990's, illegal trade in ODS has become a cause of serious concern for the future of the

ozone treaty. When the phase-out in industrialized countries began, demand for chlorofluorocarbons (CFCs) remained high, while expanding production in developing (Article 5) countries, which were exempted from compliance with the control measures until 1999, ensured abundant supplies of CFCs to their markets. CFC-12 could be bought for $1 US per kilogram in China and sold for $16 US in the UK.

Black market in CFCs and halons has been tracked since the mid-1990's, when illegal trade in ODS grew to an alarming rate. Since then, ODS smuggling in developed countries has fallen, but developing (Article 5) countries have experienced an upsurge in contraband ODS movement, as they recently began implementing the control measures of the protocol. By increasing available supplies and avoiding the excise tax, CFC smuggling reduces the incentives for users to shift to alternatives and penalizes legitimate companies that made huge investments in developing and supplying alternatives to CFCs.

Smuggling of CFCs has been said to be the second most lucrative smuggling operation after illegal drugs (Brack 1996). The size of the CFC black market is estimated by the UN to range from 20,000 to 30,000 metric tones annually. In late 1995, as much as 20 percent of the CFCs then in use in the world were believed to have been obtained on the black market (Brack 1996). Describing different types of deception practiced by CFC smugglers, Benedick (1998) points out that tracing of illegal shipments is particularly difficult because of the falsification of import documentation[1]. Corruption in the form of bribes collected by government officials

for providing permits and licenses or giving passage through customs has been extensively discussed in recent literature (Shleifer and Vishny 1993). This paper analyzes the linkages between this type of corruption, law enforcement, environmental policy and smuggling under compliance with the Montreal Protocol.

One of the difficulties of studying smuggling is that data on illegal trade is not available. It is not possible to conduct an empirical analysis of illegal imports of CFCs, as there is no way to obtain any reliable data on unauthorized shipments of ODS. Thus, the paper starts with a partial equilibrium analysis of both legal and illegal imports of CFCs, and proceeds to test the theoretical predictions about the response of legal imports to changes in the smuggling-related parameters, using unbalanced panel data for 82 countries. This allows us to circumvent the data problem regarding illegal trade, as we can obtain insights about changes in illegal activity by estimating the model describing legal imports.

The theory builds on the model of illegal trade by Martin and Panagariya (1983) that explicitly incorporates the uncertainty associated with smuggling into the analysis. The probability of detection depends on the ratio of illegal to total imports, making the two types of trade 'joint' goods. The model yields three main predictions. First, a tariff imposed to reduce the negative externality tends to decrease the level of legal trade as smugglers switch to illegal activities so that they can avoid tariff payments. Second, the effect of a fall in corruption on legal imports is conditional on the level of fine imposed as a penalty for breaking the law. Given that the fine is low, a fall in corruption is associated with an increase in legal imports of CFCs, as it

increases the probability of being caught. When the fine is high, the effect is reversed: less corrupt countries tend to have fewer legal imports of CFCs as a fall in corruption decreases total imports and when the fine is high, the effect is amplified. Finally, the effect of the fine is conditional on the level of corruption. In highly corrupt countries, a rise in the fine increases legal imports as it raises the expected cost of illegal trade. In countries with low levels of corruption, the effect is reversed: a higher fine reduces legal imports as total imports fall due to substitution with alternatives and when corruption is low, this effect dominates.

The empirical findings generally support the expectations of the theory. The basic conclusions of the theoretical and empirical analyses can be summarized as follows: knowledge about the level of law enforcement, corruption and environmental tariff may help gain better understanding of the true level of environmental performance in different countries. For example, in countries where corruption is low and law enforcement is weak or where corruption is high and environmental tariffs are high, lower legal imports of CFCs reflect higher environmental performance as they coincide with lower total use of CFCs. However, in highly corrupt countries where law enforcement is weak, lower legal imports indicate deterioration in the observance of environmental regulations as they coincide with higher amounts of CFCs transported illegally and an increase in the overall use of CFCs.

The rest of this chapter consists of five sections. The first section provides a literature review. The second section outlines the theoretical model. The third section

derives the predictions. The fourth section presents the empirical work. The fifth section concludes.

Literature Review

The design of international institutions has been a focus of many studies. From the pure public good perspective, incorporating selective incentives into the design of international agreements improves their effectiveness and mitigates the free-rider problem. Thus, by allowing developing (Article 5) nations to postpone their compliance with the control measures and offering assistance through a Multilateral Fund, the Montreal Protocol has achieved a higher level of cooperation in contrast to other treaties[2] (Sandler and Arce, 2003). But from the moral hazard perspective, the enforcement of new rules and regulations that follows the introduction of international agreements expands the range of activities through which self-interested officials can extract bribes. Although such multilateral agreements as the Convention in International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal have met with success, they have also been threatened by a buoyant illegal trade having opened up possibilities for corruption in issuing paper certificates and movement documents required for the traded goods.

Compliance with laws and regulations restricts private economic activity, and whenever administrative authority is delegated to a self-interested official,

opportunities for corrupt behavior arise. The implementation of environmental controls can be rather costly to industry owners; bribes to public servants are often cheaper than complying with the regulations. Studies of corruption in an environmental context have shown that policy options to monitor environmental compliance in the presence of corruption may be quite limited, as in some cases greater enforcement may lead to stronger incentives to under-provide a public good and consequently increase the instance or scope of bribery[3] (Damania 2002; Mookherjee and Png 1995). Lopez and Mitra (2000) analyze the implications of corruption for the relationship between pollution and growth. They consider both a cooperative Nash bargaining interaction between the government and the private firm generating pollution and a non-cooperative Stackelberg model with the firm as leader, and conclude that in both types of interactions corruption does not preclude the existence of the environmental Kuznets curve, but the turning point occurs at income and pollution levels above those corresponding to the social optimum[4].

Two works provide empirical studies of the effect of corruption on the determination of environmental policy. Fredriksson and Svensson (2003) analyze the effect of corruption on the stringency of environmental policy, conditional on the degree of political instability. Their findings suggest that corruption reduces the stringency of environmental regulations, but as the degree of political instability increases, this effect disappears. Since the probability of the incumbent government remaining in office declines, there are fewer incentives for a producer lobby to influence environmental policy by offering a bribe. Similarly, Damania et al. (2003)

focus on the interaction between corruption and trade liberalization. They conclude that while a reduction in corruption is unambiguously associated with a higher pollution tax, the effect of trade liberalization on environmental regulation depends on the level of corruption: the greater the level of governmental corruption, *ceteris paribus*, the larger the increase in environmental stringency associated with an increase in openness to trade. However, in countries with the most honest governments, the effect of trade openness is reversed: more open trade regimes tend to have less stringent regulations.

The analysis performed in this paper differs from the two studies discussed above because it explores the link between corruption and the *implementation* of environmental policies, as distinct from the *formation* of environmental policy[5]. The distinction is important because there is often a gap between environmental laws and regulations, on the one hand, and their implementation and enforcement, on the other[6]. As Desai (1998) points out, this problem is particularly pertinent to industrializing nations as the "state's autonomy and its capacity to work its will on the society often are quite limited in these countries."

Theoretical Model

The following model assumes that all prices accept that of CFCs are fixed. This facilitating assumption is possible because we focus on a narrowly defined market which is a relatively small sector of the economy. Moreover, taking into account the fact that illegal CFC trade is widespread and that much of CFC

smuggling is conducted by small operations who are also legitimate suppliers of the ozone-depleting chemicals, the number of CFC smugglers should be quite large to preclude monopoly behavior on the CFC market.

Consider a small, open economy that produces a final consumption good Y[7] using two intermediate inputs: chlorofluorocarbons (CFCs), X, and environmentally friendly CFC alternatives, K, where X and K are substitutes. The economy imports all CFCs used in the production process for Y from abroad. The government imposes an ad valorem tariff rate equal to τ on imports of CFCs that cause a negative externality.[8] Distributing firms importing CFCs face strong incentives to transport the good across the border surreptitiously: first, because there are quantitative restrictions on imports of CFCs as part of the implementation of the Montreal Protocol and second, because this allows the distributors to increase their profits by avoiding tariff payments. In the absence of a domestic monopolist, an import quota will raise the domestic price of the imported good by the same amount as a tariff that limits imports to the same level. Therefore, for simplicity, only trade restrictions in the form of a tariff are included in the model. The quantities of legal and illegal CFCs imported by a typical importer are denoted by *l* and *s*, respectively.

The distributors face a probability $\lambda\alpha$ that the illegal activity is detected and results in prosecution, where λ is the fraction of illegal imports, i.e. $\lambda = s/x$ (here, x denotes a given quantity of total imports), and α is a measure of honesty in society, which is scaled to range between 0 and 1 (note that α is inversely related to corruption and can be viewed as the proportion of honest bureaucrats within the

political system). As in Martin and Panagariya (1984) and Copeland (2001), we assume that the probability of detection depends positively on the fraction of illegal imports, so that legal imports may be used to mask illegal activities. In other words, an increase in the probability of being caught may result from (1) an increase in illegal trade with legal imports held constant; or (2) a decrease in legal imports with illegal activity held constant.

As long as smuggling is taking place, the importers offer a bribe to government officials or customs officers to provide them with the needed paperwork or fail to report the contraband if illegal activity is being suspected. Bribe per unit of value of illegal imports is denoted by *b*. The bribe rate is treated as given because, once the black market in CFCs has developed, it is assumed that any importer or corrupt official is too small to have a significant effect on the size of the bribe per unit of illegal imports. If caught smuggling, importers pay a fine of *f* for each unit of the contraband. The fine rate is treated as exogenous[9]. Whenever illegal activity is discovered, the quantity being smuggled is confiscated.

All distributors of CFCs are assumed to be identical and maximize expected profits. Denoting the price of good *X* in the world and domestic markets by p^* and *p*, respectively, the importers' profits denoted by Π_1 and Π_2, when smuggling is and is not successful, respectively, can be written as

$$\Pi_1 = p(s+l) - [p^*(s+l) + \tau p^* l + bp^* s] \quad (1)$$

$$\Pi_2 = pl - [p^*(s+l) + \tau p^* l + bp^* s + fs]. \quad (2)$$

The importers receive a revenue of $p(s+l)$ if not discovered, but only pl if discovered, since the quantity smuggled is confiscated. The terms in square brackets in (1) and (2) indicate the total cost to the distributors of importing $(s+l)$ units of CFCs when smuggling is and is not detected, respectively. $p^*(s+l)$ is the amount the distributors pay to buy $s+l$ units of CFCs at the world market. The amount of tariff they pay for importing *l* units equals $\tau p^* l$. The importers avoid paying the tariff on *s* units that are transported across the border illegally. The amount given as bribes to customs officers or government officials is denoted by $bp^* s$. If caught, the smugglers are fined an amount *fs* for the contraband, making the total costs in (2) greater.

Using (1) and (2), the distributors' expected-profit function can be written as

$$\max_{s,l}\left\{\begin{matrix}(1-\lambda\alpha)\{p(s+l)-[p^*(s+l)+\tau p^* l+bp^* s]\} \\ +\lambda\alpha\{pl-[p^*(s+l)+\tau p^* l+bp^* s+fs]\}\end{matrix} \quad \text{s.t.} \quad s+l=x \right\}.$$

Note that this function is linear in *x* and with a change of variables ($s=\lambda x$ and $l=(1-\lambda)x$) can be rewritten as

$$\begin{aligned}&\max_{\lambda,x}(1-\lambda\alpha)\{px-[p^* x+\tau p^*(1-\lambda)x+bp^*\lambda x]\} \\ &+\lambda\alpha\{p(1-\lambda)x-[p^* x+\tau p^*(1-\lambda)x+bp^*\lambda x+f\lambda x]\}\end{aligned} \tag{3}$$

where *p** is fixed because of the small country assumption. The first-order conditions for the optimal choice of total imports and the fraction of illegal imports satisfy[10]

$$x: \quad p-(\lambda\alpha)(p\lambda)=p^*+(\tau p^*)(1-\lambda)+bp^*\lambda+(\lambda\alpha)(f\lambda) \tag{4}$$

$$\lambda: \quad -(\lambda\alpha)(p)-(\alpha)(p\lambda)=-\tau p^*+bp^*+(\lambda\alpha)(f)+(\alpha)(f\lambda). \tag{5}$$

Note that if the fine and /or bribe is very large, condition (5) implies that $\lambda = 0$. However, since it is more interesting to examine the case where $0 < \lambda < 1$, the analysis below focuses on the interior solution.

Condition (4) simply states that the marginal revenue derived from total trade equals the marginal cost of total imports. The left-hand side of (4) captures the revenue from sale of one extra unit of total imports of CFCs, i.e. *p*, and the expected loss in revenue per unit of total imports if smuggling is detected, i.e. $\lambda\alpha(p\lambda)$[11]. The right-hand side of (4) represents the cost of obtaining one extra unit of total imports consisting of the world price *p**, the effective tariff rate $\tau p^*(1-\lambda)$, the bribe $bp^*\lambda$ and the expected fine $\lambda\alpha(f\lambda)$ paid per unit of total imports. Condition (5) indicates that the marginal revenue from importing one extra unit through illegal as compared to legal channels equals its marginal cost. Thus, the left-hand side of (5) represents the sum of the direct negative effect on revenue resulting from the confiscation of illegal imports if smuggling is detected and the indirect negative effect on revenue through a rise in the probability of detection. Similarly, the last two terms in the right-hand side of (5), indicate the direct and indirect positive effects on the cost of one extra unit of illegal, as opposed to legal, imports. Other terms in the right-hand side of (5) represent the increase in cost in the form of the bribe paid for one extra unit of illegal imports (bp^*) and the direct savings on tariff payments from importing one extra unit illegally, as opposed to legally (τp^*).[12]

Since all importers have the same probability function and are subject to the same values of p^*, p, τ, f and α, they choose the same values of x and λ. Thus, it is possible to consider x and λ as industry-wide values of total imports and the share of illegal imports. Then conditions (4) and (5) can be treated as being applicable to the industry equilibrium. Note that conditions (4) and (5) together determine the domestic price of CFCs p and the fraction of illegal imports λ, given p^*, τ, α, f and b. To determine the quantities of legal and illegal imports, however, the demand for total imports used as inputs in the production process for Y needs to be specified.

But first, consider the following implication of conditions (4) and (5). Solving (5) for bp^* and substituting the resulting expression in the right-hand side of (4), we get

$$p + \alpha p\lambda^2 + \alpha f\lambda^2 = (1+\tau)p^*. \tag{6}$$

Hence, if $\lambda > 0$, $p < (1+\tau)p^*$. The difference between the domestic market price and the tax-inclusive world price as a result of smuggling was defined as price disparity by Pitt (1981). Because traders avoid paying a tariff on the smuggled quantity of the good, they are able to sell it at a price lower than the tariff inclusive world price. An importer may be willing to accept a loss on the legal part of imports since legal trade reduces the probability of detection and thus increases the expected profits from smuggling.

To specify the remainder of the model, it is assumed that the technology for Y exhibits decreasing returns to scale and is given by

$$H(y,x,k)=0\,,$$

which can be inverted to yield

$$y=h(x,k)\,,$$

where h is assumed to be strictly concave and increasing in x and k.

The profit function for producers of good Y can be written as

$$\max_{x,k}\left[p^{y}h(x,k)-px-rk\right],$$

where p^{y} and r denote the domestic prices of good y and CFC alternatives, respectively. The first-order conditions for the optimal choice of inputs satisfy

$$x: \quad p^{y}h_{x}(x,k)=p \tag{7}$$

$$k: \quad p^{y}h_{k}(x,k)=r\,, \tag{8}$$

which set the value of the marginal product of each input equal to its price.

We also assume that in the long run, perfect competition results in zero profits, i.e.,

$$p^{y}h(x,k)=px+rk\,. \tag{9}$$

As in the case of importers, all producers of good Y are subject to the same values of p^{y}, p and r, and therefore they choose identical solution quantities of x and k. Thus, k and x can be relabeled as industry-wide values of alternatives and total imports of CFCs, and conditions (7) and (8) can be treated as being applicable to the industry equilibrium.

Comparative statics

Our primary interest is to find out the effects of corruption, the fine and the tariff on legal and illegal imports of CFCs to derive predictions for the empirical work. First, consider how demand for CFCs responds to changes in the parameters. Totally differentiate (4), and rearrange to get[13]

$$dp = \frac{(1+\tau(1-\lambda)+b\lambda)}{(1-\lambda^2\alpha)}dp^* + \frac{p^*(1-\lambda)}{(1-\lambda^2\alpha)}d\tau + \frac{p^*\lambda}{(1-\lambda^2\alpha)}db + \frac{\lambda^2(p+f)}{(1-\lambda^2\alpha)}d\alpha + \frac{\lambda^2\alpha}{(1-\lambda^2\alpha)}df. \quad (10)$$

Totally differentiating (7), (8), and (9) and rearranging, we obtain (with $dr = 0$)[14]

$$dx = \frac{(h_k h_{xk} - h_x h_{kk})x + h_{kk}h(x,k)}{p^y(h_{xx}h_{kk} - h_{xk}^2)h(x,k)}dp. \quad (11)$$

From the second-order conditions, it follows that the sign of the denominator is positive[15]. To determine the sign of the numerator, solve (7) and (8) for h_x and h_k, substitute the resulting expressions in (11) and use (8) to obtain

$$dx = \frac{(h_{xk}x + h_{kk}k)r}{(p^y)^2(h_{xx}h_{kk} - h_{xk}^2)h(x,k)}dp = \sigma\frac{x}{p}dp, \quad (12)$$

where σ is the price elasticity of demand for CFCs. Since *x* and *k* are substitutes, h_{xk} is negative. σ is negative.

Substitution of (10) into (12) yields (with $dp^* = 0$)

$$\frac{dx}{d\tau} = \sigma\frac{x}{p}\frac{p^*(1-\lambda)}{(1-\lambda^2\alpha)}$$

$$\frac{dx}{d\alpha} = \sigma \frac{x}{p} \frac{\lambda^2 (p+f)}{(1-\lambda^2 \alpha)}$$

$$\frac{dx}{df} = \sigma \frac{x}{p} \frac{\lambda^2 \alpha}{(1-\lambda^2 \alpha)}.$$

Thus, total imports decrease with a rise in tariff (i.e., $dx/d\tau < 0$),an increase in the fine $(\text{i.e., } dx/df < 0)$ and a fall in corruption $(\text{i.e., } dx/d\alpha < 0)$. A rise in tariff, a fall in corruption and an increase in fine all raise the domestic price of CFCs: the tariff increases the cost of legal imports, a fall in corruption increases the detection probability and raises the expected loss from illegal trade and a higher fine results in an increase in the expected cost of smuggling. As the price of CFCs increases, producers' demand for CFCs falls and they substitute alternatives for CFCs.

To find out the response of the fraction of illegal imports to changes in the parameters, differentiate (5) to get

$$d\lambda = -\frac{\lambda}{(p+f)} dp + \frac{\tau - b}{2\alpha(p+f)} dp^* + \frac{p^*}{2\alpha(p+f)} d\tau - \frac{p^*}{2\alpha(p+f)} db - \frac{\lambda}{\alpha} d\alpha - \frac{\lambda}{(p+f)} df. \quad (13)$$

Combine (10) and (13), to obtain (with $db = dp^* = 0$)[16]

$$\frac{d\lambda}{d\tau} = \frac{(1+\lambda^2\alpha - 2\lambda\alpha)p^*}{2\alpha(p+f)(1-\lambda^2\alpha)} \quad (14)$$

$$\frac{d\lambda}{d\alpha} = -\frac{\lambda}{\alpha(1-\lambda^2\alpha)} \quad (15)$$

$$\frac{d\lambda}{df} = -\frac{\lambda}{(p+f)(1-\lambda^2\alpha)}. \quad (16)$$

Note that $(1-2\lambda\alpha+\lambda^2\alpha)$ is positive for all values of α and λ that lie between 0 and 1. Hence, with corruption and the fine held constant, a rise in tariff increases the fraction of illegal imports (i.e., $d\lambda/d\tau > 0$). Although a higher tariff raises the domestic price of CFCs which results in higher losses for the importers if illegal imports are confiscated (the effect is captured by the third term in brackets in the numerator of (14)), legal trade becomes more costly and the importers choose to increase the share of illegal imports. For a given tariff and fine, a rise in corruption increases the fraction of illegal imports (i.e., $d\lambda/d\alpha < 0$). This happens because higher corruption reduces the probability of detection and makes illegal imports relatively more profitable. An increase in fine, with corruption and the tariff held constant, decreases the share of illegal imports (i.e., $d\lambda/df < 0$) as a higher fine raises the expected costs of importing CFCs illegally.

To see how corruption, the fine and tariff affect illegal imports, use $ds = \lambda dx + x d\lambda$ to get[17]:

$$\frac{ds}{d\tau} = \left[\sigma\frac{\lambda x}{p} + \frac{\lambda x}{(p+f)}\right]\frac{p^*(1-\lambda)}{(1-\lambda^2\alpha)} + \frac{p^* x}{2\alpha(p+f)} \tag{17}$$

$$\frac{ds}{d\alpha} = \left[\sigma\frac{\lambda^2(p+f)}{p} - \frac{1}{\alpha}\right]\frac{\lambda x}{(1-\lambda^2\alpha)} \tag{18}$$

$$\frac{ds}{df} = \left[\sigma\frac{\lambda^2\alpha}{p} - \frac{1}{p+f}\right]\frac{\lambda x}{(1-\lambda^2\alpha)}. \tag{19}$$

The results in these equations indicate that a fall in corruption and a rise in fine decrease illegal imports of CFCs (i.e., $ds/d\alpha < 0$ and $ds/df < 0$). A fall in

corruption raises the probability of detection, while a higher penalty increases the expected costs of illegal imports. Either of these effects makes smuggling less attractive. Moreover, by raising the domestic price of CFCs, a fall in corruption and an increase in fine lead to greater substitution of alternatives for CFCs.

The effect of a higher tariff on illegal trade is, however, ambiguous. There are three ways in which a higher tariff effects the quantity of smuggled CFCs: (i) by increasing the domestic price of CFCs, it encourages the producers to change to alternatives; (ii) since a higher price also increases the expected loss in revenue on the confiscated goods, it makes illegal imports relatively less attractive; (iii) it increases the share of smuggled CFCs by raising the cost of legal imports. Effects (i) and (ii) are negative and are captured by the first and second terms in square brackets in (17); effect (iii) is positive and is captured by the third term. The more responsive the demand for CFCs is to changes in price (i.e., the larger is the absolute value of σ), the larger is effect (i). Also, the lower is corruption (i.e., the higher is α), the larger are effects (i) and (ii) and the smaller is effect (iii). Finally, the higher is the value of fine *f*, the smaller are effects (ii) and (iii). From (14) we know that the size of (iii) is always greater than that of (ii), so that the net effect of the tariff on illegal imports will depend on the relative strength of effect (i) and the difference between (ii) and (iii).

Using $dl = (1-\lambda)dx - xd\lambda$, we get

$$\frac{dl}{d\tau} = \left[\sigma\frac{(1-\lambda)^2}{p} - \frac{(1+\lambda^2\alpha-2\lambda\alpha)}{2\alpha(p+f)}\right]\frac{p*x}{(1-\lambda^2\alpha)} \qquad (20)$$

$$\frac{dl}{d\alpha} = \left[\sigma \frac{\lambda(p+f)(1-\lambda)}{p} + \frac{1}{\alpha}\right] \frac{\lambda x}{(1-\lambda^2\alpha)} \tag{21}$$

$$\frac{dl}{df} = \left[\sigma \frac{\lambda\alpha(1-\lambda)}{p} + \frac{1}{p+f}\right] \frac{\lambda x}{(1-\lambda^2\alpha)} \tag{22}$$

From (20), we note that a higher tariff reduces the amount of CFCs imported legally (i.e., $dl/d\tau < 0$). With a rise in tariff, the importers get higher expected profits from illegal relative to legal trade and hence import fewer legal CFCs, and the producers start to use more substitutes as a response to an increase in the domestic price of CFCs.

The effects of corruption and the fine on the quantity of legal imports are, however, ambiguous. A fall in corruption unambiguously reduces the share of illegal imports in the total mix by increasing the probability of detection, but the absolute quantity of legal imports does not necessarily rise. If the absolute value of σ is high, the reduction in total imports due to substitution with alternatives may be so large that, on balance, a fall in corruption reduces legal imports. Note also that if the initial value of fine f is large, the reduction in total imports is amplified so that as corruption falls, the amount of legal imports decreases. Formally,

if $f < -\frac{(1+\sigma(1-\lambda)\lambda\alpha)p}{\sigma(1-\lambda)\lambda\alpha}$, a fall in corruption increases legal imports, but as the fine gets larger, i.e. $f \geq -\frac{(1+\sigma(1-\lambda)\lambda\alpha)p}{\sigma(1-\lambda)\lambda\alpha}$, the effect of a fall in corruption disappears or becomes negative. A higher fine leads to a higher rise in the domestic price of

CFCs as a response to a fall in corruption; the higher is the change in price, the more willing the producers are to use alternatives to CFCs.

Just as a fall in corruption, an increase in fine reduces the share of illegal imports. But since total imports decline due to substitution with alternatives, the absolute quantity of legal imports may fall with a rise in fine. The larger is the absolute value of σ, the larger is the reduction in total imports. Also, the larger is the initial value of α, the greater is the decline in total imports. Formally, if

$\alpha < -\frac{p}{\sigma(1-\lambda)\lambda(p+f)}$, legal imports increase with a rise in fine, while if

$\alpha \geq -\frac{p}{\sigma(1-\lambda)\lambda(p+f)}$, the effect of fine disappears or becomes negative.

Intuitively, the lower is the level of corruption, the higher is the increase in the domestic price of CFCs as a result of a rise in fine and the greater is the decline in the demand for CFCs as producers turn to alternatives.

Equations (19) – (21) have important implications for the empirical analysis below. Although the tariff unambiguously decreases legal imports, the size of its effect depends on both the level of corruption and fine. However, since we do not impose any specific form on the production function for good *Y*, it is not possible to derive the sign of the interaction effects between the tariff and corruption or the fine. Both the sign and the size of the effect of corruption on legal imports depends on the level of fine and tariff, while the sign and the size of the effect of the fine is dependent on the level of corruption and the tariff.

The comparative statics results are summarized in Table 1.

Table 1. Comparative static results

Comparative Statics	Interpretation
$\frac{ds}{d\tau} >=< 0$	As the tariff rises, the share of illegal imports increases. However, total imports fall because producers substitute alternatives for CFCs. If the latter effect dominates, a raise in the tariff may lower illegal imports. If $f > -p - \frac{\left(1-2\lambda\alpha+\lambda^2\alpha\right)}{2\sigma\alpha(1-\lambda)\lambda}$, the latter effect dominates.
$\frac{ds}{d\alpha} < 0$	A fall in corruption decreases illegal imports through a rise in the probability of detection.
$\frac{ds}{df} < 0$	A rise in the fine decreases illegal imports through a rise in their marginal cost.
$\frac{dl}{d\tau} < 0$	A rise in the tariff decreases legal imports through a rise in their marginal cost.
$\frac{dl}{d\alpha} >=< 0$	As corruption falls, the share of illegal imports declines. However, total imports fall because producers substitute alternatives for CFCs. If the latter effect dominates, a fall in corruption may lower legal imports. If $f > -\frac{(1+\sigma(1-\lambda)\lambda\alpha)p}{\sigma(1-\lambda)\lambda\alpha}$, the latter effect dominates.
$\frac{dl}{df} >=< 0$	As the fine increases, the share of illegal imports declines. However, total imports fall because producers substitute alternatives for CFCs. If the latter effect dominates, a rise in the fine may lower legal imports. If $\alpha > -\frac{p}{\sigma(1-\lambda)\lambda(p+f)}$, the latter effect dominates.

Empirical Work

Specification

Although the theoretical model predicts the direction of change in both legal and illegal imports as a response to changes in the parameters, it is not possible to test the relationships captured in (17), (18) and (19) since data on illegal trade is not available. Thus, the objective of the empirical analysis is to test implications on the relationship between the level of legal imports of CFCs, honesty (corruption), the

tariff and the fine captured in (20), (21) and (22) using unbalanced panel data on consumption of CFCs for 82 countries for the period from 1996 to 2002. Based on the results of this estimation, inferences about illegal imports can later be made.

The random-effects regression model is used to take into account important heterogeneity between countries. The hypothesized relationship is:

$$l_{it} = \gamma + z'_{it}\beta^{z} + \beta^{\alpha}\alpha_{it} + \beta^{f} f_{it} + \beta^{\tau}\tau_{it} + \beta^{\alpha f}\alpha_{it} f_{it} + \beta^{\alpha\tau}\alpha_{it}\tau_{it} + \beta^{f\tau} f_{it}\tau_{it} + \nu_{i} + e_{it}, \quad (23)$$

where l_{it} is legal imports of CFCs for country *i* at time period *t*; γ is a constant; z_{it} is a vector of controls; α_{it} is the level of honesty in country *i* at time period *t*; f_{it} is the level of fine; τ_{it} is the level of tariff; β^{z} is a coefficient vector and $\beta^{\alpha}, \beta^{f}, \beta^{\tau}, \beta^{\alpha f}, \beta^{\alpha\tau}, \beta^{f\tau}$ are coefficient scalars. The random error component ν_{i} captures time-invariant country-specific effects and is assumed to be uncorrelated with the explanatory variables. The error component e_{it} is an independent, normally distributed random variable with zero mean and constant variance for all *i* and *t*.

This specification allows interaction effects between honesty and law, between honesty and tariff and between law and tariff implied by the model. The predictions of the theory are:

Prediction 1. The tariff unambiguously decreases legal imports, which implies that the sign of the coefficient on the tariff should be negative even though the size of its effect is dependent on the level of honesty and the fine.

Prediciton 2. Honesty increases legal imports if the fine is low but reduces legal imports if the fine is high. Thus, we should expect the sign of the

coefficient on honesty to be positive and the sign of the coefficient on the interaction term between honesty and the fine to be negative.

Prediciton 3. The fine increases legal imports if honesty is low but reduces legal imports if honesty is high. Our expectations are thus that the sign of the coefficient on the fine will be positive and again, the sign of the coefficient on the interaction between honesty and the fine will be negative.

As explained above, the signs of the interaction effects between honesty and the tariff and the fine and the tariff can not be derived from the theory. Thus our inference about their effects should be based on the empirical estimation.

Data

The data on CFC production and consumption are reported by the United Nations Environmental Program (UNEP), where consumption is defined as production plus imports minus exports[18]. Since the theoretical model assumes that all CFCs are imported, only those countries where CFC production is zero are included in the sample. As a result the data on consumption represent net legal imports of CFCs in tonnes multiplied by ozone-depleting potential (ODP).

An index of corruption is drawn from the International Country Risk Guide (ICRG) produced by The Political Risk Services (PRS) Group, Inc. The ICRG corruption index captures the degree to which "high government officials are likely to demand special payments," but also the extent to which "illegal payments are generally expected throughout lower levels of government" in the form of "bribes

connected with import and export licenses, exchange controls, tax assessment, policy protection, or loans" (Knack and Keefer 1995). In the theoretical model, α is inversely related to corruption representing a measure of public honesty; thus, the ICRG index is referred to as honesty. This corresponds to the scale of the ICRG index where 0 indicates the highest level of corruption, or the lowest level of honesty, and 6 the lowest level of corruption, or the highest level of honesty.

The ICRG dataset contains data on law and order that capture the strength and impartiality of the legal system, on the one hand, and popular observance of the law, on the other. Higher scores indicate "sound political institutions, a strong court system, and provisions for an orderly succession of power." Lower scores indicate "a tradition of depending on physical force or illegal means to settle claims" (Knack and Keefer 1995). Since it is not possible to obtain comparable data on environmental fines in different countries and since countries with strong legal systems are expected to impose higher fines on illegal CFCs, this index is used as a proxy for the level of fine and is further referred to as the rule of law. It ranges from 0 to 6, with 0 being the lowest level and 6 being the highest level of the rule of law.

The connection between the level of fine and the rule of law can be demonstrated by comparing the maximum fines in countries with economies in transition (CEITs) and the European Union (EU) member states. In 2001, the average score in terms of rule of law was 3.8 for CEITs and 5.4 for the EU member states. According to the UNEP OzonAction Newsletter (2001), almost all CEITs had legislation that accorded fines of up to US$25,000 for illegal trade in ODS by that

time, but only one or two countries introduced penalties of imprisonment. In contrast, fines on illegal activities involving ODS in some EU countries could be unlimited and the legislation in the majority of the EU member states ensured imprisonment penalties in addition to fines.

Data on average tariffs for CFCs are taken from the Trade Analysis and Information System (TRAINS) database maintained by the United Nations Conference on Trade and Development (UNCTAD). The dataset provides data on CFC tariffs since 1996. An alternative measure of tariff can be taken from the World Bank's "Trends in Average Tariff Rates for Developing and Industrial Countries, 1986-2003." This database contains average tariff rates for all goods. However, since environmentally conscious countries may have low tariffs on most of the goods, but high tariffs on environmental goods (e.g., developed countries), and vice versa, this is not a very good proxy for tariffs imposed on imports of CFCs. This measure is therefore only used in the robustness analysis as a proxy for the overall openness to trade.

Although in the theoretical analysis it was possible to treat the equilibrium values of total imports and the share of illegal imports (and consequently the values of legal and illegal imports) as being applicable to the whole industry, in the empirical analysis we have to control for the size of the CFC industry in different countries. Population could be used as a proxy for this variable as it reflects the demand for goods where CFCs are used as inputs in the production process. Naturally, the greater is the demand for CFC using goods, the higher are the levels of

legal CFC imports. Besides, to take into account the level of economic development and the demand for environmental quality in different countries, Gross Domestic Product (GDP) is used as a control variable. Moreover, the quadratic term of GDP is added while conducting robustness checks to allow for the possibility of an inverted-U relationship between environmental quality and economic growth as specified in the literature on the Kuznets curve. According to the Kuznets hypothesis, the coefficient on GDP should be positive and the coefficient on the quadratic term of GDP should be negative indicating that imports of CFCs grow at low income levels and decline at high levels. Data on population and GDP are taken from the World Bank's "World Development Indicators." These variables constitute the basic set of controls.

Additionally, the 1986 level of CFC imports is used in some of the robustness checks as a control variable. The level of CFC imports should depend on the marginal cost of satisfying the targets of the Montreal Protocol. The Protocol requires that nations reduce their consumption of CFCs by a certain percentage of their level of consumption in 1986: each party should achieve its 1986 level by July 1, 1989, 75% of its 1986 level by January 1, 1994 and 100% of its 1986 level by January 1, 1996. Countries with high import levels in 1986 initially incurred greater costs of complying with the Protocol than countries with low levels. Thus the initial 1986 level should be positively correlated with legal imports of CFCs. Since some of the countries in the sample could be involved in the production of CFCs in 1986, the

data on CFC imports in 1986 are obtained by subtracting production from consumption; that is why some of the values may be negative.

Summary statistics are reported in Table 2.

Table 2. Descriptive statistics

Variable	Observations	Mean	Std. Dev.	Minimum	Maximum
CFC imports (in ODP tones)	226	740.326	1475.375	0.000	9275.050
Honesty	226	2.884	1.233	0.167	6.000
Rule of Law	226	3.704	1.325	1.000	6.000
Tariff on CFCs	226	5.922	6.036	0.000	35.000
GDP (in ten trillion constant 2000 US $)	226	15.564	62.906	0.073	477.000
Population (in millions)	226	33.218	47.016	0.270	212.000
Average tariff on all goods	225	12.222	7.106	0.000	36.600
1986 CFC imports	219	842.121	1655.673	-4944.000	6626.800

Results

Empirical results from estimation of (23) are presented in Table 3. Model 1 shows results when only GDP and population are included as control variables. GDP enters negatively and significantly implying that the higher is the level of economic development, the greater is the demand for environmental quality and the faster is the process of substitution of alternatives for CFCs[19]. The coefficient on population is positive and significant indicating that an increase in population which measures the demand for goods that use CFCs, such as refrigerators and air conditioners, and

consequently reflects the size of the CFC industry, leads to a higher quantity of legal imports.

The coefficient on honesty is positive and significant at the 10-percent level. The coefficient on the rule of law (which is used as a proxy for the fine in the empirical analysis) is also positive and significant at the 1-percent level. The interaction term between honesty and the rule of law is negative and significant at the 5-percent level suggesting that the effects of honesty and the rule of law on the level of legal imports are interdependent. All of these results are consistent with the theory.

The coefficient on the CFC tariff is negative as predicted by the model but not significant. Note, however, that the interaction between honesty and the CFC tariff is positive and significant at the 5-percent level implying that the effect of tariff on legal imports is conditional on honesty and vice versa, consistent with the theory. The interaction between the tariff and the rule of law is negative but not significant. Although the theoretical model does not yield any predictions about the sign of the interaction effects with the CFC tariff, the empirical findings suggest that the negative impact of the CFC tariff on legal imports is stronger in those countries where corruption is high (i.e., honesty is low).

Table 3. Random-effects GLS regression estimates

	Model 1	Model 2	Model 3	Model 4	Model 5
Honesty	310.433*	335.960*	291.945*	351.141**	286.507*
	(170.796)	(172.550)	(174.003)	(172.271)	(169.842)
Honesty*Rule of law	-76.904**	-84.293**	-67.6267*	-83.804**	-87.242**
	(38.131)	(38.847)	(39.984)	(38.830)	(37.976)
Rule of law	451.207***	456.981***	346.142**	418.347***	353.604***
	(137.771)	(138.208)	(148.338)	(137.870)	(136.309)
Rule of law*CFC tariff	-3.070	-3.060	2.306	-4.791	-4.602
	(9.601)	(9.597)	(9.912)	(9.847)	(9.621)
CFC tariff	-53.166	-51.454	-79.87546*	-33.080	-25.582
	(44.677)	(44.711)	(46.802)	(48.750)	(47.693)
Honesty*CFC tariff	20.853**	20.634*	17.695*	17.684	13.882
	(10.662)	(10.662)	(10.701)	(11.151)	(10.962)
GDP	-7.054***	3.505	8.352	6.932	13.031
	(2.218)	(11.979)	(11.933)	(11.741)	(11.560)
GDP squared		-0.022	-0.030	-0.027	-0.038
		(0.025)	(0.024)	(0.024)	(0.024)
Population	24.903***	23.676***	22.466***	22.113***	20.432***
	(2.907)	(3.209)	(3.191)	(3.220)	(3.170)
Average tariff on all goods			30.741**		
			(15.305)		
1986 CFC imports				0.122*	0.124**
				(0.062)	(0.061)
Time trend					-84.197***
					(26.187)
Constant	-1672.887***	-1710.901***	-1652.011***	-1761.469***	-171.885
	(519.527)	(522.417)	(522.084)	(522.809)	(710.673)
Observations	226	226	225	219	219
Wald statistic	89.90***	92.35***	100.69***	87.48***	103.02***

Notes: Dependent variable is imports of CFCs in ODP tones. Standard errors in parenthesis beneath coefficient estimates. ***,**,* Denotes significance at the 1, 5 and 10 percent level, respectively.

The marginal effect of honesty on legal imports, conditional on the rule of law and the CFC tariff is depicted in Table 4. The columns show the marginal effect of honesty for minimum, mean and maximum values of the rule of law while the rows depict the marginal effect of honesty for minimum, mean and maximum values

of the CFC tariff. For both the minimum and mean values of the tariff, the marginal effect of honesty is positive (and significant) if the rule of law is weak and negative (although not significant) if the rule of law is strong, supporting the theoretical conjectures. When the rule of law is weak (i.e., the penalty for illegal trade is minimal), there are more incentives for illegal trade so that the level of legal imports is maintained high as the latter can be used to mask illegal activities. On the other hand, strong rule of law makes illegal trade a less attractive option; as a result, legal imports fall due to a faster transition to alternatives.

Table 4. Marginal effect of honesty conditional on the rule of law and the CFC tariff

Rule of Law / CFC Tariff	Minimum	Mean	Maximum
Minimum	233.529*	25.616	-150.992
Mean	357.027***	149.113**	-27.494
Maximum	963.390***	755.476**	578.869

***,**,* Denotes significance at the 1, 5 and 10 percent level, respectively

Table 5 depicts the marginal effect of the rule of law conditional on honesty and the CFC tariff where columns refer to the minimum, mean and maximum values of honesty and the rows to the minimum, mean and maximum values of the CFC tariff. Consistent with the theory, the marginal effect is positive (and significant) if honesty is low and negative (although not significant) if honesty is high. Although higher corruption creates a better environment for illegal trade, legal imports should be quite high so that they could be used as a cover for smuggling. In countries where

honesty is very high, the rule of law has a negative effect on legal imports because CFCs become very expensive and producers switch to alternatives.

Table 5. Marginal effect of law conditional on honesty and the CFC tariff

Honesty / CFC Tariff	Minimum	Mean	Maximum
Minimum	438.389***	229.427**	-10.218
Mean	420.207***	211.244***	-28.401
Maximum	330.933	121.970	-117.675

***,**,* Denotes significance at the 1, 5 and 10 percent level, respectively

The marginal effect of the CFC tariff on legal imports conditional on honesty and the rule of law is shown in Table 6. The columns indicate the minimum, mean and maximum values of the rule of law and the rows the minimum, mean and maximum values of honesty. The predictions of the theory are supported at the low level of honesty where the marginal effect of CFC tariff on legal imports is negative regardless of the level of the rule of law and significant at the mean and maximum values. When honesty is high, the marginal effect becomes positive, inconsistent with the theory. None of the positive effects is, however, significant. Thus, Table 6 provides evidence, even though weak, for the theoretical conclusion that legal imports will be lower in those countries that have higher tariffs on CFCs. The results also suggest that the stronger is the rule of law and the higher is the tariff, the lower are legal imports of CFCs. A higher fine reduces the incentives for illegal trade, while a higher tariff results in faster substitution for alternatives.

Now we can proceed to examine changes in illegal imports based on the regression estimates and the implications of the theory. It turns out that knowledge about a country's level of corruption and rule of law may help determine the actual level of compliance with the Montreal Protocol. Tables 4 and 5 show that both countries with strong rule of law and low corruption and countries with weak rule of law and high corruption have lower legal imports of CFCs than countries where either rule of law is strong and corruption is high or rule of law is weak and corruption is low. Since the theory suggests that total and illegal imports are also lower in countries with strong rule of law and low corruption and higher in countries with weak rule of law and high corruption, we can conclude that lower legal imports in the former is a sign of better observance of environmental regulations (which require a decrease in the consumption of CFCs), while lower legal imports in the latter point to widespread illegal activity and deterioration in environmental performance. [20]

Table 6. Marginal effect of the CFC tariff conditional on honesty and the rule of law

Rule of Law / Honesty	Minimum	Mean	Maximum
Minimum	-52.761	-61.061**	-68.112*
Mean	3.901	-4.399	-11.450
Maximum	68.882	60.582	53.531

***,**,* Denotes significance at the 1, 5 and 10 percent level, respectively

Similarly, Table 6 shows that legal imports are lower in both countries with weak rule of law and low CFC tariffs and countries with strong rule of law and high CFC tariffs than in countries with either weak rule of law and high CFC tariffs or

strong rule of law and low CFC tariffs. The theoretical model suggests that total imports of CFCs are higher in the former and lower in the latter, so that lower legal imports in countries with weak rule of law and low tariffs point to a slower transition to alternatives and a lower level of compliance with the Montreal Protocol.

Robustness checks

Since the empirical model includes three interaction terms, there is a possibility that the results are influenced by high correlation between the explanatory variables. To see whether the inclusion of additional variables or changes to the sample size may have a significant impact on the coefficient estimates, a few robustness tests on the results of Model 1 reported in Table 3 are warranted.

In Model 2, the quadratic term of GDP is added to account for the possibility of an inverted-U relationship between economic growth and demand for environmental quality. The signs of coefficients on both of the GDP variables are as expected; none of them is however, significant. All other results remain practically the same. In Model 3, an experiment with the average tariff on all goods as an additional control variable is made. The rationale behind the inclusion of this variable is that the overall openness to trade (i.e., lower average tariffs) may be negatively correlated with legal imports of CFCs as open trade facilitates the introduction and procurement of CFC free technologies and products and CFCs are substituted with alternatives. The coefficient on the CFC tariff becomes significant, and all the other findings continue to hold. In Model 4, yet another variable, the 1986

level of CFC imports, is added to the set of controls. Its coefficient is positive and significant at the 10-percent level, supporting the hypothesis that the level of imports in 1986, used as a benchmark for verifying compliance with the protocol, should be correlated with the level of imports in subsequent years. However, with the inclusion of the 1986 import level, the interaction term between honesty and the CFC tariff becomes insignificant; all other results do not change much. Finally, Model 5 contains the time trend in addition to all other variables. The time trend captures the increasing reductions in the use of CFCs specified in the phase out schedule of the Montreal Protocol as well as any dynamic changes in technological development and changes in preferences due to education. Its coefficient is negative and significant, implying that legal imports of CFCs decline with time.

Moreover, since we have an unbalanced panel data and the number of overall observations is not much higher than 200, all of the five models in Table 3 were estimated using the maximum-likelihood method. The estimates are not reported here, but all of the findings remain intact.

Since Article 5 countries were allowed to delay the implementation of the control provisions in the Montreal Protocol until 1999, all of the five models presented in Table 3 were estimated on a smaller sample that included observations only on Article 5 developing countries. (Since there are 18 non-Article 5 countries in the sample, it was not possible to estimate the models using only non-Article 5 countries.) Broadly speaking, the primary findings are confirmed in this subsample; however, the coefficient on honesty and its interaction effect with the rule of law

become insignificant. A possible explanation may be that since Article-5 countries could delay their compliance with the Montreal Protocol until 1999, corruption did not play a significant role before that date.

Concluding Remarks

In this paper, a partial equilibrium model of illegal trade in environmental goods is analyzed. Because of the clandestine nature of smuggling, it is not possible to test the predictions of the theory about the extent and direction of response of the illegal activity to changes in parameters. But the theoretical model allowed us to determine changes in legal activity taking place in the presence of smuggling and test the theoretical predictions using panel data on legal imports of CFCs.

Both the theoretical and empirical conclusions have important implications for determining compliance with environmental regulations under an international treaty when the imposition of quantitative restrictions results in the smuggling of certain polluting substances across borders. Since illegal trade in these substances cannot be observed, data on legal imports reported to international monitoring agencies do not always reflect the actual level of compliance with the requirements of the treaty. The analysis in this paper shows that knowledge about legal environment, the level of corruption and environmental tariffs in different countries may help international observers gain better understanding of the true level of pollution emitted in those countries. For example, in countries where penalties for illegal behavior are high, lower corruption or higher environmental tariffs lead to

lower legal imports of CFCs. Since lower legal imports in this case are accompanied with lower total imports of CFCs, they point to higher environmental performance. However, in highly corrupt countries where penalties are low, lower legal imports indicate that higher amounts of CFCs have been transported illegally and the overall use of CFCs has been increased.

Both the theory and the empirical evidence identify an interaction between corruption, rule of law, environmental tariff and illegal trade. In general, higher penalties for illegal behavior and lower corruption reduce the overall use of CFCs and the best outcome is reached in those countries where the two complement each other. The results regarding the effect of tariff are rather mixed but it is clear that the negative effect of tariff on legal imports is more pronounced when the rule of law is strong.

This study focuses on compliance with the Montreal Protocol, but could be extended to other environmental issues, laying the groundwork for a more general analysis of the role corruption plays in securing adherence to international agreements.

Chapter 2 Notes

[1] There is evidence from the Environmental Investigation Agency (EIA) that Pakistan's Ministry of Commerce has issued import authorization for shipments of CFCs to parties who are not involved in the refrigeration business, and have never before imported refrigerants. EIA's report "A Crime against Nature," cites examples of illegal traders in China telling EIA undercover investigators that they will be able to secure the necessary papers from the local authorities, or when they in fact produce documents for smuggled shipments stamped by the China Council for the Promotion of International Trade (Shanghai).

[2] Sandler and Arce (2003) analyze benefit-cost duality to differentiate between pure public goods and commons and find that a public good contribution scenario involves positive inducements while a commons game is characterized by selective punishments, which are more difficult to implement. They compare the Montreal Protocol (a contribution problem), which resulted in widespread participation, to the Kyoto Protocol on climate change (a commons problem).

[3] Damania (2002) using a principal-agent framework considers a case when emission tax is imposed on the firm that emits pollution and concludes that a higher tax creates stronger incentives to underreport for the inspector charged with monitoring pollution levels by the government, which in turn requires greater auditing. Mookherjee and Png in a similar setting show that penalties for corruption and the extent of bribery may reverse direction so that "small increases in penalties may raise bribery, while larger increases will reduce it."

[4] According to the Kuznets curve hypothesis, the relationship between economic growth and environmental degradation takes an inverted-U shape so that at low levels of income countries value material well-being more than environmental quality but as their income grows and cleaner production technologies develop public demand for higher environmental standards increases. Empirical estimations of the Kuznets curve have been done by Grossman and Krueger (1995), Shafik (1994), Cole et al. (1997), Kaufmann *et al.* (1998) and others.

[5] Most of the studies of the Montreal Protocol also focus on the participation or ratification decision rather than on the actual implementation of the provisions in the Protocol (see Beron, Murdoch and Vijverberg (2003) and Congleton (1992)).

[6] A simultaneous analysis of both the participation decision and the level of participation in an environmental treaty can be found in Murdoch, Sandler and

Vijverberg (2003), who formulate a two-stage game, for which nations first decide whether or not to participate and then choose their level of participation.

[7] For example, *y* could stand for the manufacture of refrigerators or air-conditioners.

[8] The government imposes the tariff to reduce the imports of CFCs but the assumption is that once the tariff is set, it is costly for the government to change the tariff schedule often. Thus, the tariff is treated as exogenous.

[9] This is a reasonable approximation because as indicated in Copeland (2001), endogenizing the fine would require an analysis of the entire legal system.

[10] Condition (4) implies zero expected profits for the importer. To see that, set the expected profit function equal to zero, divide it by *x* and rearrange, to get (4).

[11] The total loss in revenue if illegal imports are discovered and confiscated can be written as $-\lambda\alpha(p\lambda x)$.

[12] Condition (5) can be rewritten as $2\lambda\alpha p + 2\lambda\alpha f + bp^* = \pi p^*$, where the left-hand side represents the expected loss (consisting of a decrease in revenue and an increase in cost) from choosing to import one extra unit of CFCs illegally instead of legally and the right-hand side indicates the expected gain.

[13] We used (5) to eliminate $\frac{(2\lambda\alpha p - \pi p^* + bp^* + 2\lambda\alpha f)}{(1-\lambda^2\alpha)} d\lambda$ from (10).

[14]The change in the price of alternatives is set equal to zero because the change of technology required for the introduction of alternatives or adjustment of equipment that uses CFCs is rather costly and is likely to be slow. Therefore, it is assumed that the price of alternatives did not change much in the 10-year period covered in the empirical analysis.

[15] The second-order condition requires that $p^y\left(h_{xx}dx^2 + 2h_{xk}dxdk + h_{kk}dk^2\right) < 0$. One of the conditions for the quadratic form in the brackets to be negative is that the Hessian determinant $\left(h_{xx}h_{kk} - h_{xk}^2\right)$ should be positive.

[16] As long as there is demand for illegal shipments of CFCs, the distributors will transport CFCs illegally to those countries where the bribe rate is the lowest, so that eventually competition will beat down the bribe rate to the lowest expected marginal cost of the services provided by corrupt governmental officials or customs officers. Therefore, it is assumed that the bribe rate per unit of value of illegal imports is

constant. The change in the world price of CFCs is also set equal to zero in developing the theoretical model since later in the empirical analysis, we only need to control for changes in the world price across periods as it does not change across countries.

[17] Note that $d\lambda = \frac{(1+\lambda^2\alpha-2\lambda\alpha)p^*}{2\alpha(p+f)(1-\lambda^2\alpha)}d\tau - \frac{\lambda}{\alpha(1-\lambda^2\alpha)}d\alpha - \frac{\lambda}{(p+f)(1-\lambda^2\alpha)}df$ and $dx = \sigma\frac{x}{p}\frac{p^*(1-\lambda)}{(1-\lambda^2\alpha)}d\tau + \sigma\frac{x}{p}\frac{\lambda^2(p+f)}{(1-\lambda^2\alpha)}d\alpha + \sigma\frac{x}{p}\frac{\lambda^2\alpha}{(1-\lambda^2\alpha)}df$ with $db = dp^* = dr = 0$.

[18] Only data on CFC-11, CFC-12, CFC-113, CFC-114 and CFC-115 listed in Annex A of Group I of the Montreal Protocol were used in the analysis since illegal trade in these substances has been particularly widespread.

[19] This result is consistent with Murdoch and Sandler (1997), who show that there is a nearly linear relationship between CFC reductions and national income prior to the Montreal Protocol taking effect.

[20] In our dataset, countries with strong rule of law and low corruption are high-income nations whose environmental performance has traditionally been very strong. For example in 1998, Canada, Denmark, Finland, Iceland, Netherlands and Sweden were assigned the maximum value of 6 both in the honesty and legal system ratings.

Chapter 2 References

Benedick, Richard Elliot (1998), *Ozone Diplomacy: New Directions in Safeguarding the Planet*, Harvard University Press: Cambridge, MA.

Beron, Kurt J., James C. Murdoch, and Wim P.M. Vijverberg (2003), "Why Cooperate? Public Goods, Economic Power, and the Montreal Protocol," *The Review of Economics and Statistics* 85 (2), 286-297.

Brack, Duncan (1996), *International Trade and the Montreal Protocol*, London: Royal Institute of International Affairs.

Cole, M.A., A.J. Rayner, and J.M. Bates (1997), "The Environmental Kuznets curve: an Empirical Analysis," *Environmental and Development Economics*, 2, 401-416.

Congleton, Roger D. (1992), "Political Institutions and Pollution Control," *The review of Economics and Statistic* 74 (3), 412-421.

Copeland, Brian R. (2001), "International Trade in Waste Products in the Presence of Illegal Disposal," in A. A. Batabyal, H. Beladi, eds., *The Economics of International Trade and the Environment*, Lewis Publishers, Boca Raton.

Damania, Richard (2002), "Environmental Controls with Corrupt Bureaucrats," *Environment and Development Economics* 7, 407-427.

Damania, Richard, Per G. Fredriksson, and John A. List (2003), "Trade Liberalization, Corruption, and Environmental Policy Formation: Theory and Evidence," *Journal of Environmental Economics and Management* 46, 490-512.

Desai, Uday (1998), *Ecological Policy and Politics in Developing Countries: Economic Growth, Democracy and Environment*, State University of New York Press, Albany.

Fredriksson, Per G., and Jakob Svensson (2003), "Political Instability, Corruption and Policy Formation: The Case of Environmental Policy," *Journal of Public Economics* 87, 1383-1405.

Grossman, Gene M., and Alan B. Krueger (1995), "Economic Growth and the Environment," *The Quarterly Journal of Economics* 110 (2), 353-377.

Kaufmann, Robert K., Brynhildur Davidsdottir, Sophie Garnham, and Peter Pauly (1998), "The Determinants of Atmospheric SO_2 Concentrations: Reconsidering the Environmental Kuznets Curve," *Ecological Economics* 25, 209-220.

Knack, S., and P. Keefer (1995), "Institutions and economic performance: Cross-country tests using alternative institutional measures," *Economics and Politics* 7 (3), 207-227.

Lopez, Ramon, and Siddhartha Mitra (2000), "Corruption, Pollution, and the Kuznets Environment Curve," *Journal of Environmental Economics and Management* 40, 13-150.

Martin, Lawrence, and Arvind Panagariya (1984), "Smuggling, Trade, and Price Disparity: A Crime Theoretic Approach," *Journal of International Economics* 17, 201-217.

Mookherjee, Dilip, and I.P.L. Png (1995), "Corruptible Law Enforcers: How Should They Be Compensated?" *The Economic Journal* 105 (428), 145-159.

Murdoch, James C., and Todd Sandler (1997), "The Voluntary Provision of a Pure Public Good: The Case of Reduced CFC Emissions and the Montreal Protocol," *Journal of Public Economics* 63, 331-349.

Murdoch, James C., Todd Sandler, and Wim P.M. Vijverberg (2003), "The Participation Decision versus the Level of Participation in an Environmental Treaty: a Spatial Probit Analysis," *Journal of Public Economics* 8, 337-362.

Pitt, Mark M. (1981), "Smuggling and Price Disparity," *Journal of International Economics* 11, 44-458.

Sandler, Todd, and Daniel G. Arce M. (2003), "Pure Public Goods versus Commons: Benefit-Cost Duality," *Land Economics* 79 (3), 355-368.

Shafik, Nemat (1994), "Economic Development and Environmental Quality: An Econometric Analysis," *Oxford Economic Papers*, New Series 46, Special Issue on Environmental Economics, 757-773.

Shleifer, Andrei, and Robert W. Vishny (1993), "Corruption," *The Quarterly Journal of Economics* 108 (3), 599-617.

United Nations Environment Program, (2001) “Illegal trade in ozone depleting substances: is there a hole in the Montreal Protocol?” OzonAction Program, Division of Technology, Industry and Economics, OzonAction Newsletter Special Supplement, Number 6.

Chapter 3. Corruptible Inspectors and Air Pollution in Europe

This chapter examines transboundary air pollution in Europe. The focus is on a polluting firm that has strong incentives to bribe an environmental inspector to report emissions lower that the actual levels. Since part of the emissions from one nation falls on the territory of neighboring countries, transboundary spillovers are taken into account. The theoretical model derives predictions about the effect of corruption, the rule of law and transbpundary spillovers on both actual and reported emissions. The hypothesized relationships regarding reported emissions are tested using spatial econometric techniques and the EMEP data on sulphur pollution. Inferences about actual pollution levels are made. The findings indicate that both corrupt countries with weak legal systems and honest regimes with strong judicial institutions have relatively low emission reports. However, actual emissions in the former are much higher than in the latter, indicating lower environmental performance.

The link between sulphur emissions in continental Europe and the acidification of lakes in Scandinavia was first suspected by scientists during the 1960s. As evidence that pollutants could travel hundreds of kilometers from their point of emission to affect air quality and ecosystems far away had accumulated, the need for regional solutions to address the problem was soon recognized. International efforts to improve the air quality led to the ratification of the

Convention on Long-Range Transboundary Air Pollution (LRTAP), signed in Geneva in 1979. The convention has set a broad framework for action to stop air pollution and has been extended by three specific protocols aimed at reducing sulphur dioxide emissions to the atmosphere.

Although from1980 to 2000, there has been a considerable decrease in sulphur emissions over most parts of Europe (the overall reduction has been nearly 70%), there are large differences in achievements between countries and regions. The largest reductions, close to 90%, have been achieved in regions such as Austria-Germany-Switzerland and the Nordic countries. The smallest reductions are seen in south-eastern Europe[1], where the emissions in average have decreased by around 40%. In several Mediterranean countries and in Iceland, there have even been increasing emissions during the period.

This research project suggests that the amount of pollution produced by different countries may partly depend on such political conditions as corruption and the rule of law. In order to implement the changes required by the protocols, governments introduce a system of charges and/or taxes on emissions. For example, in Bulgaria where the charge for air pollution is calculated taking into account pollutant type, period of discharge, quantity over the admissible level, and price per kg, the offender must pay monthly until emissions reach admissible level. However, the task of monitoring the degree of compliance with environmental regulations is usually delegated to bureaucrats who act as governmental agents. If these agents are self-interested, they may exploit their administrative authority for personal gain,

rather than the purposes intended by the policy makers, and extract bribes. Bribery is facilitated by weak enforcement on the part of the government or lack of rule of law.

The paper focuses on the effects of corruption and the fine imposed on environmental violations on compliance with regulations that have to take into account the long-range transport of the pollutants. When environmental inspectors who are appointed by the government to monitor pollution from firms accept a bribe to report emissions lower than the actual level, there exists a gap between the levels of actual and reported emissions. If the firm and the inspector never get caught, it is impossible to obtain data on the amount of emissions that did not get into the reports, while the data on reported emissions are available in any event.[2] Thus, the analysis begins with a theoretical model that derives predictions about the effects of corruption, the fine imposed on a polluting firm and an inspector for underreporting and transboundary spillovers for both total and reported emissions. Then, the theoretical conjectures are tested using data for 40 European countries for five separate years and inferences about total emissions and the difference between total and reported emissions are made.

The basic conclusions of the theory for reported emissions can be summarized as follows. A fall in corruption increases reported emissions if the fine rate is high; however, it decreases reported emissions if the fine rate is low. The intuition behind this result is that as corruption declines, the expected fine for underreporting rises and it is in the interests of the firm and the inspector to

simultaneously increase reported emissions and lower actual emissions. However, as actual emissions go down, the damage from an additional unit of pollution declines and the government starts to spend fewer resources on auditing. As a result, reported emissions may fall with a fall in corruption. The incentives for underreporting are particularly strong when the fine rate is low. A higher fine rate increases emission reports if corruption is low; however, the effect is reversed if corruption is high. The explanation is similar to the one above: as the fine rate gets higher, the expected penalty for underreporting increases encouraging the firm and the inspector to increase reported and lower actual emissions. When the amounts of actual emissions decline, the damage from an extra unit of pollution is rather low and the government audits are conducted less often which may cause reported emissions to decline with a rise in the fine rate. The latter effect should be particularly strong when corruption is high.

These theoretical predictions are tested using indices on corruption and the rule of law constructed by the International Country Risk Guide. The rule of law is used as a proxy for the fine rate imposed on environmental violations in the empirical analysis since higher fine rates point to a more severe penal code applied to environmental crimes and the latter is characteristic of sound political institutions and a strong court system able to enforce environmental laws. The empirical analysis largely supports the predictions of the theory. In countries with weak rule of law (and consequently lower fines) and high corruption, an improvement in either of the two conditions is associated with lower emission reports. However, in countries where

the rule of law is relatively strong and corruption is relatively low, a similar improvement results in higher emission reports.

The rest of the paper contains five sections. The first section presents the literature review. The theoretical model and predictions are derived in the second section. The third section contains the empirical model and the data. The fourth section presents the empirical results. The fifth section concludes.

Literature Review

According to Barrett (2003), international institutions are successful only if they incorporate "mechanisms like carrots (positive incentives) and sticks (negative incentives) that make it attractive for countries to contribute to the greater good." Compliance levels per se may sometimes be considered as an important evaluative criteria in regime design (Mitchell, 1994); however, in many cases, a higher level of compliance may only be an indication that the international agreements codify what most of the parties were planning to do anyway (Downs et al., 1996). A number of studies argue that the Helsinki Protocol on the Reduction of Sulphur Emissions and their Transboundary Fluxes did not noticeably change the behavior of states as most of them were going to reduce their emissions even if the agreement had never been negotiated (Levy, 1993; Levy, 1995; Murdoch and Sandler, 1997a; Murdoch et al., 1997; Murdoch et al., 2003; Ringquist and Kostadinova, 2005). Similar conclusions are drawn in Barrett (1994) and Murdoch and Sandler (1997b) with respect to the *initial* Montreal Protocol; however, the amendments to the protocol (in particular, the

London Amendment) have changed the incentive structure, so that by differentiating between poor and rich nations and by requiring that the rich countries offer financial assistance to developing countries through a Multilateral Fund , the Montreal Protocol has achieved a higher level of cooperation in contrast to other treaties (Barrett, 2003; Sandler and Arce, 2003).

There is an extensive literature on environmental regulation, which focuses upon policy instruments (Burrows, 1977; Burrows, 1979), compliance behavior and penalties (Keller, 1991; Malik, 1990; van Egteren and Weber, 1996; Heyes and Rickman, 1999), the implications of political institutional arrangements (Congleton, 1992) and uncertainty (Downs and Rocke, 1995) for pollution control. This literature, however, has largely ignored the effect of corruption on environmental compliance.

The inherent difficulty of collecting (and hence the nonexistence of) good empirical data on the subject of corruption makes research in this area quite challenging. In recent years, however, a number of subjective indices that rank countries in terms of corruption have appeared resulting in a new interest in the implications of corruption for political and economic behavior. Following Bardhan (1997), corruption in this paper is defined as “the use of public office for private gains, where an official (the agent) entrusted with carrying out a task by the public (the principal) engages in some sort of malfeasance for private enrichment which is difficult to monitor for the principal”. This perspective is similar to Shleifer and

Vishny's (1993) view of corruption as "the sale of government officials of government property for personal gain."

A lot of literature on corruption has focused on the incentives for bribery and ways to lower the benefits to be gained from it. Rose-Ackerman (1975), for example, studies the relationship between market structure and the incidence of corrupt dealings in the government contracting process. Mookherjee and Png (1995) apply the analysis of the optimal compensation policy to the problem of environmental pollution. They show that an increase in the penalty for corruption imposed on the inspector charged with monitoring pollution from a factory may raise the bribe rather than reduce corruption and that a sufficiently large, discrete, increase in the penalty is necessary to eradicate bribery.

As Klitgaard (1998) points out, tax departments are often one of those contexts that are most conducive to corruption, particularly in developing countries (Klitgaard 1998). A number of studies have dealt with tax evasion in the area of environmental pollution. Damania (2002), for example, examines the optimal design of environmental regulations when the environmental inspector and the firm emitting pollution may collude to misreport emissions and finds that corruption even though can be deterred, substantially impedes the ability of a regulator to control environmentally degrading activities.

The literature on compliance also states that countries respecting the rule of law are far more likely to comply with their international commitments (Simmons, 2000). Interestingly, in the case of the formation of environmental policy,

Fredrikksson and Mani (2002) find that an increase in the degree of rule of law may have two opposing effects. On the one hand, a stronger legal system results in a higher stringency of environmental policy. On the other hand, a greater degree of rule of law raises a polluting industry lobby's incentives to offer the incumbent government a bribe in return for favorable policies because, as a result of lower costs involved with protecting property rights, the industry group can keep a greater share of profits; thus, the stringency of environmental policy falls. Although this study examines the process of environmental policy formation as opposed to compliance with existing regulations, it points to the need for considering the joint impacts of corruption and rule of law on environmental performance as investigating their separate effects is not enough.

Becasue sulphur dioxide emissions may remain in the air for several days and be transported across national boundaries by winds, governments are not expected to "internalize" transboundary spillovers and as a result, the international abatement is likely to be inefficient. In the absence of supranational governments with enforcing power, local planners may act strategically with regard to national abatement effort. Murdoch and Sandler (1997b) build an impure public subscription model of sulphur dioxide emission reductions that accounts for transport of emissions across borders and then test their theoretical predictions using spatial autoregressive techniques. In a later paper, Murdoch et al. (2003) augment this analysis to a two-stage game, for which nations first decide whether or not to ratify the Helsinki Protocol (that mandates the reduction of sulphur dioxide by 30%) and then they choose their level

of participation. Both studies find that a country's emission cutbacks decrease as spillins resulting from the emission reductions by other countries increase, pointing to the problem of free-riding in transboundary pollution scenarios. Similar evidence is presented in Ansuategi (2003), who addresses the relationship between income and sulphur emissions by considering the transboundary nature of this type of pollutant. Murdoch et al. (2003) also show that spillins have the opposite effect at the ratification stage where they represent the potential gains from cooperation.

Theoretical Model

Consider a firm which, as a result of its production process, discharges emissions (x). To control pollution, the government levies an emissions tax (τ) on each unit of emissions and engages an inspector to monitor pollution from the firm. The tax paid by the firm is based on the level of emissions reported by the inspector ($\hat{x}$). This creates an opportunity for the inspector and firm to engage in corrupt behavior: the firm may offer a bribe (b) to the inspector to report emissions $\hat{x} \leq x$. For simplicity, all firms and inspectors are assumed to be identical. The probability with which word of a bribe may leak out and result in prosecution is given by $\alpha\lambda(\hat{x})$, where $\alpha \in [0,1]$ denotes the proportion of honest bureaucrats in the judiciary (an inverse measure of corruption) and $\lambda(\hat{x})$ is the probability of an audit by a government agency. It is supposed that λ is decreasing in the level of reported emissions $\hat{x}$.

If information about the bribe and the firm's true discharge leaks out, the regulator imposes a fine $p^F(\theta)(x-\hat{x})$ on the firm and a fine $p^I(\theta)(x-\hat{x})$ on the inspector, where θ denotes the penalty rate. The fine paid per unit of emissions missing in the report is allowed to differ for the firm and the inspector; however, both the penalty imposed on the firm and that on the inspector are assumed to depend on some parameter θ which represents the severity of the penal code applied to environmental violations in general. Alternatively, this parameter can be viewed as an indicator of the strength of the legal system since concern with the environment is characteristic of sound political institutions and a strong court system able to enforce environmental laws. It is assumed that the fines for corruption per unit of emissions are increasing in the penalty rate (θ) at an increasing rate. Note that if the firm and the inspector get away with bribery, the true level of emissions does not become known to the government. However, if bribery is uncovered and the violators are prosecuted, it is assumed that the government can procure information about the actual level of emissions so that the fine imposed is commensurate with the level of underreporting.

The sequence of events is as follows. First, the government sets the tax rate. Taking the tax rate as given, the firm and the inspector jointly determine the level of total (x) and reported ($\hat{x}$) emissions. The problem is solved by backward induction.

If the firm decides to bribe the inspector an amount $b>0$ to report emissions $\hat{x} < x$, the expected gains to the firm from bribery are:

$$U^f = [\pi(x) - \tau\hat{x} - b - \alpha\lambda(\hat{x})p^F(\theta)(x - \hat{x})] - [\pi(x^h) - \tau x^h]. \quad (1)$$

The terms in the first square parenthesis in the above expression represent the expected payoffs to the firm from offering a bribe. $\pi(x)$ denotes the firm's profits from emission levels *x* under corrupt behavior, gross of taxes, bribes and fines. The expected costs of a bribe include the taxes paid by the firm on reported emissions $\tau\hat{x}$, the amount of the bribe *b* and the fine the firm pays to the regulator $p^F(\theta)(x - \hat{x})$ with probability $\alpha\lambda(\hat{x})$. The terms in the second square parenthesis represent the payoffs when the firm does not pay a bribe. The firm receives gross profits of $\pi(x^h)$ where x^h denotes emission levels under honest behavior and pays taxes on actual emissions of τx^h.

The expected gains to the inspector are:

$$U^i = [w + b - \alpha\lambda(\hat{x})p^I(\theta)(x - \hat{x})] - w, \quad (2)$$

where *w* is the fixed salary received by the inspector. The terms in the square parenthesis represent the expected payoffs to the inspector from accepting a bribe. The inspector receives a fixed salary of *w* and a bribe of *b*. With probability $\alpha\lambda(\hat{x})$, the inspector pays a fine of $p^I(\theta)(x - \hat{x})$ for underreporting the level of emissions. The payoff from honest behavior for the inspector is simply a fixed salary of *w*.

Taking the tax rate and the fine as given, reported and actual emissions are chosen to maximize joint payoffs from the bribe. Hence, the equilibrium level of reported and actual emissions is established by

$$\underset{x,\hat{x}}{Max}\, L = U^F + U^I = \pi(x) - \tau\hat{x} - \alpha\lambda(\hat{x})P(\theta)(x-\hat{x}) - \pi(x^h) + \tau x^h, \qquad (3)$$

where $P(\theta) = p^F(\theta) + p^I(\theta)$. The first-order conditions for x and $\hat{x}$ satisfy:

$$x: \quad \pi_x - \alpha\lambda(\hat{x})P(\theta) = 0 \qquad (4)$$

$$\hat{x}: \quad -\tau + \alpha\lambda(\hat{x})P(\theta) - \alpha\lambda_{\hat{x}}P(\theta)(x-\hat{x}) = 0 \qquad (5)$$

where subscripts denote partial derivatives. To ensure that a unique maximum exists and that it is stable, it is assumed that $L_{xx} = \pi_{xx} < 0$, $L_{\hat{x}\hat{x}} = \alpha P\mathrm{B} < 0$, $|L_{x\hat{x}}| < |L_{\hat{x}\hat{x}}|$, and $|L_{x\hat{x}}| < |L_{xx}|$ where $\mathrm{B} \equiv 2\lambda_{\hat{x}} - \lambda_{\hat{x}\hat{x}}(x-\hat{x})$ and $L_{x\hat{x}} = \alpha\lambda_{\hat{x}}P$. Observe that the tax rate has a direct effect on reported emissions but only an indirect effect on actual emissions through its effect on the expected fine.

Equation (4) states that the equilibrium emissions satisfy the condition that the marginal benefit from pollution to the firm (i.e. π_x) equals the expected marginal cost of increasing emissions (i.e. $\alpha\lambda(\hat{x})P(\theta)$). Equation (5) suggests that in the equilibrium, reported emissions are determined by equating the marginal cost of increasing reported emissions by one unit (i.e. τ) to the marginal benefit from doing so. The latter consists of the direct savings on the fine (i.e. $\alpha\lambda(\hat{x})P(\theta)$) and the indirect effect on savings through a decrease in the probability of a government audit (i.e. $\alpha\lambda_{\hat{x}}P(\theta)(x-\hat{x})$).

Note that although the analysis is carried out in terms of one firm and one inspector, all firms and inspectors in the industry are subject to the same values of α, θ and τ and consequently, choose identical solution vales of x and $\hat{x}$. Thus,

conditions (4) and (5) are valid for all firms and inspectors in the industry and can be treated as applicable to the industry-wide equilibrium.

Now we can proceed to examine the welfare-maximizing response of the government. We assume a utilitarian welfare function which is given by the sum of the payoffs of all the agents in the model with equal weights assigned to the payoffs from different sources. Thus, social welfare is given by the sum of profits, inspector's payoffs, government revenue from taxes and fines, less government spending on inspector wages and auditing, less the damage from pollution. The costs associated with auditing are denoted by $c(\lambda)$ and are assumed to be increasing in the probability of an audit at an increasing rate.

Since sulphur dioxide emissions can travel across borders and get deposited in neighboring nations, the damage from air pollution can not be analyzed in terms of one country: the transboundary spillovers coming from other nations have to be taken into account. We follow Murdoch and Sandler (1997b) and denote the damage from pollution in country *i* by $D(X_i)$, where $X_i = w_{ii}x_i + \tilde{X}_i$, w_{ii} is the fraction of emissions generated in country *i* and deposited on itself, $\tilde{X}_i$ is the emission spillins from *n* other countries and $i = 1,...,n$. Note that $\tilde{X}_i = \sum_{j \neq i}^{n} w_{ij}x_j$ where w_{ij} denotes the fraction of country *j*'s emissions deposited on country *i* and x_j is the level of emissions in country *j*. It is supposed that the damage function is increasing in emissions levels and convex. Further, in equation (6), the country indices are

suppressed for ease of exposition since the discussion focuses on the government maximization problem in one country. Upon simplification, the government's problem is to maximize social welfare given by

$$\underset{\tau}{Max} W = \pi(x(\tau,\alpha,\theta)) - D\left(wx(\tau,\alpha,\theta) + \tilde{X}\right) - c(\lambda(\hat{x}(\tau,\alpha,\theta))). \quad (6)$$

The first-order condition for τ satisfies

$$-(\pi_x - D_X w)\partial x/\partial\tau + c_\lambda \lambda_{\hat{x}}\, \partial\hat{x}/\partial\tau = 0 \quad (7)$$

which can be simplified to yield (see Appendix A)

$$-(\pi_x - D_X w)\alpha P + c_\lambda \pi_{xx} = 0 \quad (8)$$

Note that (8) implies that $(\pi_x - D_X w) < 0$, since $\pi_{xx} < 0$ and $c_\lambda > 0$.

Condition (8) states that the emissions tax rate should be set such that the expected net damage to society from pollution (i.e. the damage from pollution minus the profits to the firm) resulting from a higher tax (i.e. $(-(\pi_x - D_X w)\alpha P)$) equals the marginal cost of auditing by the government (i.e. $c_\lambda \pi_{xx}$). For example, when pollution is high, the net damage to society from increasing pollution by one more unit is also high and the government spends more on auditing so that the marginal cost of auditing rises. In the presence of corruption, an equilibrium tax rate represents a trade-off between the benefits from taxation against those from auditing (also see Damania (2002) for the discussion of the issue).

The equilibrium solutions for the effects of changes in honesty, the fine rate, the fraction of own depositions and spillovers on total and reported emissions are as follows (see Appendix B for derivation):

$$\partial x/\partial \alpha = -P\lambda_{\hat{x}}\{c_{\lambda\lambda}\pi_{xx}\lambda + (\pi_x - D_X w)\alpha P\}/\Gamma < 0 \quad (9)$$

$$\partial x/\partial \theta = -\alpha\lambda_{\hat{x}}P_\theta\{c_{\lambda\lambda}\pi_{xx}\lambda + (\pi_x - D_X w)\alpha P\}/\Gamma < 0 \quad (10)$$

$$\partial x/\partial w = \alpha\lambda_{\hat{x}}P(D_{XX} wx + D_X)\alpha P/\Gamma < 0 \quad (11)$$

$$\partial x/\partial \tilde{X} = \alpha\lambda_{\hat{x}}PD_{XX} w\alpha P/\Gamma < 0 \quad (12)$$

$$\partial \hat{x}/\partial \alpha = P\{-(\pi_{xx} - D_{XX} w^2)\alpha P\lambda + \lambda c_\lambda \pi_{xxx} - \pi_{xx}(\pi_x - D_X w)\}/\Gamma \gtrless 0 \quad (13)$$

$$\partial \hat{x}/\partial \theta = \alpha P_\theta\{-(\pi_{xx} - D_{XX} w^2)\alpha P\lambda + c_\lambda \pi_{xxx}\lambda - (\pi_x - D_X w)\pi_{xx}\}/\Gamma \gtrless 0 \quad (14)$$

$$\partial \hat{x}/\partial w = \pi_{xx}(D_{XX} wx + D_X)\alpha P/\Gamma < 0 \quad (15)$$

$$\partial \hat{x}/\partial \tilde{X} = \pi_{xx}D_{XX} w\alpha P/\Gamma < 0 \quad (16)$$

where $\Gamma = \lambda_{\hat{x}}\{(\pi_{xx} - D_{XX} w^2)(\alpha P)^2 - c_\lambda \pi_{xxx}\alpha P - c_{\lambda\lambda}\pi_{xx}{}^2\}$. The second order condition for the maximization problem in (6) requires that $\Gamma > 0$.

Equations (9)-(12) indicate that total emissions decrease with honesty, the fine, the share of emissions that falls on a country's own territory and the spillovers coming from neighboring countries. Lower corruption increases the probability that the collusion between the firm and the inspector becomes known to the government and the latter imposes a fine on both the agents, so the amount of pollution declines. As the fine rate increases, the expected amount of the fine imposed on the difference between actual and reported emissions rises. To reduce the expected size of the penalty for underreporting, actual emissions should fall. As both the share of emissions that falls on a country's own territory and the spillovers coming from other nations rise, the net damage from an extra unit of pollution increases and the government starts to conduct more audits. As monitoring increases, the expected fine

for underreporting gets higher, so that the costs of pollution rise and the firm reduces total emissions.

Equation (13) indicates that the effect of honesty on reported emissions is ambiguous: honesty increases reported emissions if the fine rate is high, however, if the fine rate is low, i.e., $P < \frac{\lambda c_\lambda \pi_{xxx} - \pi_{xx}(\pi_x - D_X w)}{(\pi_{xx} - D_{XX} w^2)\alpha\lambda}$ the effect is reversed. Lower overall corruption increases the amount of emissions reported as it raises the probability of prosecution and increases the expected costs associated with the fine. At the same time, lower corruption decreases total emissions as the costs of underreporting increase and total emissions fall. When total emissions go down, the expected net marginal damage from pollution reduces and hence, the government auditing becomes rarer. As a result, the firm and the inspector may report less pollution as overall corruption declines. If the fine rate is set very low, the expected penalty is small and the firm and the inspector have more incentives to underreport emissions.

Similarly, equation (14) indicates that reported emissions increase with the penalty rate if honesty is high, however, reported emissions start to decrease with the rise in the penalty rate when honesty is low, i.e., $\alpha < \frac{c_\lambda \pi_{xxx}\lambda - (\pi_x - D_X w)\pi_{xx}}{(\pi_{xx} - D_{XX} w^2)P\lambda}$. The explanation is similar to the one above. A higher fine rate raises the expected amount of the fine for underreporting thereby encouraging the firm and the inspector to increase reported emissions while lowering actual emissions. As actual emissions

fall, the expected net marginal damage from pollution falls and government conducts fewer audits. As a result, reported emissions may decline with a higher fine. The latter effect should be particularly pronounced when corruption is high.

Equations (15) and (16) show that reported emissions decline with both the share of emissions that fall on a country's own territory and the spillovers from neighboring nations. Recall that an increase in both the share of own depositions and the spillovers reduces total emissions. As total emissions decline, the expected net marginal damage from pollution falls and government monitoring becomes less intense. The firm decreases reported emissions as underreporting is less likely to be detected. Observe that equations (15) and (16) suggest that the absolute value of the effect of own deposition fraction is larger than the effect of spillovers.

Since $dv \equiv d(x - \hat{x}) = dx - d\hat{x}$, use (32) and (33) (Appendix B) to obtain

$$\partial v/\partial \alpha = -P\{c_{\lambda\lambda}\pi_{xx}\lambda\lambda_{\hat{x}} + (\pi_x - D_X w)(\alpha P\lambda_{\hat{x}} - \pi_{xx}) - (\pi_{xx} - D_{XX} w^2)\alpha P\lambda + \lambda c_\lambda \pi_{xxx}\}/\Gamma \gtreqless 0 \quad (17)$$

$$\partial v/\partial \theta = -\alpha P_\theta\{c_{\lambda\lambda}\pi_{xx}\lambda\lambda_{\hat{x}} + (\pi_x - D_X w)(\alpha P\lambda_{\hat{x}} - \pi_{xx}) - (\pi_{xx} - D_{XX} w^2)\alpha P\lambda + c_\lambda \pi_{xxx}\lambda\}/\Gamma \gtreqless 0 \quad (18)$$

$$\partial v/\partial w = \alpha P\{(D_{XX} wx + D_X)(\alpha P\lambda_{\hat{x}} - \pi_{xx})\}/\Gamma > 0 \quad (19)$$

$$\partial v/\partial \tilde{X} = \{(\alpha\lambda_{\hat{x}} P - \pi_{xx})D_{XX} w\alpha P\}/\Gamma > 0 \quad (20)$$

Equation (17) implies that the difference between total and reported emissions decreases with honesty if the fine rate is high, but increases, if the fine rate

is low, i.e., $P < \frac{\pi_{xx}(\pi_x - D_X w) - \lambda c_\lambda \pi_{xxx} - \lambda_{\hat{x}} c_{\lambda\lambda} \pi_{xx} \lambda}{\alpha\{(\pi_x - D_X w)\lambda_{\hat{x}} - (\pi_{xx} - D_{XX} w^2)\lambda\}}$. As corruption falls, the expected penalty for underreporting rises and there is an increase in emission reports. However, since total imports fall, the net marginal damage from pollution declines and the government conducts fewer audits. As a result, the firm and the inspector may report fewer emissions and the difference between actual and reported emissions may increase as overall corruption decreases. The incentives for the firm and the inspector to report fewer emissions are the greatest when the fine rate is set low.

Similarly, equation (18) implies that the difference between total and reported emissions decreases with the penalty rate if honesty is high, but increases if honesty is low, i.e., $\alpha < \frac{-c_\lambda \pi_{xxx} \lambda + (\pi_x - D_X w)\pi_{xx} - c_{\lambda\lambda} \pi_{xx} \lambda \lambda_{\hat{x}}}{P\{(\pi_x - D_X w)\lambda_{\hat{x}} - (\pi_{xx} - D_{XX} w^2)\lambda\}}$. A higher fine generally increases emission reports. However, since total emissions fall due to an increase in the expected cost, an improvement in the environmental quality encourages the government to reduce its monitoring and a higher fine may lead to a decrease in reporting. The latter effect is amplified when corruption is high.

Equations (19) and (20) imply that the difference between total and reported emissions is increasing in both the share of emissions that fall on a country's own territory and the spillovers from other nations. As shown above, both actual and reported emissions fall with either an increase in the share of own depositions or in the spillovers. In the presence of corruption, however, reported emissions fall by a

greater amount since the incentives to avoid the payment of tax are stronger than the incentives to lower the expected fine. As a result, the difference between actual and reported emissions increases.

Before we can proceed to the empirical analysis, it is important to note that although the damage from pollution depends on actual emissions originating from neighboring countries, in practice, we can only collect data on reported emissions coming from other nations. Thus, it is not possible to estimate the coefficient on actual spillovers where $\tilde{X}_i = \sum_{j \neq i}^{n} w_{ij} x_j$, but it is possible to estimate the coefficient on reported spillovers where $\bar{X}_i = \sum_{j \neq i}^{n} w_{ij} \hat{x}_j$. The question is, however, whether an increase in actual spillovers is always combined with an increase in reported spillovers so that whether we could conclude that the correlation between reported emissions and *reported* spillovers is of the same sign as that between reported emissions and *actual* spillovers.

To begin with, consider the relationship between reported and actual emissions in some country *j*. Assuming that but for the difference in parameters (i.e., honesty, the penalty rate, the share of own depositions and transboundary spillovers) all countries are the same, actual and reported emissions in country *j* can be described by equations (9) – (16). For example, the pair of equations in (11) and (15) and that in (12) and (16) indicate that *ceteris paribus*, both actual and reported missions in country *j* decrease with an increase in the share of own depositions and

spillovers in country *j*, respectively. However, the pair of equations in (9) and (13) and that in (10) and (14) imply that *ceteris paribus*, actual and reported emissions do not necessarily change in the same direction with a rise in honesty and the penalty rate, respectively. When honesty (or the penalty rate) increases, actual emissions unambiguously fall; however, reported emissions may either rise or fall depending on the values of the penalty rate (or honesty), the share of own depositions and spillovers. In other words, a decrease in actual emissions in one country can be combined with an increase in reported emissions in the same country if the change is caused by a rise in honesty (or the penalty rate), all other things held constant. This means that the relationship between the weighted sum of actual emissions and that of reported emissions in (*n-1*) countries is not straightforward: an increase in actual spillovers may be combined with either an increase or a decrease in reported spillovers originating from the same countries. Consequently, the association between reported *emissions* and reported *spillovers* can either be negative or positive, depending on the cause of variation in reported spillovers originating from neighboring countries (i.e., whether variation in reported spillovers results from variation in honesty, the penalty rate or the combination of spatial weights).

Empirical Model and Data

Since it is only possible to obtain data on sulphur pollution reported by the governments to the Cooperative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollution in Europe (EMEP), the empirical analysis

focuses on the implications of the theory for reported emissions. The first-order conditions in (7) and (8) indicate that the level of reported emissions that will result in equilibrium depends on the following parameters: $\hat{x}\left(\alpha, \theta, w, \tilde{X}\right)$. Using Taylor series expansion, we can estimate a linear approximation of the function to test our theoretical predictions. The data on sulphur emissions and the other variables used in the empirical analysis below are drawn from 40 European countries from 2001 through 2003 and from 39 countries from 1999 to 2000.

The theory suggests that the effect of honesty on reported emissions is conditional on the value of the fine: when the fine rate is low, an increase in honesty decreases reported emissions; however, when the fine rate is high, an increase in honesty increases reports. Similarly, the effect of the fine is conditional on the value of honesty: when honesty is low, an increase in the fine rate decreases reported emissions; however, when honesty is high, an increase in the fine rate increases reported emissions. Thus, our empirical specification will include an interaction term between honesty and the fine and we would expect the sign of the coefficients on honesty and the fine rate to be negative while the sign of the coefficient on the interaction term to be positive. Moreover, although the theoretical model predicts that both the share of own depositions and the spillovers unambiguously reduce reported emissions, the magnitude of their effects depends on the values of honesty and the fine which implies interaction effects between own deposition share, on the one hand, and honesty and the fine, on the other, as well as between spillovers, on the one hand, and honesty and the fine, on the other. Note, however, that without any

additional assumptions about the form of the profit function $\pi(x)$ and the damage function *D(x)*, it is not possible to determine the signs of these interaction terms. Since our dataset consist of only 40 observations, we begin with the simplest model that takes into account only the interaction between honesty and the fine.

The basic regression equation is specified as follows:

$$\hat{x} = \rho W\hat{x} + Z\beta + \varepsilon \tag{21}$$

where $\hat{x}$ is an $n \times 1$ vector of reported sulphur emissions (in 10^3 tonnes) measured as a share of GDP (in 10^6 US dollars)[3]; W is the $n \times n$ matrix with the diagonal elements equal to zero and each of the off-diagonal elements representing the fraction of emissions from country *j* that falls on the territory of country *i* (i.e., w_{ij}) ; Z is an $n \times k$ matrix of independent variables including a constant, the fraction of emissions that falls on a country's own territory (i.e., w_{ii}) and the interaction terms; β is a $k \times 1$ vector of coefficients; and ε is an $n \times 1$ vector of independent and identically distributed normal random variables with mean zero and variance σ^2.

The presence of the spillover term (i.e., $W\hat{x}$) in equation (21) indicates that the regression model is characterized by spatial dependence where W represents a spatial weight matrix and $W\hat{x}$ is a weighted average of the dependent variable (often refereed to as a spatially lagged dependent variable). Hence, the application of ordinary least squares to the regression would produce biased and inconsistent estimates. The literature on spatial process models has focused on the maximum likelihood principle as an alternative estimating technique (Ord 1975; Anselin 1988).

Anselin (1988) derives the appropriate log-likelihood function for a model with a spatially lagged dependent variable based on a joint normal distribution for the error term ε:

$$L = -\frac{n}{2}\ln\pi - \frac{n}{2}\ln\sigma^2 + \ln\left|I - \rho W\right| - \frac{1}{2\sigma^2}\left(\hat{x} - \rho W\hat{x} - Z\beta\right)'\left(\hat{x} - \rho W\hat{x} - Z\beta\right) \qquad (22)$$

This likelihood function includes the Jacobian term $\left|I - \rho W\right|$ which results from the transformation of ε into y. If the weight matrix is symmetric, the computation can be simplified by expressing the determinant as a function of the eigenvalues of W. However, in our case, the spatial weight matrix is not symmetric and the determinant has to be calculated at each iteration.

Data on sulphur emissions are drawn from the UNECE/EMEP emission database WebDab. Recall that our theoretical analysis treats the equilibrium value of reported emissions derived for one firm and one inspector as being applicable to the whole polluting industry in a given country. However, the larger is the size of the polluting industry in a country, the larger is the amount of emissions. To separate the effect of the size of the polluting industry on emission levels from the effect of variables in *Z*, we divide emissions of sulphur dioxide by GDP (we, thus, use GDP as a proxy for the size of the polluting industry). As a result, we get the amount of emissions in tonnes produced per each one thousand US dollars of GDP. The model is estimated separately for five different years: 2003, 2002, 2001, 2000 and 1999. These years are chosen because they ensure the largest available datasets. The number of available observations in preceding years is much smaller.

To calculate the fraction of a country's sulphur emissions that falls on its own territory and the spatial weight matrix, the EMEP data on source-receptor relationships are used. Since for the time period chosen, source-receptor matrices are only available for 2000 and 2003 in the EMEP documentation, the 2000 matrix is used to estimate the model using the 1999 and 2000 datasets, while the 2003 matrix is used to estimate the model using the 2001, 2002 and 2003 datasets. Murdoch et al. (2003) state that the underlying source-receptor relationships normalized by emissions do not change much between years: they find the correlation between the spillover terms ($W\hat{x}$) calculated using the 1985 and 1990 matrices to be 0.892 and that between the own deposition fractions (w_{ii}) to be 0.958. In our case, the results are very similar since the correlation between the spillover terms calculated using the 2000 and 2003 matrices is 0.927 and that between the own deposition fractions is 0.910. Thus, we can conclude that the 2000 and 2003 matrices can be used to represent the source-receptor relationships in preceding years as well.

The deposition matrix for 2000 is presented in the EMEP Status Report 2003, while the deposition matrix for 2003 is found in the EMEP Status Report 2005. Both matrices show the contribution in terms of sulphur emissions from one country to another, i.e. each column indicates where the pollutant emitted by a country ends up, while each row indicates where the pollutant in a given country comes from. The share of a country's emissions that falls within its own borders (*Own Deposition*) is obtained by dividing the amount of sulphur emitted by a country and deposited on its own territory by the amount of the country's total emissions. For example, in 2000,

Armenia's total emissions measured 4,200 tonnes. According to the EMEP source-receptor matrix, 1,200 tonnes of this fell in Armenia itself. Consequently, the share of its own depositions in 2000 is 12/42=0.286.

Based on the EMEP source-receptor matrices, the elements of the spatial weight matrix w_{ij} are derived by dividing the amount of country *j*'s emissions deposited on country *i*'s territory by country *j*'s total emissions. For example, in 2000, out of 491,000 tonnes of Bulgaria's sulphur emissions, 30,600 tonnes fell on Romania, and 41,400 tonnes on Russia. Thus, the elements of the 2000 spatial weight matrix for Bulgaria (in columns) and Romania and Russia (in rows) are 306/4910=0.062 and 414/4910=0.084, respectively. The diagonal elements of the weight matrix are all made equal to zero. The amount of spillovers ($W\hat{x}$) is denoted by *Spillover*.

In addition to a vector of own deposition fractions w_{ii}, the variables in the Z matrix include a vector of ones, a vector of honesty rankings, a vector of fines and a vector of interactions between honesty and the fine. To measure honesty and the fine, the data from the International Country Risk Guide (ICRG) provided by the Political Risk Services group (The PRS group, Inc.) are used. The ICRG corruption variable (referred to as *Honesty* here) measures both the extent to which "high government officials are likely to demand special payments" and the extent to which "bribes connected with import and export licenses, exchange controls, tax assessment, policy protection, or loans" are generally expected throughout lower levels of government (Knack and Keefer 1995). The ICRG variable on law and order (denoted by *Rule of*

Law here) measures the strength and impartiality of the legal system as well as popular observance of the law. Both *Honesty* and *Rule of Law* range from 0 to 6 with 0 indicating low honesty and weak rule of law, respectively, and 6 indicating high honesty and strong rule of law, respectively.

The appropriateness of the use of *Rule of Law* as a proxy for the fine imposed on environmental violations can be demonstrated using the following facts about developing countries. As Russel and Vaughan (2003) point out, the difficulties that developing countries face in building effective environmental institutions include weak systems of environmental enforcement and lack of respect for the rule of law by industrial polluters. For example, in Albania, where monitoring agencies impose fines on violators, the main difficulty in environmental enforcement is the collection of fines (Dimovsky and Glaser, 2002). The law does not specify any penalties for non-payments, which makes the collection of fines sometimes impossible. Moreover, the record keeping system is poorly developed, so that when environmental violators appeal to court, they usually win. This has had a demoralizing effect on environmental inspectors and as a result, the number of fines has significantly declined in Albania since 1997. The example highlights a connection between the fine and the rule of law as it implies that environmental fines will not deter non-compliant behavior if the legal system cannot ensure that the fines are collected. Thus, the size of the fine that environmental polluters *actually* face depends on the strength of the legal system in a country.

To further stress the connection between the fine and the rule of law, a comparison of data for three countries in South Eastern Europe is presented in Table 7[4]. In 2000 and 2001, the ICRG rankings of Albania in terms of the rule of law equal 2, while those of Bulgaria and Croatia equal 4 and 5, respectively. Not only is the mean amount of fine (i.e., the total amount of fines divided by the number of fines collected) in Albania the lowest (700 EUR as compared to 944.444 EUR in Bulgaria and 931.677 EUR in Croatia), but also is the number of cases won by environmental inspectors in court (it is zero in Albania as compared to 120 in Bulgaria and 240 in Croatia). Thus, the data for the three South Eastern European countries show that countries with stronger rule of law are likely to collect higher fines on environmental violations.

Table 7. Comparison of fines and rule of law rankings in some Eastern European countries

	Albania	**Bulgaria**	**Croatia**
Number of fines per year	10	1,800	161
Amount of fines collected (EUR)	7,000	1,700,000	150,000
Mean amount of fines collected (EUR)	700	944.44	931.68
Number of court cases won	0	120	240
Rule of law (ICRG rankings)	2	4	5
Year	2001	2000	2000

The summary statistics for all variables and all years are presented in Table 8.

Table 8. Summary statistics

Year	Variable	Mean	S. D.	Minimum	Maxumum
2003	*Sulphur emissions (share of GDP)*	7.47	12.96	0.07	67.25
	Spillover	3.06	5.69	0.00	31.16
	Own	0.23	0.10	0.04	0.61
	Corruption	3.14	1.36	1.00	6.00
	Law	4.63	1.03	2.00	6.00
2002	*Sulphur emissions (share of GDP)*	7.76	13.50	0.08	69.93
	Spillover	3.16	5.90	0.00	32.89
	Own	0.23	0.10	0.04	0.61
	Corruption	3.12	1.40	1.00	6.00
	Law	4.63	1.03	2.00	6.00
2001	*Sulphur emissions (share of GDP)*	8.10	13.96	0.08	71.76
	Spillover	3.31	6.16	0.01	34.36
	Own	0.23	0.10	0.04	0.61
	Corruption	3.54	1.38	1.00	6.00
	Law	4.69	1.09	2.00	6.00
2000	*Sulphur emissions (share of GDP)*	8.81	14.98	0.08	77.94
	Spillover	4.15	8.87	0.01	51.83
	Own	0.22	0.10	0.04	0.49
	Corruption	3.74	1.41	1.00	6.00
	Law	4.74	1.14	2.00	6.00
1999	*Sulphur emissions (share of GDP)*	9.31	14.95	0.11	78.58
	Spillover	4.44	9.46	0.01	55.71
	Own	0.22	0.10	0.04	0.49
	Corruption	3.85	1.40	1.00	6.00
	Law	4.82	1.09	2.42	6.00

Empirical Results

ML estimates of the basic model using datasets of different years are presented in Table 9. The signs of the coefficients stay the same across years. *Own*

Deposition, *Corruption* and *Rule of Law* are not significant in 1999 and 2000 but all the variables enter significantly in 2001, 2002 and 2003. Consider the results of the estimation using 2003 dataset. The coefficient on honesty is negative and significant at the 5% level, consistent with the theory. The coefficient on the rule of law (which is used as a proxy for the fine) is also negative and significant at the 10% level, as predicted by the theoretical model. The coefficient on the interaction term between honesty and the rule of law is positive and significant at the 10% level. This result suggests that the effect of honesty and that of the rule of law are interdependent supporting our a priori expectations.

The marginal effect of the rule of law measured at the minimum value of honesty found in the sample is equal to -9.15+3.26(1)=-5.89. Thus, when the rule of law is weak, honesty decreases the reported amount of sulphur emissions as a share of GDP. In particular, as the rule of law ranking increases by 1, reports of sulphur emissions decline by approximately 6 tonnes per one thousand US dollars of GDP. However, at the maximum value of honesty, the marginal effect of law is positive and equals -9.15+3.26(6)=10.40. Thus, as the rule of law increases by 1, reported emissions of sulphur increase by approximately 10 tonnes per one thousand US dollars of GDP implying that as countries become less corrupt, an improvement in the rule of law starts to exert a positive influence on emission reports, as the theory predicted.

Table 9. Maximum-likelihood estimates of the basic model

	Datasets				
	2003	2002	2001	2000	1999
Spillover	0.64	0.52	0.69*	0.14	0.23
	(0.40)	(0.40)	(0.37)	(0.30)	(0.29)
Own Deposition	-52.64**	-55.94***	-67.13***	-29.04	-31.61
	(20.73)	(21.20)	(21.98)	(25.20)	(24.79)
Honesty	-21.36**	-22.77**	-14.85**	-5.25	-0.06
	(9.74)	(9.01)	(6.09)	(6.29)	(1.58)
*Honesty*Rule of Law*	3.26*	3.46**	2.14*	0.77	0.01
	(1.74)	(1.60)	(1.15)	(1.19)	(0.26)
Rule of Law	-9.15*	-9.40*	-8.54**	-7.60*	-5.77*
	(5.26)	(4.94)	(4.27)	(4.49)	(2.95)
Constant	76.24***	79.67***	76.29***	55.86**	43.22***
	(26.35)	(24.22)	(20.96)	(21.84)	(11.85)
Mean log-likelihood	-2.82	-2.83	-2.84	-3.03	-3.05
# of observations	40	40	40	39	39

Note: Dependent variable is sulphur dioxide emissions (in 10^3 tonnes) as a share of GDP (in 10^6 US$). Standard errors in parenthesis beneath coefficient estimates. */**/*** Denotes significance at the 10/5/1 percent level, respectively

Similar changes can be seen examining the marginal effect of honesty, although the results in this case fall a little short of our expectations. At the minimum value of the rule of law in the sample, the marginal effect of honesty is equal to -21.36+3.26(2)=-14.84. Thus, when the rule of law is weak, honesty decreases emission reports supporting the theoretical conjectures. When the marginal effect of honesty is measured at the maximum value of the rule of law in the sample, it still

remains negative although according to the model we would anticipate a change in sign. The magnitude of the effect, however, considerably declines (-21.36+3.26(6)=-1.81). A larger sample is probably necessary to obtain more consistent results.

Based on our estimates and the theoretical model, we can now make inferences about the actual level of pollution and the gap between reported and actual emissions in different countries. Our results indicate that reported emissions will be higher not only in countries where both honesty is high and the rule of law is strong but also in countries where both honesty is low and the rule of law is weak (as compared to nations where either honesty is high and the rule of law is weak or vice versa). However, the theory suggests that total emissions as well as the difference between actual and reported emissions will be the lowest in honest countries where the rule of law is strong while the highest total emissions and the largest gap in reporting will be found in corrupt countries where the rule of law is weak and honesty is low. Thus, a proper assessment of the level of compliance with environmental regulations cannot be based solely on the data submitted to environmental monitoring agencies since such characteristics of political regimes as corruption and weak rule of law may have a distorting influence on reporting practices in those countries.

Other empirical estimates presented in Table 9 concern the share of emissions that falls on a country's own territory and spillovers from other nations. The fraction of own depositions enters negatively and significantly, supporting the hypothesis that

countries that receive a relatively larger share of their own emissions emit a relatively lower amount of the pollutant. The effect of reported spillovers is positive and insignificant. Since the theoretical model identifies potential interactions between spillovers, on the one hand, and corruption and the fine, on the other, we experimented with the inclusion of these additional interaction terms in the regression.[5] ML estimates for this alternative specification are presented in Table 10. The coefficient estimates for the share of own depositions, corruption, the rule of law and their interaction are robust to these changes in the model. The coefficient on spillovers is now negative for all five datasets and marginally significant (at the 10% level) for 2002. The interaction effect with honesty is positive for all years except for 2002 but is never significant. The interaction term between spillovers and law is always positive and is only marginally significant in 2002.

We also ran a set of regressions including interactions between the share of own deposition on the one hand and honesty and the rule of law, on the other and excluding the interactions with spillovers. The results are shown in Table 11. Now, the coefficient on spillovers is positive and significant. All the other results stay the same, although it becomes difficult to find significant relationships between reported emissions and own depositions fraction or the rule of law using 2003 and 2002 datasets. The results, however, imply that as reported spillovers increase, a country's own emission reports increase as well. As it was discussed in the theoretical section,

the sign of the effect of reported spillovers depends to a great deal on the combination of countries in the sample. Thus, for 40 countries in our dataset, the positive relationship seems to hold.

Our empirical results, thus, are not necessarily at odds with the previous works on the subject (Murdoch and Sandler 1997b; Murdoch et al. 1997; and Murdoch et al. 2003) that find that reductions of sulphur emissions over a 5 or 10-year interval are negatively and significantly correlated with the reductions of sulphur emissions undertaken by other nations over the same period, consistent with the hypothesis of strategic behavior and free-riding. The sample of countries in these works include 25 or 26 nations while our sample consists of 39 or 40 countries. Thus, the combination of the spatial weights and the characteristics of the countries may be quite different in our datasets.

Moreover, according to our model, spillovers have an effect on reported emissions only through their effect on the tax. In other words, as spillovers increase, pollution damage rises and the government sets a higher tax rate to reduce the amount of pollution. As pollution falls, government auditing becomes less intense and reported emissions fall. Thus, the model presupposes an immediate response on the part of the government to any changes in the amount of emissions coming from other nations. In practice, however, the government may not change the tax rate as often so that when we estimate our empirical model using cross-sectional data for one year, we cannot capture the effect of spillovers as the tax rate might have stayed the same over this short period.

Table 10. Maximum-likelihood estimates of the model with spillover interactions

	Datasets				
	2003	2002	2001	2000	1999
Spillover	-2.67	-5.41*	-2.50	-2.59	-2.20
	(4.22)	(2.89)	(1.76)	(2.07)	(1.99)
*Spillover*Honesty*	0.20	-0.44	0.12	0.20	0.20
	(0.49)	(0.58)	(0.48)	(0.55)	(0.62)
*Spillover*Rule of Law*	0.76	1.80*	0.88	0.78	0.66
	(1.14)	(0.94)	(0.68)	(0.84)	(0.90)
Own Deposition	-57.63***	-57.47***	-67.36***	-48.22**	-45.08*
	(20.86)	(19.84)	(19.99)	(23.95)	(23.83)
Honesty	-22.00**	-21.12**	-18.38***	-10.61	-5.10
	(9.89)	(8.87)	(7.05)	(7.49)	(8.71)
*Honesty*Rule of Law*	3.32*	3.44**	2.88**	1.68	0.84
	(1.73)	(1.52)	(1.21)	(1.27)	(1.52)
Rule of Law	-9.94*	-12.40**	-12.11***	-10.46**	-9.05*
	(5.42)	(4.90)	(4.12)	(4.23)	(5.39)
Constant	81.58***	88.13***	90.74***	73.33***	61.92**
	(26.59)	(23.05)	(20.33)	(21.23)	(27.61)
Mean log-likelihood	-2.80	-2.78	-2.77	-2.94	-2.98
# of observations	40	40	40	39	39

Note: Dependent variable is sulphur dioxide emissions (in 10^3 tonnes) as a share of GDP (in 10^6 US$). Standard errors in parenthesis beneath coefficient estimates. */**/*** Denotes significance at the 10/5/1 percent level, respectively.

Table 11. Maximum-likelihood estimates of the model with own deposition interactions

	Datasets				
	2003	2002	2001	2000	1999
Spillover	1.18**	1.13**	1.52***	0.67*	0.63*
	(0.48)	(0.46)	(0.39)	(0.39)	(0.36)
Own Deposition	-172.28	-198.99	-303.75***	-249.17**	-214.79*
	(134.82)	(132.68)	(91.05)	(126.26)	(125.37)
Own Deposition Honesty*	30.05	25.43	21.60	13.13	14.72
	(25.39)	(30.95)	(22.75)	(24.62)	(25.78)
Own Deposition Rule of Law*	4.68	13.23	34.17	32.00	22.74
	(42.99)	(47.29)	(32.52)	(35.62)	(36.25)
Honesty	-30.84***	-31.03***	-24.55***	-9.63	-5.95
	(9.96)	(9.83)	(6.28)	(6.93)	(8.30)
*Honesty*Rule of Law*	3.72**	3.94***	3.11***	1.00	0.50
	(1.69)	(1.52)	(1.08)	(1.18)	(1.42)
Rule of Law	-10.94	-13.38	-19.27**	-14.52	-12.35
	(11.94)	(12.27)	(9.30)	(9.17)	(10.26)
Constant	107.12**	116.07***	142.67***	103.49***	90.44**
	(44.93)	(41.23)	(32.28)	(35.82)	(42.25)
Mean log-likelihood	-2.74	-2.75	-2.68	-2.98	-3.01
# of observations	40	40	40	39	39

Note: Dependent variable is sulphur dioxide emissions (in 10^3 tonnes) as a share of GDP (in 10^6 US$). Standard errors in parenthesis beneath coefficient estimates. */**/*** Denotes significance at the 10/5/1 percent level, respectively.

By focusing on reductions over a period of time, rather than on the level of emissions at one point in time, Murdoch and Sandler (1997b), Murdoch et al. (1997) and Murdoch et al. (2003) could capture the changes that occurred in government policy over time. Since the primary purpose of our analysis is to investigate how compliance with air pollution regulations depends on corruption and the rule of law whose indicators change very little over time, we, however, have to constrain ourselves to examining the level of emissions at one point in time and thus might fail to capture any changes in the tax rate due to transboundary spillovers.

Concluding Remarks

The analysis in this paper has important implications for the interpretation of data on pollution reported to international monitoring agencies. Although levels of reported emissions play an important role in determining compliance with environmental regulations, they do not always reflect the actual level of compliance required by the relevant agreement. If corruption in a country is very low and it is combined with strong rule of law, reported emissions of sulphur are likely to be rather high. This, however, should not be interpreted automatically as a lower level of compliance because total emissions and the difference between total and reported emissions will be lower in these countries than in nations where either honesty is low or rule of law is weak, or where both honesty and the rule of law are low. At the same time, if a country is very corrupt and the rule of law is very weak, its reports of sulphur emissions may also be high. However, in this case, the amount of actual

pollution they emit is also higher than in countries with either low corruption or strong rule of law or in countries that are both honest and have strong rule of law. Since corruption and rule of law may influence actual pollution and reported emissions in opposite directions, one important lesson is that too much of a focus on formal compliance with international environmental regulations may be counterproductive.

International organizations responsible for monitoring air pollution should direct part of their efforts at reducing the pernicious effects of high corruption and weak rule of law on both reported and actual emissions. Since the difference between actual and reported emissions is the greatest in highly corrupt countries with weak political and judicial systems, the strategy developed to reduce pollution in these nations should differ from that developed for noncorrupt regimes with strong judicial institutions. The importance of designing procedures to increase transparency in data reporting should be emphasized in these countries since this would make collusion between environmental inspectors and firms less common. Moreover, any attempts to reduce corruption connected to environmental pollution should go together with similar attempts to strengthen the legal system as there are important interaction effects between the two.

Chapter 3 Notes

---

[1] The south-eastern region includes Albania, Armenia, Belarus, Bosnia-Herzegovina, Bulgaria, Croatia, Cyprus, Georgia, Kazakhstan, Republic of Moldova, Romania, Slovenia, The FYROM Macedonia, Turkey, Ukraine and Yugoslavia.

[2] It is, however, assumed that if collusion between the firm and the inspector becomes known, the information about the true level of emissions can be procured.

[3] Data on GDP from the World Bank's World Development Indicators are used.

[4] Data on environmental fines are taken from Dimovsky and Glaser (2002).

[5] To perform this estimation, the log-likelihood function was rewritten as: $\mathrm{L} = -\frac{\mathrm{n}}{2}\ln\pi - \frac{1}{2}\ln\sigma^2 + \ln\left|I - \rho_0 W_0 - \rho_H W_H - \rho_L W_L\right| - \frac{1}{2\sigma^2}\varepsilon'\varepsilon$ where $\varepsilon'\varepsilon = \left((I - \rho_0 W_0 - \rho_H W_H - \rho_L W_L)\hat{x} - Z\beta\right)'\left((I - \rho_0 W_0 - \rho_H W_H - \rho_L W_L)\hat{x} - Z\beta\right)$ and W_0 denotes the spatial weight matrix, W_H and W_L denote the result of the element-by-element multiplication of W_0 and the vector of honesty and that of the rule of law, respectively, ρ_0 is the coefficient on spillovers and ρ_H and ρ_L are the coefficients on the interaction terms between spillovers and honesty and between spillovers and the rule of law, respectively.

Chapter 3 References

Anselin, Luc (1988), "Spatial Econometrics: Methods and Models," Kluwer Academic Publishers.

Ansuategi, Alberto (2003), "Economic Growth and Transboundary Pollution in Europe: An Empirical Analysis," *Environmental and Resource Economics* 26, 305-328.

Bardhan, Pranab (1997), "Corruption and Development: A Review of Issues," *Journal of Economic Literature* 35 (3), 1320-1346.

Barrett, Scott (2003), "Environment and Statecraft: The Strategy of Environmental Treaty-making," Oxford University Press.

Barrett, Scott (1994), "Self-Enforcing International Environmental Agreements," Oxford Economic Papers, New Series, Vol. 64, Special Issue on Environmental Economics, 878-894.

Burrows, Paul (1979), "Pigovian Taxes, Polluter Subsidies, Regulation, and the Size of a Polluting Industry," *The Canadian Journal of Economics*. 12 (3), 494-501.

Burrows, Paul (1977), "Pollution Control with Variable Production Process," Journal of Public Economics 8, 357-367.

Congleton, Roger D. (1992), "Polititcal Institutions and Pollution Control," *The Review of Economics and Statistics* 74, (3), 412-421.

Damania, Richard (2002), "Environmental Controls with Corrupt Bureaucrats," *Environment and Development Economics* 7, 407-427.

Dimovski, Mikhail and Rob Glaser (2002), *Environmental Enforcement and Compliance in South Eastern Europe,* The Regional Environmental Center for Central and Eastern Europe, Szentendre, Hungary.

Downs, George W., and David M. Rocke (1995), "Optimal Imperfection? Domestic Uncertainty and Instiotutions in International Relations," Princeton University Press.

Downs, George W., David M. Rocke and Peter N. Barsoom (1996), "Is the Good News about Compliance Good News about Cooperation?" *International Organization* 50 (3), 379-406.

Fredriksson, Per G., and Muthukumara Mani (2002), "The Rule of Law and the Pattern of Environmental Protection," Working Paper WP/02/49, International Monetary Fund.

Heyes, A. and N. Rickman (1999), "Regulatory dealing – revisiting the Harrington paradox," *Journal of Public Economics* 72, 361-378.

Keeler, A., "Noncompliant firms in TDP markets (1991)," *Journal of Environmental Economics and Management* 21, 180-189.

Klitgaard, Robert (1988), "Controlling Corruption," University of California Press, Berkeley.

Knack, S., and P. Keefer (1995), "Institutions and economic performance: Cross-country tests using alternative institutional measures," *Economics and Politics* 7 (3), 207-227.

Levy, M.A. (1993), "European Acid Rain: The Power of Tote-Board Diplomacy," in P.M. Haas, R.O. Keohane, and M.A. Levy (eds), Institutions for the Earth: Sources of Effective International Environmental Protection, Cambridge, MA: MIT Press, 75-132.

Levy, M.A. (1995), "International Co-operation to Combat Acid Rain," Green Globe Yearbook.

Malik, A. (1990), "Markets for pollution control when firms are noncompliant," *Journal of Environmental Economics and Management* 18, 97-106.

Mitchell, Ronald B. (1994), "Regime Design Matters: International Oil Pollution and Treaty Compliance," *International Organization* 48 (3), 425-458.

Mookherjee, Dilip, and I.P.L. Png (1995), "Corruptible Law Enforcers: How Should They Be Compensated?" *The Economic Journal* 105 (428), 145-159.

Murdoch, James C., and Todd Sandler (1997a), "The voluntary provision of a pure public good: The case of reduced CFC emissions and the Montreal Protocol," *Journal of Public Economics* 63, 331-349.

Murdoch, James C., and Todd Sandler (1997b), "Voluntary Cutbacks and Pretreaty Behavior: The Helsinki Protocol and Sulphur Emissions," *Public Finance Review* 25 (2), 139-162.

Murdoch, James C., Todd Sandler, and Keith Sargent (1997), "A Tale of Two Collectives: Sulphur versus Nitrogen Oxides Emission Reduction in Europe," Economica, New Series 64 (254), 281-301.

Murdoch, James C., Todd Sandler, and Wim P.M. Vijverberg (2003), "The Participation Decision versus the Level of Participation in an Environmental Treaty: a Spatial Probit Analysis," *Journal of Public Economics* 8, 337-362.

Ord, Keith (1975) "Estimation methods for models of spatial interaction," *Journal of the American Statistical Association*, 70, 120-126.

Ringquist, Evan J., and Tatiana Kostadinova (2005), "Assessing the Effectiveness of International Environmental Agreements: The Case of the 1985 Helsinki Protocol," *American Journal of Political Science*. 49 (1), 86-102.

Rose-Ackerman, (1975) "The Economics of Corruption," *Journal of Public Economics* 4, 187-203.

Russel, Clifford and William Vaughan, (2003) "The Choice of Pollution Control Policy Instruments in Developing Countries: Arguments, Evidence and Suggestions," In Henk Folmer and Tom Tietenberg, eds. *The International Yearbook of Environmental and Resource Economics 2003/2003*, Cheltenham, UK: Edward Elgar.

Sandler, Todd, and Daniel G. Arce M. (2003), "Pure Public Goods versus Commons: Benefit-Cost Duality," *Land Economics* 79 (3), 355-368.

Shleifer, Andrei, and Robert W. Vishny (1993), "Corruption," *The Quarterly Journal of Economics* 108 (3), 599-617.

Simmons, Beth A. (2000), "The Legalization of International Monetary Affairs," *International Organization* 54 (3), 573-602.

Van Egteren, H. and M. Weber (1996), "Marketable permits, market power and cheating," *Journal of Environmental Economics and Management* 30, 161-173.

Chapter 4. CBRN Incidents: Political Regimes, Perpetrators, and Targets

This chapter investigates the relationship between regime characteristics and the likelihood of chemical, biological, radiological, and nuclear (CBRN) terrorist incidents. Odds ratios establish that democratic ideals – democratic rule, strong rule of law, and honest regimes – are associated with more CBRN incidents. Failed states may be where some terrorist groups form or take refuge, but these states have not been the venue of choice for CBRN incidents. Religious (cults and fundamentalists) and nationalist/separatist groups are not more likely than others to engage in CBRN attacks. To date, indiscriminate CBRN attacks are as likely as discriminate attacks to cause casualties. Transnational terrorist groups are less adept than others in concealing their acquisition of CBRN substances. For some regressions, democratic rule and strong rule of law are positive determinants of CBRN incidents.

Since the March 20, 1995 sarin attack by Aum Shinrikyo on the Tokyo subway, there has been a real concern that terrorists will resort to weapons of mass destruction (WMDs) in the form of chemical, biological, radiological, or nuclear (CBRN) attacks. This fear of CBRN terrorism was heightened with the mass casualties of about 3000 people caused by terrorist attacks on September 11, 2001 (hereafter 9/11) and the subsequent intelligence that the perpetrator, al-Qaeda, had

been trying to acquire WMDs (Parachini 2003). Shortly after 9/11, the anthrax letter attacks demonstrated that a weaponized version of the bacterium could be acquired and sent to elected officials and the media. By "raising the bar," 9/11 means that future terrorist attacks must involve still greater casualties or consequences if they are to attract *similar* media attention. A radiological or dirty bomb that shuts down a portion of a major city or a biological attack that sickens or kills scores of people would surely achieve long-term media coverage to rival that of 9/11. The latter prospect is being taken seriously by the US Department of Homeland Security (DHS), which allocated $2.5 billion in 2005 to begin to accumulate a stockpile of vaccines against biological attacks (US DHS 2005). DHS Secretary Chertoff's statement on July 13, 2005 about DHS priorities indicated that protection against CBRN attacks is a key imperative when allocating department resources. In fact, Chertoff stated that there needs to be a "particular focus on catastrophic events."[1]

Until the Tokyo subway attack, the conventional wisdom among terrorist experts was that terrorists had little interest in acquiring WMDs, because terrorists wanted more people to witness their attacks than to die from them (Jenkins 1985; Hoffman 1998, 205-206). This characterization is supported by casualty figures that show that each terrorist incident prior to the 1990s killed less than one person on average and that many incidents killed no one (Enders and Sandler 2000, 2006). Many factors supported the once-conventional viewpoint that terrorists do not seek WMDs.[2] First, resort to a CBRN attack could lose constituency support and funds

for the terrorists. Second, such attacks would likely lead to massive retribution by the targeted country, analogous to the US response against al-Qaida and the Taliban following 9/11. Third, there are weaponization hurdles to surpass even after the ingredients for the device are obtained. Fourth, efforts to secure a CBRN weapon could compromise a group's cover because members may be exposed to a sting operation. Fifth, CBRN development poses handling risks to the terrorists – e.g., poisoning or radioactive contamination. Sixth, given the cost effectiveness of conventional attacks, there once seemed little need to resort to CBRN attacks. However, the rise of religious fundamentalist terrorism, the need to surpass the shock benchmark of 9/11, terrorists' acquisition of scientific expertise, and better means to hide members' identities may have weakened these restraints and made CBRN use more likely.

The purpose of this article is to use data on CBRN incidents, collected by the Monterey Institute of International Studies (2005), to investigate three factors that are hypothesized to influence the use of CBRN terrorism. We first examine whether characteristics of political regimes (i.e., democracy, strong rule of law, and noncorruption) are related to past CBRN incidents. In the terrorism literature, democratic values and institutions have been shown to support and encourage terrorist attacks owing to freedom of association, protection of civil liberties, media coverage of events, and an ability to acquire weapons, funding, and information.[3] We contend that democratic rights and principles are positively associated with CBRN incidents. Weak rule of law, as characterizing failed states, may be

conducive to terrorist groups getting organized, but strong rule of law presents an ideal venue for CBRN incidents. This follows because terrorists' rights are protected and successful attacks call into question the ability of the government to protect life and property, which leads to a damaging societal autoimmune response (Steinbruner 2005). Next, we use data on CBRN incidents to ascertain if groups' motives and structure are conducive to such events. The literature identified religious cults, fundamentalist groups, and nationalist/separatist groups as likely perpetrators of WMD attacks (Ackerman 2004; Gurr 2005; Post 2005; Sinai 2005)[4]. This hypothesized association is tested. In addition, we test whether transnational groups are less likely to conceal their acquisition of CBRN weapons (Blum et al. 2005). Finally, we investigate whether target choice (e.g., government or nongovernment) is related to democratic institutions. From a policy perspective, we test whether casualties associated with CBRN incidents correspond to target choice (i.e., indiscriminate versus discriminate or government versus nongovernment) or the transnational orientation of the group. Our study is the first to use statistical inference on past CBRN attacks to ascertain some of their key properties. As an initial foray, we rely on simple statistical tests to see what the data imply about potential relationships before applying more complex statistical techniques in subsequent studies.

There are a number of noteworthy findings. CBRN incidents are, indeed, more likely to occur in democracies. Both strong rule of law and the absence of corruption increase the odds of CBRN events. Contrary to much of the recent

literature, religious (i.e., cults and fundamentalists) and nationalist/separatist groups are *not* more likely than others to engage in CBRN incidents.[5] Moreover, the odds of religious cults and fundamentalists being involved in CBRN events are not significantly different in democracies or autocracies; however, the odds of them being involved in CBRN incidents are generally greater where governments are noncorrupt or there is strong rule of law. Contrary to anticipation (Post 2005), indiscriminate CBRN attacks are as likely as discriminate attacks to result in casualties. Transnational terrorist groups are less likely to conceal CBRN agents; other groups have higher odds of using acquired CBRN agents.

The remainder of the chapter contains seven sections. The first section presents essential definitions and describes the data sets. In the second section, the odds ratio test methodology is briefly reviewed. The third section indicates the results for political regimes and the use of CBRN attacks, while the fourth section presents the relationship between group type and CBRN events. The association between CBRN events and target choices and casualties are studied in the fifth section. The sixth section presents some regressions where democracy and strong rule of law are determinants of CBRN attacks, thereby supporting our odds ratio tests. Concluding remarks and policy recommendations are contained in the final section.

Essential Definitions and Data Sets

Terrorism is the premeditated use or threat of use of violence by individuals or subnational groups to obtain political or social objectives through intimidation of a large audience beyond that of the immediate victim. Our definition leaves out state terrorism so that Saddam Hussein's use of a chemical attack on a Kurdish village would not satisfy our terrorism definition. Any modern definition of terrorism includes two key elements: the presence or threat of violence and a political/social motive. Violence is used to extort concessions from a targeted government. In the absence of a political/social objective, a violent act is a crime rather than an instance of terrorism. Terrorists make their attacks appear random to elevate the targeted population's anxiety and to increase governments' expenditure on defensive measures. By resorting to attacks with mass casualties, terrorists create even greater fear and necessitate more expensive countermeasures. Even the hint of a CBRN attack forces a liberal democracy, whose legitimacy rests on protecting lives and property, to spend massive outlays to protect against the prospect.

Another essential distinction involves domestic and transnational terrorism. Domestic terrorism is homegrown with consequences for just the host country, its institutions, citizens, property, and policies. The Oklahoma City bombing of the Alfred P. Murrah federal building by Timothy McVeigh on April 19, 1995 was a domestic incident involving the United States. In contrast, transnational terrorism has implications for two or more countries. The 9/11 hijackings are transnational terrorist acts, since victims were from almost 80 countries, the perpetrators were

foreign, and financial repercussions involved the global economy. A shoulder-fired, surface-to-air missile that brings down a plane with citizens from two or more countries is a transnational terrorist event. A transnational group engages in one or more transnational terrorist attacks.

As the central notion of this study, we must make clear our definition of CBRN terrorism. In the terrorism literature, WMDs consist of any mine, bomb, or device that releases chemicals, biological organisms, or radiation in sufficient quantity to cause the loss of life (Bunker 2000; Blum et al. 2005). There is no official requirement that this loss of life be extensive – the mere application of CBRN substances is enough to qualify as WMD terrorism. CBRN attacks may kill many or few. Up until now, CBRN terrorist attacks have killed relatively few people: the anthrax letters in the United States killed five and sickened twenty-two people, while the Aum Shinrikyo sarin attack near the judicial building in Matsumoto, Japan on June 27, 1994 killed seven and sickened 150. The Monterey Institute of International Studies data set (2005) follows the literature and classifies terrorist WMD incidents as those involving CBRN devices. We, however, feel that equating CBRN and WMD attacks gives a misleading impression of CBRN incidents. In fact, 92 per cent of CBRN events in our sample resulted in no fatalities, while 77 per cent resulted in no injuries or deaths. Once three mass-casualty outliers (i.e., the Sarin attacks on the Tokyo subway on March 20, 1995; the poisoning of Christian demonstrators by Hausa military youths on February 21, 2000 in Kaduna, Nigeria; and the poisoning and use of sulfuric acid by a doomsday cult on March 17,

2000 in Kanungu, Uganda) are removed, casualties and/or deaths per incident are less than those of standard terrorism events. For example, deaths per CBRN incident in our sample are just 0.51, about half of that of standard transnational terrorism events. This agrees with the insightful article by David Rapoport which argues that such attacks have not been very deadly (Rapoport 1999). To provide the proper impression, we, henceforth refer to CBRN, rather than WMD, incidents.

Although we recognize that a conventional terrorist incident – such as 9/11 – may result in thousands of casualties, we still see much gained by studying CBRN events. Because CBRN incidents may be precursors to future incidents with much greater carnage, their study provides insights as to perpetrators, location, targets, and other factors. CBRN incidents have the potential to cause mass casualties or to result in billions of dollars in damages if executed correctly. For example, a dirty bomb exploded in a major city or seaport would cost billions in cleanup and lost commerce. Most conventional attacks do not have the same potential to cause mass casualties or significant long-term business losses. A knowledge of the likely venue and target associated with past CBRN incidents can inform policymakers. With DHS redirecting its focus on CBRN incidents, a study of CBRN incidents can indicate the wisdom of this reallocation. Past casualty figures suggest that some of this reallocation may not be justified.

The Monterey WMD terrorism database records both politically and criminally motivated incidents by substate actors that involve CBRN substances. Given our interest in terrorist CBRN acts, we exclude purely criminal acts with no

terrorism motive (classified as Type II in the database) from the analysis. Furthermore, we do not include cases for which there was no confirmation of a realistic threat of a CBRN substance. As such, "plot only" incidents – where the perpetrator allegedly planned to acquire and use CBRN material but never managed to possess the substance – are not included in our sample of incidents. We also cull instances of hoax, prank, or threat where there is *no evidence of possession* of the CBRN agent. A hoax or prank is a claimed past act that either did not occur or involved a fake substance – e.g., a letter with baby powder mailed to an elected official with a note claiming that the powder is anthrax. A threat is a promised action that is never fulfilled. The extent of culling is extensive – our sample includes only 316 of the 1093 CBRN incidents in the Monterey data set for 1988-2004. The greatest culling occurs for 2001, where we use only 21 of the 309 incidents from the Monterey Institute data.

Tables 12 and 13 provide some key aspects of our sample of 316 CBRN attacks. In Table 12, we list the incident frequency by region, type of agent, type of group, and type of delivery device. Most CBRN attacks occurred in Asia, followed by the United States and Canada, and then Europe. Chemical incidents are by far the most common, accounting for almost two-thirds of all CBRN events in the sample. Biological attacks are second and include a couple of attempts by Aum Shinrikyo to use anthrax. Radiological incidents involve a couple of dirty bombs by Chechen militants that did not explode, along with efforts by others to acquire radiological materials for terrorism purposes. Group involvement is also indicated, with

unknown perpetrators accounting for over a third of the attacks (109), followed by nationalists/separatists (69). Religious fundamentalists and cults engaged in a total of 54 attacks in the sample. Finally, the delivery system is indicated.

Table 12. Descriptive categories for sample drawn from Monterey WMD terrorism database

Category	Subcategory	Frequency
Region	Asia	98
	Australia and Oceania	7
	Europe	44
	Latin America	16
	Middle East and North Africa	22
	Russia and Newly Independent States	29
	Sub Saharan Africa	12
	United States and Canada	85
	Worldwide	3
Type of Agent	Biological	42
	Chemical	207
	Combination	7
	Nuclear	8
	Radiological	26
	Unknown	26
Type of Group	Criminal Organization	2
	Left-wing	28
	Lone Actor(s)	23
	Nationalists/Separatists	69
	Religious (Cults)	28
	Religious (Fundamentalists)	26
	Right-wing	9
	Single-issue	21
	Unknown	109
Type of Delivery	Aerosol/Spray	19
	Casual/Personal/Direct Contact	43
	Consumer Product Tampering	18
	Explosive Device	28
	Food/Drink	22
	Injection/Projectile	19
	Jug/Jar/Canister	13
	Letter/Package	46
	Not Applicable (Case of possession)	45
	Reaction Device	3
	Unknown	47
	Ventilation System	1
	Water Supply	12

Table 13. Other aspects of the data on CBRN attacks (1988-2004)

Sample Countries (All)			
Afghanistan	France	Malaysia	Sudan
Albania	Germany	Mauritius	Tajikistan
Angola	India	Myanmar	Trinidad and Tobago
Australia	Iran	New Zealand	Turkey
Bangladesh	Iraq	Nigeria	Uganda
Belgium	Israel	Pakistan	United Kingdom
Bosnia&Herzegovina	Italy	Philippines	United States
Bulgaria	Japan	Romania	Uzbekistan
Cambodia	Jordan	Russian Federation	Vietnam
Canada	Kenya	South Africa	Zimbabwe
China	Kyrgyzstan	Spain	
Colombia	Lebanon	Sri Lanka	

Sample Groups (Some)
Al-Qaeda
Algerian Salafist Group for Combat and Preaching (GSPC)
Ansar al-Islam
Aum Shinrikyo
Chechen Militants
Fuerzas Armadas Revolucionarios de Colombia (FARC)
Groupe Islamique Armee (GIA)
Hamas
Hizbollah
Irish Republican Army (IRA)
Islamic Jihad
Jaish-e-Muhamad
Jemaah Islamiyah
Kach
Kurdistan Workers Party (PKK)
Lashkar-e-Jhangvi
Lashkar-e-Toiba
Liberation Tigers of Tamil Eelam (LTTE)
Mujahedin Khalq (MKO)
National Union for the Total Independence of Angola (UNITA)
Oromo Liberation Front (OLF)
Popular Front for the Liberation of Palestine (PFLP)
Revolutionary People's Liberation Party (DHKP_C)
Scottish National Liberation Army (SNLA)

Sample Statistics	
Casualties per incident:[1] 10.54	% of radiological incidents: 8.23
Deaths per incident:[2] 3.93	% of nuclear incidents: 2.53
% of chemical incidents:65.51	% of combination incidents: 2.22
% of biological incidents: 13.29	% of incidents involving unknown agents:8.23

Table 13 offers additional information including the countries and the primary terrorist groups in our sample. Some sample statistics are given at the

bottom of the table. Before outliers are removed, casualties per sample CBRN incident is 10.54, while deaths per sample CBRN incident is 3.93. After the removal of three casualty incidents and two death incidents, these figures drop to 3.82 and 0.51 per incident, respectively. This gives a more accurate picture that such incidents have not yet imposed the same threat as non-CBRN incidents. Of course, this could change.

Based on Monterey WMD data, Figure 1 displays the annual number of terrorist CBRN incidents for 1960-2004. This time series excludes criminal and nonsubstantiated incidents as described above. Given this time plot, we see that terrorist WMD events do not really show much presence or variation until 1984. We include such incidents from the second quarter of 1988 on in the statistical analysis because there are sufficient incidents for statistical inference.

To measure possible relationships between past CBRN terrorism and the type of political regime, we rely on yearly data drawn from the Polity IV Project, "Political Regime Characteristics and Transitions, 1800-2003 (Marshall and Jaggers 2004)." Polity data are collected by the Integrated Network for Societal Conflict Research (INSCR) at the University of Maryland and permit a distinction between democratic and autocratic regimes. Democracy possesses three essential interdependent elements: (1) institutions and procedures that facilitate political participation, (2) institutional constraints that limit executive power, and (3) government-backed guarantees that protect civil liberties (e.g., freedom of speech, freedom of association, and due process). In contrast, autocracies (nondemocracies)

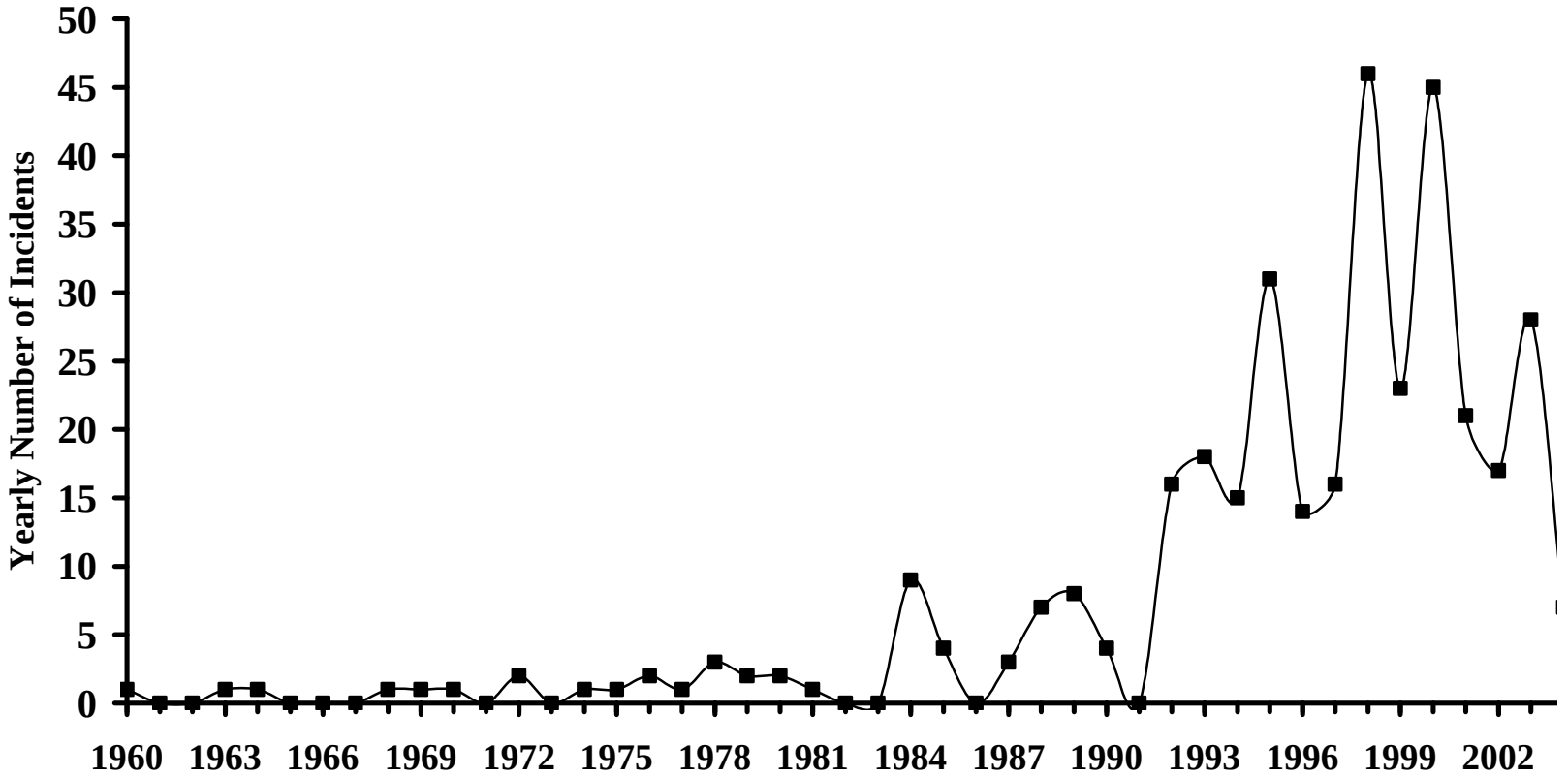
greatly restrict political participation and regular, competitive elections. Moreover, autocracies display few restraints on executive power and significant restrictions on civil liberties. In Polity IV, the score on regime type is scaled from 0 to 10 for the democracy indicator and from −10 to 0 for the autocracy indicator. Each of these indicators aggregate scores on the three elements of regime type into a single score. High scores for the democratic indicator reflect a strong democracy, while low scores reflect a strong autocracy. The composite polity score, which is the sum of the democracy and autocracy indicators, ranges from −10 to 10. Following Jaggers and Gurr (1995, 474), we classify nations with polity scores of 7 and above as democracies and nations with polity scores of −7 and below as autocracies.[6]

To explore the relationship between CBRN terrorism and other regime characteristics, we use monthly data on law and order (i.e., *rule of law*) and corruption for 1992 to 2001, taken from the International Country Risk Guide (ICRG) produced by the Political Risk Services (PRS) Group (2004). We use ICRG data starting in 1992 because ICRG indicates less confidence with its data prior to that date. ICRG data after 2001 are not available to us. The ICRG index of law and order is constructed using two subcomponents: (1) a law component indicating the impartiality or fairness of the legal system, and (2) an order component characterizing people's observance of the law.[7] The scores on these two components are combined into a single "rule of law" variable that ranges from 6 to 0, where high scores indicate "sound political institutions, a strong court system, and provision of orderly succession of power," and low scores suggest "a tradition of depending on

physical force or illegal means to settle claims" (Knack and Keefer 1995). The ICRG corruption index reflects the prevalence of patronage, nepotism, quid-pro-quo transactions, secret party funding, and suspicious relationships between government and business.[8] Evidence of bribes, associated with import and export licenses, exchange rate transactions, tax assessments, police activities, or loans, lowers a country's corruption index, which ranges from 0 (high corruption) to 6 (low corruption).

The rule of law and the corruption variables are two components used by ICRG to calculate political risk to international business operators in different countries. ICRG guidelines suggest that each of the components of political risk is indicative of very high risk if the associated index is less than 50 per cent of the top score of 6.[9] When, however, the index is 80 to 100 per cent of the top score, the risk is viewed as very low. Assuming that very high risk corresponds to weak adherence to law and order and dishonest transactions, we classify countries whose rule of law or corruption index is less than 3 as having weak rule of law or corrupt regimes. Similarly, we classify countries whose indices equal or exceed 4.8 as displaying strong rule of law or an absence of corruption.[10]

Figure 1. CBRN terrorist incidents: 1960-2004



The type of perpetrator – i.e., religious cult, religious fundamentalists, nationalists/separatists, or others – comes from the Monterey WMD data. We also use this database's information to ascertain whether the government or something else was targeted by the CBRN incident. The Monterey dataset classifies attacks as *indiscriminate* if the CBRN substance is *not* directed at a particular target or victim (i.e., a specific individual or institution), but is, instead, used where the victim is a random draw (e.g., the people within the vicinity when a device goes off). Thus, the Tokyo sarin attack was an indiscriminate attack. In contrast, Aum Shinrikyo's sarin attack near the judicial complex in Matsumoto on June 27, 1994 was a *discriminate* attack, aimed at killing the three judges who presided over a land dispute case involving the terrorist group. The three judges were sickened by the attack and their ruling delayed. Other victims were unintended collateral damage.

Odds Ratio Methodology

Because the establishment of causality may be problematic, a careful investigation of a relationship between different variables should first begin with a demonstration that there is a statistical association among key variables. The analysis can then proceed to investigate the nature of the association: i.e., is it casual?; and is it direct or indirect? The Monterey data on CBRN incidents have scarcely been used. Thus, our goal is to conduct a preliminary analysis to ascertain whether there is any statistical association or correlation between variables of interest, such as regime characteristics and the presence of CBRN incidents.

Because most of the variables that we investigate are categorical in nature, the odds ratio test provides a simple method to detect the magnitude and significance of the association between such variables. A host of these tests allows us to address a wide range of questions. With an odds ratio test, we can investigate not only relationship between an explanatory and a dependent variable, but also the relationship where both variables are interdependent outcomes (i.e., both are dependent variables). This may apply to the association between the type of targets (i.e., governmental or nongovernmental) and political regime.[11] In the terrorism literature, odds ratio tests were first used by Eubank and Weinberg (1994) to test the relationship between democracies and the presence of terrorist groups. In a later section, we provide some initial regression findings where regime characteristics and income per capita are explanatory variables for the number of CBRN incidents.

The odds of an event are the ratio of the chance that it will occur to the chance that it will not occur. The odds ratio equals the odds of an event in a group exposed to some factor divided by the odds of an event in the group unexposed to that same factor. Suppose that we are interested in investigating the relationship between CBRN terrorism and democracies, where democracies represent the exposed groups, while autocracies denote the unexposed group. The odds ratio is computed as follows: During the designated period, the number of democracies where one or more CBRN incidents took place is divided by the number of democracies where no CBRN incidents took place. This then gives the odds of CBRN incidents occurring in democracies. For the same period, a similar

calculation for autocracies yields the odds of CBRN incidents happening in autocracies. Finally, we divide the CBRN odds in democracies by its odds in autocracies to get the associated odds ratio.

If the odds ratio equals 1, then there is no relationship between the variables as the odds of an event in the exposed group is identical to the odds of an event in the unexposed group. If, however, the odds ratio exceeds 1, then there is a positive association between variables so that the event (e.g., a CBRN incident) is more likely to occur in the exposed group (e.g., democracies) than in the unexposed group (e.g., autocracies). Odds ratios less than 1 imply a negative association in which the event is less apt to happen in the exposed than in the unexposed group. The significance of the odds ratio is determined by a chi-square test for independence between the row and column variables in a two by two table, as reported below. We use a .05 level of significance and report the *prob* or *p* value. One can also conclude that the odds ratio is statistically significant at the .05 level provided that the 95 per cent confidence interval *does not* include an odds ratio of 1.

CBRN Attacks and Political Regimes

We begin with an examination of the influence of democracy, rule of law, and corruption on the occurrence of CBRN incidents. Since we only had yearly data on regime type, we assume that the type of regime did not change between quarters in a given year. For each quarter between 1988 and 2003, we subdivide democracies and autocracies into those where one or more CBRN terrorist incidents took place

and those where no such incident took place.[12] Based on the number of democracies, the number of autocracies, and the number of quarters, the sample size, *N*, is 6056. The subdivision results in the 2×2 frequency counts in Table 14, from which we compute the odds of CBRN terrorist incidence occurring in democracies and autocracies, respectively. The odds ratio is found by dividing 0.0319 by 0.0069 in Table 14. Thus, the odds of terrorist incidents involving CBRN material are 4.64 times higher in democracies than in autocracies. The associated *p* value is 0.0000; the odds ratio of 1 lies outside of the 95 per cent confidence interval. Hence, the odds of CBRN incidents are significantly higher in democracies compared with autocracies. This finding suggests that democracies will be the likely venue for future CBRN attacks. Clearly, freedom of information, the right to privacy, and freedom of association offer the right environment and support for such incidents.

For the 1992-2001 period, similar exercises relate the odds of CBRN incidents to strong and weak rule of law and to the level of corruption. Because we have monthly data on rule of law (i.e., law and order) and corruption, we assign the average rule of law and corruption scores during each three-month period as the country's quarterly scores for these two attributes. In Table 15, the odds of CBRN incidents are 3.24 times greater where the rule of law is strong rather than weak. This ratio is significant ($p = 0.0005$). Our findings indicate that Gurr's (2005) predicted relationship between failed states (where the rule of law is weak) and CBRN attacks must be interpreted with caution. Although failed states may facilitate the genesis of a terrorist group that might resort to a CBRN attack, the staging of

these attacks have been where the rule of law is strong. Table 16 indicates that the odds of CBRN incidents is 1.94 times greater in noncorrupt than in corrupt regimes.[13] This ratio is significant at the .05 level. Thus, honest regimes appear to attract CBRN incidents; however, this association is not strong like that for democracy and strong rule of law.

Democratic ideals and institutions have a downside since they appear to facilitate WMD acquisition and use. By restraining executive power and protecting individuals' (including terrorists') freedoms, democratic regimes and values provide terrorists with the opportunity and means to engage in WMD terrorism. Thus, Chertoff's (2005) concerns appear well-founded based on past experiences that could portend the future. Nevertheless, the appropriate level of protection for CBRN attacks must be judged not only on their likely venue but also their likely consequences. To date, these attacks have not caused many deaths per incident.

Group Type and CBRN Events

Next, we focus on the perpetrators of CBRN incidents. Tables 17-19 use the odds ratio tests to judge if the likely perpetrators are religious cults and fundamentalists and/or nationalist/separatist groups (frequently, called nationalist groups) as hypothesized in the literature (e.g., Gurr 2005; Post 2005; Sinai 2005). In Tables 17-19, we use quarterly observations from the second quarter of 1988 through the second quarter of 2004 on whether a particular class of potential perpetrators did or did not engage in a CBRN incident. The period now includes through the first

half of 2004, since the availability of regime data needs not constrain our investigation for these three odds ratio tests.

Table 14. Relationship between CBRN terrorism incidents and regime type (1988-2003)

	Democracies	Autocracies
One or more CBRN incidents occurred in a given quarter	124	14
No CBRN incidents occurred in a given quarter	3884	2034
Odds of CBRN terrorist incidents occurring	0.0319	0.0069
Odds ratio = 4.64 Chi-square = 35.36 Standard error = 1.31 *N* = 6056 *p* = 0.0000	Lower 95% confidence limit = 2.65 Upper 95% confidence limit = 8.75	

Table 15. Relationship between CBRN terrorism incidents and rule of law (1992-2001)

	Strong rule of law	Weak rule of law
One or more CBRN incidents occurred in a given quarter	68	9
No CBRN incidents occurred in a given quarter	1975	847
Odds of CBRN terrorist incidents occurring	0.0344	0.0106
Odds ratio = 3.24 Chi-square = 12.10 Standard error = 1.16 *N* = 2899 *p* = 0.0005	Lower 95% confidence limit = 1.60 Upper 95% confidence limit = 7.42	

Table 16. Relationship between CBRN terrorism incidents and corruption (1992-2001)

	Noncorrupt	Corrupt
One or more CBRN incidents occurred in a given quarter	38	32
No CBRN incidents occurred in a given quarter	934	1523
Odds of CBRN terrorist incidents occurring	0.0407	0.0210
Odds ratio = 1.94 Chi-square = 7.61 Standard error = 0.47 *N* = 2527 *p* = 0.0058	Lower 95% confidence limit = 1.17 Upper 95% confidence limit = 3.22	

In Table 17, religious groups refer to religious cults and religious fundamentalists, while "all others" refer to potential perpetrators of CBRN events who did not belong to these religious groups. *N* is 130 because there are two categories of potential agents for the 65 quarters. The odds ratio of 0.16 indicates that the odds of the perpetrator being a religious group are less than one fifth of the odds of the perpetrator being some other type. In other words, nonreligious agents are over five times more likely than religious groups to engage in CBRN incidents. This outcome is quite significant ($p = 0.0000$) and is against conventional wisdom.

In Table 18, we examine nationalist/separatist groups (e.g., Tamil Tigers in Sri Lanka) in comparison with all other potential perpetrators. The odds ratio of 0.33 indicates that all others are three times more likely than nationalist/separatist groups to execute CBRN incidents. This result is significant at the .05 level. We next combine religious and nationalist/separatist groups into a single category of religious/nationalists. This combination is thought to pose the greatest threat of CBRN terrorism (Blum et al. 2005; Post 2005). The odds ratio test, however, shows

that religious/nationalists *are not more likely* than others to conduct CBRN incidents (see Table 19). Although the odds ratio is not significantly different than 1, the odds of such attacks by others is greater than that of religious/nationalist groups. This result is rather surprising and serves policy ends by identifying the orientation of the likely perpetrator.

Table 17. Relationship between CBRN terrorism and religious groups (1988-2004)

	Religious groups	All others
One or more CBRN incidents occurred in a given quarter	29	54
No CBRN incidents occurred in a given quarter	36	11
Odds of CBRN terrorist incidents occurring	0.8056	4.9091
Odds ratio = 0.16 Chi-square = 20.83 Standard error = 0.07 *N* = 130 *p* = 0.0000	Lower 95% confidence limit = 0.07 Upper 95% confidence limit = 0.39	

Table 18. Relationship between CBRN terrorism and nationalist groups (1988-2004

	Nationalist groups	All others
One or more CBRN incidents occurred in a given quarter	40	54
No CBRN incidents occurred in a given quarter	25	11
Odds of CBRN terrorist incidents occurring	1.6000	4.9091
Odds ratio = 0.33 Chi-square = 7.53 Standard error = 0.14 *N* = 130 *p* = 0.0061	Lower 95% confidence limit = 0.13 Upper 95% confidence limit = 0.79	

Table 19. Relationship between CBRN terrorism and religious and nationalist groups (1988-2004)

	Religious/Nationalists	All others
One or more CBRN incidents occurred in a given quarter	46	51
No CBRN incidents occurred in a given quarter	19	14
Odds of CBRN terrorist incidents occurring	2.4211	3.6429
Odds ratio = 0.67 Chi-square = 1.02 Standard error = 0.27 *N* = 130 *p* = 0.3136	Lower 95% confidence limit = 0.28 Upper 95% confidence limit = 1.58	

In Tables 20-22, we explore how CBRN terrorist incidents by religious groups relate to regime characteristics. This investigation allows us to join elements of our first two exercises. In particular, we investigate whether regime type is associated with CBRN activity by religious cults and fundamentalists. Table 20, for example, computes the odds ratio of religious group involvement in a CBRN event in democracies compared with their involvement in autocracies. Even though religious groups are 3.46 times more likely to carry out a CBRN event in democracies compared with autocracies, the chi-square value is *not* significant. The raw counts in the four cells are still consistent with CBRN incidents being perpetrated by others in democracies. In Table 21, the relationship between the type of group and the rule of law is just significant with $p = 0.042$. The associated odds ratio equals infinity because there are no CBRN terrorist events by religious groups in lawless countries. When the rule of law is strong, religious groups are more likely to engage in CBRN incidents. Table 22 shows that the odds of religious groups rather than other actors carrying out a CBRN terrorist attack are 3.67 times higher in

noncorrupt than in corrupt countries. The associated chi-square is significant with $p = 0.005$. In summary, Tables 20-22 indicate that religious cults and fundamentalists favor staging CBRN incidents in democracies with strong rule of law and honest governments.

Table 20. Relationship between CBRN terrorist incidents carried out by religious groups and regime type (1988-2003)

	Democracies	Autocracies
Religious cults or fundamentalists	38	1
All other actors	187	17
Odds of religious group involvement in a CBRN incident	0.2032	0.0588
Odds ratio = 3.46 Chi-square = 1.59 Standard error = 3.61 *N* = 243 *p* = 0.2075	Lower 95% confidence limit = 0.51 Upper 95% confidence limit = 148.09	

Table 21. Relationship between CBRN terrorist incidents carried out by religious groups and rule of law (1992-2001)

	Strong rule of law	Weak rule of law
Religious cults or fundamentalists	27	0
All other actors	108	17
Odds of religious group involvement in a CBRN incident	0.25	0
Odds ratio = infinity Chi-square = 4.13 Standard error = – *N* = 152 *p* = 0.042	Lower 95% confidence limit = 1.08 Upper 95% confidence limit = –	

Table 22. Relationship between CBRN terrorist incidents carried out by religious groups and corruption (1992-2001)

	Noncorrupt	Corrupt
Religious cults or fundamentalists	24	7
All other actors	42	45
Odds of religious group involvement in a CBRN incident	0.5714	0.1556
Odds ratio = 3.67 Chi-square = 7.88 Standard error = 1.76 *N* = 118 *p* = 0.005	Lower 95% confidence limit = 1.34 Upper 95% confidence limit = 11.07	

We also computed analogous odds ratio tests (available upon request) that relate nationalist perpetrators and the three characteristics of regimes. Compared with other agents, the odds of nationalists/separatists CBRN involvement is no different in democracies than in autocracies. Unlike religious groups, nationalists/separatists have greater odds of CBRN terrorist activity compared with other actors where the rule of law is weak or there is corruption. Thus, some democratic principles inhibit CBRN actions for nationalists/separatists but not for religious groups. Thus, CBRN incidents in failed states are apt to come at the hands of nationalist/separatist terrorists.

Recently, Blum et al. (2005, 135) noted that "secretive, cult-like groups are more likely to be able to keep CBRN activity concealed, whereas transnational groups are more likely to be able to obtain CBRN resources but are less likely to be able to conceal CBRN activity." We cannot test this hypothesis directly because we cannot obtain data on concealed activities. However, the Monterey WMD database

differentiates between incidents where the CBRN substance was actually used (classified as "use of agent") from those cases where the perpetrator only threatened to use a CBRN substance in their possession (classified as a "threat with possession"). The database also indicates instances where the terrorists possessed the CBRN agent with the intent to use it (classified as "possession") and cases where the terrorists' efforts to acquire the CBRN agent failed or was stopped (classified as "attempted acquisition"). By grouping the last three categories together, we can subdivide all CBRN incidents in the Monterey database as follows: (1) the terrorists succeeded in concealing their CBRN activity until the CBRN agent was used, and (2) the terrorists did not succeed in concealing their CBRN activity. In the latter case, the terrorist CBRN intention either became known or was stopped before the act was consummated.

To examine whether the *use* of a CBRN agent as opposed to its acquisition or possession varies between transnational groups and other perpetrators, we code each of the terrorist groups in the Monterey database as transnational or otherwise. If a group is included in the *International Terrorism: Attributes of Terrorist Events* (ITERATE) dataset (Mickolus et al. 2005), which records groups engaging in one or more transnational terrorist events, then the group is classified as transnational. Perpetrators in the Monterey database that are not in ITERATE are classified as "all others."

In Table 23, the chances that terrorist efforts will result in the actual use of a CBRN agent are significantly less for transnational groups. From 1988 through the

middle of 2004, the odds ratio is only 0.28, so that other perpetrators are over three times more likely to use a CBRN substance compared with transnational terrorist groups. The associated chi-square is significant. This finding supports the hypothesis that transnational groups are less adept at concealing their CBRN activity than other CBRN perpetrators. Possession of CBRN substances by transnational groups becomes known with no subsequent action in a relatively high proportion of cases.

We also investigate whether target choice is associated with a group's transnational orientation. The significant odds ratio in Table 24 highlights that transnational groups are almost twice as likely as others to choose a government target in CBRN acts. This targeting insight can help direct counterterrorist resources when a transnational group is involved. In Table 25, the odds ratio indicates that CBRN incidents with an indiscriminate target are equally likely to be carried out by either transnational groups or all other perpetrators. Thus, transnational groups do not appear to be more bloodthirsty or intent on causing widespread fear compared with other perpetrators of CBRN events.

Table 23. Relationship between the type of CBRN incidents and the transnational orientation of perpetrators (1988-2004)

	Transnational groups	All others
Actual use of CBRN substance	44	164
Acquisition or possession only	53	55
Odds of CBRN substance being used	0.8302	2.9818
Odds ratio = 0.28 Chi-square = 26.05 Standard error = 0.07 *N* = 316 *p* = 0.0000	Lower 95% confidence limit = 0.16 Upper 95% confidence limit = 0.48	

Table 24. Relationship between the target of CBRN attacks and the transnational orientation of perpetrators (1988-2004)

	Transnational groups	All others
Government Target	51	76
Nongovernment target	46	143
Odds of government being a CBRN target	1.1087	0.5315
Odds ratio = 2.09 Chi-square = 8.93 Standard error = 0.52 *N* = 316 *p* = 0.0028	Lower 95% confidence limit = 1.25 Upper 95% confidence limit = 3.49	

Table 25. Relationship between target discrimination of CBRN attacks and transnational orientation of perpetrators (1988-2004)

	Transnational groups	All others
Indiscriminate target	45	101
Discriminate target	52	118
Odds of indiscriminate target being attacked	0.8654	0.8559
Odds ratio = 1.01 Chi-square = 0.00 Standard error = 0.25 *N* = 316 *p* = 0.9642	Lower 95% confidence limit = 0.61 Upper 95% confidence limit = 1.68	

Other Target Choices

We now relate CBRN target choice to democratic institutions. In particular, we ascertain whether government targets are more likely to be attacked in democracies rather than in autocracies, or where the rule of law is strong rather than weak, or in noncorrupt rather than corrupt countries. For Table 26, we separate all CBRN incidents between 1988 and 2003 into those where the government was either the primary target (the immediate "target suffering the physical assault") or the secondary target (the ultimate "target being affected by the symbolic and psychological impact of the attack"),[14] and those where the government was not a target. CBRN incidents in democracies and autocracies are then subdivided based on target choice: government or nongovernment. Tables 26 and 27 show that the odds of the government being the target of a CBRN incident are not significantly related to democracy *or* the rule of law. In Table 28, the odds of CBRN terrorist incidents being aimed at a government are 69 per cent lower in noncorrupt countries than in corrupt ones. The associated *p* value is 0.004. This result also indicates that nongovernment targets are more likely to be hit in noncorrupt regimes, thus putting the general public in harm's way. This finding informs authorities where to allocate protective measures in various regime types.

Table 26. Relationship between target of CBRN incidents and regime type (1988-2003)

	Democracies	Autocracies
Government target	81	8
Nongovernment target	145	10
Odds of government being a CBRN target	0.5586	0.8000
Odds ratio = 0.70 Chi-square = 0.53 Standard error = 0.35 *N* = 244 *p* = 0.4655	Lower 95% confidence limit = 0.24 Upper 95% confidence limit = 2.13	

Table 27. Relationship between target of CBRN terrorist incidents and rule of law (1992-2001)

	Strong rule of law	Weak rule of law
Government target	35	5
Nongovernment target	101	12
Odds of government being a CBRN target	0.3465	0.4167
Odds ratio = 0.83 Chi-square = 0.11 Standard error = 0.47 *N* = 153 *p* = 0.745	Lower 95% confidence limit = 0.25 Upper 95% confidence limit = 3.24	

Table 28. Relationship between target of CBRN incidents and corruption (1992-2001)

	Noncorrupt	Corrupt
Government target	14	24
Nongovernment target	52	28
Odds of government being a CBRN target	0.2692	0.8571
Odds ratio = 0.31 Chi-square = 8.29 Standard error = 0.13 *N* = 118 *p* = 0.004	Lower 95% confidence limit = 0.13 Upper 95% confidence limit = 0.75	

To investigate whether CBRN incidents with casualties are more likely to be executed by transnational groups or other actors, or whether such incidents are more likely to vary with the type of target, we divide all incidents in the Monterey database into those that resulted in one or more injuries or fatalities (casualties) and those that involved no casualties. For 1988-2004, Table 29 indicates that the chances that CBRN incidents will result in one or more casualties is 40 per cent as likely for transnational groups compared with other agents. The associated chi-square is significant. Thus, the use of CBRN agents by transnational groups has been less threatening than their use by domestic terrorists thus far. Table 30 suggests that CBRN incidents are less apt to result in casualties when aimed at government targets. The odds that government-directed incidents result in casualties are 40 per cent lower for government than for nongovernment targets. The associated chi-square is, however, only significant at the .10 level, since $p = 0.0678$. Finally, Table 31 indicates that there is no significant relationship between CBRN incidents resulting in casualties and indiscriminate targeting of the general population. This finding does not support the view that "random targeting is associated with the motivation to cause social paralysis – or inflict mass casualties," (Post 2005, 149) because the odds of casualties with indiscriminate attacks are not significantly different than those with discriminate attacks. This surprising outcome may follow from past CBRN attacks, having limited casualties.

Table 29. Relationship between CBRN incidents with casualties and transnational orientation of perpetrators (1988-2004)

	Transnational groups	All others
CBRN incidents with one or more casualties	13	61
CBRN incidents with no casualties	84	158
Odds of CBRN incidents resulting in casualties	0.1548	0.3861
Odds ratio = 0.40 Chi-square = 7.83 Standard error = 0.13 *N* = 316 *p* = 0.0051	Lower 95% confidence limit = 0.19 Upper 95% confidence limit = 0.79	

Table 30. Relationship between CBRN incidents with casualties and target type (1988-2004)

	Government target	Nongovernment target
CBRN incidents with one or more casualties	23	51
CBRN incidents with no casualties	104	138
Odds of CBRN incidents resulting in casualties	0.2212	0.3696
Odds ratio = 0.60 Chi-square = 3.34 Standard error = 0.17 *N* = 316 *p* = 0.0678	Lower 95% confidence limit = 0.33 Upper 95% confidence limit = 1.07	

Table 31. Relationship between CBRN incidents with casualties and target discrimination (1988-2004)

	Indiscriminate target	Discriminate target
CBRN incidents with one or more casualties	38	36
CBRN incidents with no casualties	108	134
Odds of CBRN incidents resulting in casualties	0.3519	0.2687
Odds ratio = 1.31 Chi-square = 1.03 Standard error = 0.35 *N* = 316 *p* = 0.31	Lower 95% confidence limit = 0.75 Upper 95% confidence limit = 2.28	

CBRN Attacks and Democratic Regimes: Regression Analysis

We conclude with some regressions to ascertain whether democratic principles can explain CBRN attacks in a causal analysis. In so doing, we go beyond the correlations displayed thus far by the odds ratio tests. We are, thus, interested in explaining the variation in the number of CBRN incidents based on regime type, rule of law, and honesty (absence of corruption). For two estimations, we include a measure of the country's wealth in terms of the logged (ln) value of income per capita.[15] The dependent variable is an event count measure (the number of CBRN incidents per quarter), characterized by a preponderance of zeros (i.e., sample countries with no incidents in a quarter) and small values. The discrete nature of the data must be taken into account by the estimator, which is often done by using a regression based on the Poisson distribution (Cameron and Trivedi 1998; Greene 2003). A major shortcoming of a Poisson regression is that the conditional mean of the dependent variable is assumed to equal its conditional variance. If this underlying assumption is not appropriate, then the standard errors associated with the coefficient estimates will be underestimated.[16] A negative binomial regression is a generalization of a Poisson regression that allows for a greater underlying variance (overdispersion), not constrained to equal the mean. We apply maximum-likelihood methods to estimate the negative binomial regression model.

Given that we have cross-sectional, time-series data, it is reasonable to assume that observations from different quarters for the same country are correlated (which results in heteroscedasticity in the variance of the error term), while any two

observations for different countries are independent. To account for this correlation, we use a robust variance estimator clustered over countries that allows for heteroscedastic variance, both between and within countries (Williams 2000). Moreover, the formula for this estimator's variance matrix permits an arbitrary dependence structure for observations within countries so that estimations are robust not only to heteroscedasticity but also serial correlation.

In Table 32, we display the results for three negative binomial regressions, where CBRN incidents per quarter is the dependent variable. Model 1 contains democracy, rule of law, and honesty as independent *continuous* variables, while Model 2 also includes logged gross domestic product (GDP) per capita. In Model 3, we include dummy variables for all but one quarter to account for any temporal influences that may be associated with the number of CBRN incidents. To test between the negative binomial and Poisson regression, we examine the dispersion parameter. If this parameter equals one, then a Poisson distribution is appropriate. For all three models, we reject, at the .01 level, the hypothesis that the dispersion equals one, which means that the conditional variance exceeds the conditional mean (i.e., the negative binomial distribution applies). The log-likelihood value indicates that Model 3 is best. The Wald test indicates that the overall model is significant at the .01 level.

Table 32. Negative binomial regressions (standard errors adjusted for clustering on countries)

	Model 1	Model 2	Model 3
Democracy	0.159***	0.119***	0.116***
	(0.04)	(0.04)	(0.04)
Rule of Law	0.773***	0.510**	0.539**
	(0.25)	(0.25)	(0.23)
Honesty (no corruption)	–0.747***	–0.824***	–0.790***
	(0.16)	(0.17)	(0.20)
Ln (Income per capita)		0.435**	0.442**
		(0.22)	(0.20)
Constant	–5.002***	–6.917***	–7.178***
	(0.98)	(1.42)	(1.48)
Observations	4980	4580	4580
Dispersion = 1	24.52***	20.35***	15.49***
Log-likelihood	–639.34	–614.76	–587.72
Wald test (χ^2)	25.99***	30.51***	46229.54***

Note: Dependent variable is the number of CBRN incidents per quarter. Standard errors are in parentheses. For Model 3, the coefficients for quarterly dummies are not shown. *Significant at .10 level. **Significant at .05 level. ***Significant at the .01 level.

For all three models, coefficient estimates are amazingly robust showing little variation as variables are added. Consistent with our earlier results, democracy and strong rule of law are significant positive influences on the number of CBRN incidents. Unlike the odds ratio test, honesty is a negative influence on CBRN events. We should, however, remind the reader that the odds ratio tests for honesty was not as conclusive as for democracy and strong rule of law. Wealth, as reflected in income per capita, is also a significant positive determinant of CBRN incidents. Thus, rich countries with strong democratic regimes and strong rule of law attract CBRN attacks. Based on Model 3, a one point increase in the democracy score of a

country leads to an 11.6 per cent increase in the expected number of CBRN incidents. As a country's rule of law score increases by one point, there is a 53.9 percent increase in the expected number of CBRN incidents. The coefficient on rule of law is over four times as large as that on democracy, indicating that the effect of a one point increase in rule of law is over four times that of democracy. The estimated parameter suggests that if corruption decreases by one point, the anticipated number of CBRN incidents decreases by 79 per cent, which is a substantial change. Finally, an increase in a country's income per capita results in a large increase in its expected number of CBRN events.

Concluding Remarks

Chemical and biological attacks by Aum Shinrikyo in the mid 1990s in Japan suggest that CBRN devices *may* become a greater terrorist threat in the future. The large number of casualties associated with 9/11 and efforts by al-Qaeda to acquire CBRN substances foreshadow the possibility of future CBRN terrorist attacks as a means of causing mass casualties. Terrorists' recent actions to use larger bombs to create greater carnage also indicate that more deadly CBRN weapons may be deployed (Enders and Sandler 2006). Our paper uses the Monterey Institute WMD terrorism database to evaluate empirically the nature of CBRN terrorism. In particular, we apply odds ratio tests to judge some recent hypotheses about WMD incidents put forward by terrorist experts. In addition, we relate past CBRN incidents to regime characteristics to ascertain whether democratic principles and

values have been associated with CBRN incidents. To support these odds ratio tests for regime characteristics, we also report some regressions. Additionally, we investigate the likely CBRN perpetrators and past targeting decisions.

We find that democracy, strong rule of law, and honesty are positively and significantly *associated* with past CBRN incidents. In the regressions, democracy and strong rule of law are positive determinants of the number of CBRN incidents. Thus, liberal democratic regimes provide the environment where terrorists are more inclined to engage in such attacks. Failed states offer a place for some terrorist groups to form and seek sanctuary, but democratic states provide the staging ground for CBRN use. Thus, contrary to some conventional wisdom, CBRN incidents have taken place where the rule of law is strong. CBRN attacks in democracies may be favored by terrorists, because such attacks generate greater public anxiety and panic in regimes whose legitimacy rests on their ability to protect lives and property. Thus, democratic states must be vigilant against CBRN incidents, in keeping with the DHS shift of emphasis to be prepared for CBRN attacks.

Our results show that religious cults and fundamentalists display lower odds than others to engage in CBRN incidents. Similarly, nationalist/separatist groups are less likely than others to conduct CBRN events. As a single category, religious cults, fundamentalists, and nationalist/separatist groups are equally likely as all others to execute CBRN events. As anticipated in the literature, transnational terrorist groups display reduced odds of using CBRN devices, compared with other groups. The odds of the government being the target of a CBRN incident are not dependent on

democracy or the rule of law. Finally, we show that the likelihood of CBRN casualties is not related to indiscriminate targeting. Our analysis of targeting decisions by CBRN terrorists should inform policymakers – e.g., transnational terrorist groups favor government targets, while nongovernment targets are favored in noncorrupt regimes. This study is a modest effort on a crucial topic that requires more quantitative analysis to ascertain the validity of recent hypotheses and opinions.

Chapter 4 Notes

[1] For the text of Chertoff's speech, see http://www.dhs.gov/dhspublic/interapp/press_release_0703.xml.

[2] Past studies on democracy and terrorism includes Eubank and Weinberg (1994, 2001), Li (2005), Sandler (1995), Weinberg and Eubank (1998). Previous studies found that democracy is positively associated with terrorism.

[3] Contrary to these authors, Rapoport, "Terrorism and Weapons of the Apocalypse," does not view cults, fundamentalists, and nationalists/separatists as more prone to use CBRN terrorism.

[4] Thus, our finding agrees with the view expressed in Rapoport, "Terrorism and Weapons of the Apocalypse."

[5] These restrictive cutoffs to distinguish democratic from autocratic regimes have been applied by other studies using Polity data. Hence, we are following standard practice. In the odds ratio tests for democracy and CBRN incidents, we also used less stringent cutoffs and obtained the same statistical findings (available from the authors upon request).

[6] See the definitions for these components at the ICRG (2005) website, http://www.icrgonline.com/page.aspx?page=icrgmethods

[7] Again, see ICRG (2005) http://www.icrgonline.com/page.aspx?page=icrgmethods.

[8] Ibid.

[9] When we use 3 as the start of strong rule of law, our odds ratio results are essentially unchanged.

[10] Further analysis of such relationships can be based on log-linear models as described in Fleiss et al. (2003).

[11] We also use yearly observations, to test the relationship between CBRN incidents and regime characteristics. With yearly observations, *N* is cut by a quarter for the three cases. The results (tables available upon requests) are identical to the quarterly findings reported in the text.

[12] As an alternative exercise, we relate countries' categories (e.g., democracies and autocracies), rather than countries per se, to the presence or absence of CBRN incidents in a given quarter. Thus, there are now 128 observations – 64 for each type of country. Our results remain essentially unchanged from Tables 1-3: the odds ratio is 12.82 ($p = 0.000$) for regime type, 19.52 ($p = 0.000$) for strong rule of law, and 2.5 ($p = 0.0441$) for noncorruption.

[13] These definitions are taken from the Monterey Institute, *WMD Terrorism Database.*

[14] Data on income per capita come from World Bank Group, "World Development Indicators Online," http://devdata.worldbank.org/dataonline, accessed on January 16, 2006.

[15] The coefficient estimates will, however, be consistent.

Chapter 4 References

Ackerman, Gary (2004), "WMD Terrorism Research: Where to from Here?," Discussion Paper, Center for Nonproliferation Studies, Monterey Institute of International Studies, Monterey, CA.

Blum, Andrew, Victor Asal, and Jonathan Wilkenfeld (2005), "Nonstate Actors, Terrorism, and Weapons of Mass Destruction, Editors' Introduction," *International Studies Review* 7 (1), 133–137.

Bunker, Robert (2000), "Weapons of Mass Disruption and Terrorism," *Terrorism and Political Violence* 12 (1), 37–46.

Chertoff, Michael (2005), "Remarks by Secretary Michael Chertoff on the Second Stage Review of the Department of Homeland Security," July 13, 2005 [http://www.dhs.gov/dhspublic/interapp/press_release_0703.xml], accessed November 10, 2005.

Cameron, A. Colin and Pravin K. Trivedi (1998), *Regression Analysis of Count Data*, Cambridge: Cambridge University Press.

Enders, Walter and Todd Sandler (2000), "Is Transnational Terrorism Becoming More Threatening? A Time-Series Investigation," *Journal of Conflict Resolution* 44 (3), 307–332.

Enders, Walter and Todd Sandler (2006), *The Political Economy of Terrorism*, Cambridge: Cambridge University Press.

Eubank, William L. and Leonard B. Weinberg (1994), "Does Democracy Encourage Terrorism?," *Terrorism and Political Violence* 6 (4), 417–435.

Eubanks, William L. and Leonard B. Weinberg (2001), "Terrorism and Democracy: Perpetrators and Victims," *Terrorism and Political Violence* 13 (1), 155–164.

Fleiss, Joseph L., Bruce Levin, and Myunghee Cho Park (2003), *Statistical Methods for Rates and Proportions*, Third Edition Hoboken, NJ: John Wiley & Sons, Inc.

Greene, William H. (2003), *Econometric Analysis*, Fifth Edition Upper Saddle River, NJ: Pearson Education, Inc.

Gurr, Ted R. (2005), "Which Minorities Might Use Weapons of Mass Destruction?," *International Studies Review* 7 (1), 143-146.

Hoffman, Bruce (1998), *Inside Terrorism* New York: Columbia University Press.

International Country Risk Guide (ICRG) (2005), "About ICRG," [http://www.icrgonline.com/page.aspx?page=icrgmethods], accessed October 31, 2005.

Jaggers, Keith and Ted R. Gurr (1995), "Tracking Democracy's Third Wave with the Polity III Data," *Journal of Peace Research* 32 (4), 469–482.

Jenkins, Brian M. (1985), *The Likelihood of Nuclear Terrorism*, P-7119 Santa Monica, CA: RAND Corporation.

Knack, Stephen and Philip Keefer (1995), "Institution and Economic Performance: Cross-Country Tests Using Alternative Institutional Measures," *Economics and Politics* 7 (3), 207-227.

Li, Quan (2005), "Does Democracy Promote Transnational Terrorist Incidents?," *Journal of Conflict Resolution* 49 (2), 278-297.

Marshall, Monty G. and Keith Jaggers (2004), *Polity IV Project*: *Political Regime Characteristics and Transitions, 1800-2003 Dataset User's Manual*, Integrated Network for Societal Conflict Research (INSCR) Program, Center for International Development and Conflict Management (CIDCM), University of Maryland, College Park, MD, 2004, www.cidcm.umd/inscr/polity, accessed November 10, 2005.

Mickolus, Edward F. Todd Sandler, Jean M. Murdock, and Peter A. Flemming (2005) *International Terrorism:* A*ttributes of Terrorist Events, 1968-2004* Dunn Loring, VA: Vinyard Software.

Monterey Institute of International Studies (2005), *WMD Terrorism Database* Monterey, CA: Monterey Institute of International Studies.

Parachini, Jon (2003), "Putting WMD Terrorism into Perspective," *The Washington Quarterly* 26 (4), 37–50.

Political Risk Services (PRS) Group (2004), *International Country Risk Guide*, East Syracuse, NY: The PRS Group, Inc.

Post, Jerrold M. (2005), "The Psychology of WMD Terrorism," *International Studies Review* 7 (1), 148–151.

Rapoport, David C. (1999), "Terrorism and Weapons of the Apocalypse," *National Security Studies Quarterly* 5 (1), 49–67.

Sandler, Todd (1995), "On the Relationship between Democracy and Terrorism," *Terrorism and Political Violence* 7 (4), 1–9.

Sinai, Joshua (2005), "Forecasting Terrorists; Likelihood to Embark on 'Conventional' to CBRN Warfare," *International Studies Review* 7 (1), 151–153.

Steinbruner, John (2005), "Terrorism: Practical Distinctions and Research Priorities," *International Studies Review* 7 (1), 137–140.

United States Department of Homeland Security (2005), "Budget-in-Brief, Fiscal Year 2006," http://www.dhs.gov/interweb/assetlibrary/Budget_BIB-FY2006.pdf, accessed November 12, 2005.

Weinberg, Leonard B. and William L. Eubank (1998), "Terrorism and Democracy: What Recent Events Disclose," *Terrorism and Political Violence* 10 (1), 108–118.

Wilkinson, Paul (2001), *Terrorism versus Democracy*: *The Liberal State Response* London: Frank Cass.

Williams, Rick L. (2000), "A Note on Robust Variance Estimation for Cluster-Correlated Data," *Biometrics* 56 (2), 645–646.

World Bank Group (2006), "World Development Indicators Online," http://devdata.worldbank.org/dataonline, accessed on January 16, 2006.

Chapter 5: Conclusion

The non-existence of data on clandestine activities has long prevented researchers from handling some of the most pressing issues in international relations to date. Illegal arms trade, human trafficking, illegal immigration and transnational organized crime are examples of those problems that require immediate action but whose prevention is considerably hampered by the inability to gather relevant information and identify important actors and patterns of behavior. Most of illegal activities involve corruption of some sort whether it is related to bribing customs officials, tax collectors or any other governmental agents; as Paolo Mauro (1997) points out, corruption has been around for a very long time and will continue to be around "unless governments figure out effective ways to combat it." The analysis of illegal transactions is, thus, likely to remain high on the research agenda for at least some time ahead.

This research project approaches the data problem on clandestine activities from two different angles. On the one hand, it makes use of newly available subjective rankings of countries in terms of corruption and rule of law to investigate compliance (or noncompliance) with environmental regulations and the use of CBRN terrorism. On the other hand, it develops theoretical models to examine 1) illegal trade in polluting substances and 2) the misreporting of emissions by a polluting firm and an environmental inspector. The models yield predictions about the responses of both legal and illegal parts of the activities to changes in corruption

and the magnitude of penalty. Since only data on legal transactions are available, the theoretical conclusions concerning legal imports and reported emissions are tested. Based on the model and the empirical results, inferences about secret behavior are made.

The analyses of both illegal trade and the underreporting of emissions explicitly incorporate the uncertainty associated with smuggling. The probability of detection depends positively on the ratio of illegal to total imports, in the former case, and negatively on reported emissions, in the latter. This means that legal part of the activities can be used to mask the clandestine part so that the actors intending on violating environmental regulations have to find an optimal trade off between the profits they receive from avoiding the regulations and the increased chances of being caught as a result of an increase in monitoring after a drop in compliant behavior has been observed. Since the empirical tests of the models are done in the specific contexts (the use of CFCs controlled by the Montreal Protocol in different countries and the transport of sulphur emissions across Europe), the theoretical models incorporate some of the specific features inherent in them. However, the models still remain quite general to be applied to a lot of other cases involving either illegal trade or corruptible inspectors.

Although the mechanisms through which corruption and rule of law affect legal and illegal behavior in the case of the CFC trade and in the case of the sulphur emissions are different, the findings in both contexts are similar. The results concerning both illegal trade in CFCs and transboundary sulphur pollution indicate

that the assessment of compliance with international environmental regulations in different countries cannot solely be based on the official data reported to the relevant monitoring agencies. The analysis of illegal trade in CFCs and sulphur pollution in European countries shows that knowledge about the magnitude of penalty and the level of corruption in different countries may help international observers gain better understanding of the true level of polluting substances produced by those countries.

Both in the case of illegal trade in CFCs and the sulphur pollution in Europe, the gap between the data on reported and actual production of polluting substances is the highest in countries with high corruption and low penalties for environmental violations. Legal imports of CFCs are relatively low in these countries but they are associated with high illegal and total trade in CFCs. At the same time, countries with very low corruption and high penalties are also characterized by low levels of legal imports. However, low legal imports in these countries are combined with a much smaller amount of CFCs imported illegally indicating a much better environmental performance. In the case of sulphur pollution, relatively high amounts of reported emissions in countries with very high corruption and low penalties are associated with relatively high actual amounts of the pollutant and a high level of illegal activity. At the same time, reported emissions of harmful substances in countries with low corruption and high penalties may also be relatively high, but the actual emissions of harmful substances are much lower in these countries so that in the end they are again at the top of the environmental performance scale.

Corruption when combined with low penalties for environmental violations makes it impossible to compare compliance with the provisions of international agreements between countries based on the official data. Take, for example, Costa Rica and Indonesia. Both of them ratified the Montreal Protocol. Operating under Article 5, both of them could postpone their compliance for 10 years. After 1999, Artilce 5 countries had to freeze their consumption of CFCs at the baseline level which is the average level of consumption for the period 1995 to 1997. In 2001, 144.56 ODP tones of CFC imports were reported by Costa Rica (where the baseline is 250.18 ODP tones) and 5411.14 ODP tones by Indonesia (where the baseline is 8332.67 ODP). Thus, the official data suggest that both countries are in compliance with the Protocol. However, a closer look at the actual practices with regard to the use of CFCs in these two countries provides a different view on the situation.

According to *The Jakarta Post* article "RI likely to miss 2007 ozone deadline" published on June 20, 2006, about 4,000 ODP tones of CFC-12 (one of the five CFC gases controlled by the treaty) are smuggled into Indonesia yearly. If this estimate is true, the actual amount of CFCs imported to Indonesia in 2001 was at least 9411 ODP tones. This figure exceeds the baseline level indicating that Indonesia might, in fact, have failed to meet the treaty obligations. At the same time, illegal traffic of CFCs did not surge in Costa Rica where controls on CFC imports were in place by 1999. The figures reported by the government of Costa Rica are likely to be very close to the actual consumption levels of CFCs.

In the EIA report "Lost in Transit: Global CFC Smuggling Trends and the Need for a Faster Phase-out," the executive chairman of a Singaporean company particularly experienced in illegal CFC trade points out to an undercover EIA investigator that customs contacts are crucial to enable illegal shipments to proceed, adding that paperwork is of no consequence with the right connections. Bribery of customs officials facilitates illegal traffic so that highly corrupt countries will attract more CFC contraband. In 2001 ICRG rankings, Indonesia received a score of 1 in terms of honesty (implying high corruption) and 2 in terms of the rule of law (implying low penalties for environmental crimes). In contrast, Costa Rica scored 5 in terms of honesty and 4 in terms of the rule of law (6 being the maximum). This example illustrates that the degree of corruption and the rule of law (used as a proxy for the magnitude of penalty) may be informative as to the discrepancy between the official data and actual level of compliance with international obligations.

International organizations responsible for monitoring pollution should direct part of their efforts at reducing the pernicious effects of high corruption and low penalties associated with weak rule of law on both the legal and illegal part of the transactions in environmental sphere. Since the difference between actual and reported amounts of harmful substances is the greatest in highly corrupt countries where penalties for environmental violations are very low, the strategy developed to reduce pollution in these nations should differ from that developed for noncorrupt regimes with strict environmental laws. Transparency in data reporting is particularly important in these countries since it can discourage collusion between environmental

inspectors and firms. Moreover, any attempts to reduce corruption connected to environmental pollution should be combined with a higher penalty as there are important interaction effects between the two.

After the examination of the relationship between corruption, magnitude of penalty and environmental degradation, the focus is shifted to a different type of criminal activity, i.e., the CBRN terrorism. Although a lot of activity conducted by terrorists remains clandestine, it can be measured by the data on the actual incidents involving the use of CBRN agents. The results in this case are quite surprising. Although failed states characterized by high corruption and weak rule of law as well as lack of democratic processes may offer a place for terrorist groups to form and take refuge, it is democratic states where rule of law is strong and corruption is low that provide the staging ground for the CBRN use. By ensuring freedom of association, protection of civil liberties, media coverage of events, and an ability to acquire weapons, funding and information, democracies provide the environment where terrorists are more inclined to stage terrorist attacks. CBRN incidents are more likely to take place in countries with strong rule of law because the terrorist rights are protected and successful attacks cause greater panic and anxiety by questioning the ability of the government to protect life and property, which leads to the societal autoimmune effect. Honest regimes also appear to be associated with a higher number of CBRN incidents, although the empirical support for the effect of corruption is not as strong as it is for democracy and the rule of law.

Since the main actors in the CBRN terrorism scenario are terrorist groups, it is important to understand what factors influence their motivation and decisions. The data show that religious cults and fundamentalists are more likely to get involved in CBRN events when the rule of law is strong and corruption is low. The odds of nationalists/separatists CBRN involvement is, however, no different in democracies than in autocracies. Moreover, unlike religious groups, nationalists/separatists are more likely to stage CBRN events in countries with high corruption and weak rule of law. The result suggests that democratic principles inhibit CBRN actions for nationalists/separatists but not for religious groups. Another implication is that nationalists/separatists are more likely to be responsible for CBRN attacks in failed states. Although democracy and strong rule of law do not determine whether governments rather than other targets are chosen for a CBRN attack, there is a significant association between government targets and corrupt regimes. In particular, government targets are more likely to be hit in corrupt regimes, while the reverse is true for honest countries where the general public may be put in harm's way.

The CBRN events covered in this analysis have not incurred mass casualties or large-scale damage to qualify for WMD terrorism. However, if executed correctly, these CBRN incidents have the potential to result in much greater destruction and loss of life. They are, thus, regarded as the precursors to future incidents with a much greater number of victims and their study provides insights as to perpetrators, location, targets and other factors. Knowledge of the likely venue, target and the

orientation of the likely perpetrators associated with past CBRN incidents can inform policymakers on where to allocate protective measures. Past data indicate that democracies where there is strong rule of law and low corruption are most vulnerable to WMD attacks, should they ever take place.

Bibliography

Ackerman, Gary (2004), "WMD Terrorism Research: Where to from Here?," Discussion Paper, Center for Nonproliferation Studies, Monterey Institute of International Studies, Monterey, CA.

Anselin, Luc (1988), "Spatial Econometrics: Methods and Models," Kluwer Academic Publishers.

Ansuategi, Alberto (2003), "Economic Growth and Transboundary Pollution in Europe: An Empirical Analysis," *Environmental and Resource Economics* 26, 305-328.

Axelrod, Robert (1984), *The Evolution of Cooperation*, London: Penguin.

Bardhan, Pranab (1997), "Corruption and Development: A Review of Issues," *Journal of Economic Literature* 35 (3), 1320-1346.

Barrett, Scott (1994), "Self-Enforcing International Environmental Agreements," Oxford Economic Papers, New Series, Vol. 64, Special Issue on Environmental Economics, 878-894.

Barrett, Scott (2003), "Environment and Statecraft: The Strategy of Environmental Treaty-making," Oxford University Press.

Benedick, Richard Elliot (1998), *Ozone Diplomacy: New Directions in Safeguarding the Planet*, Harvard University Press: Cambridge, MA.

Beron, Kurt J., James C. Murdoch, and Wim P.M. Vijverberg (2003), "Why Cooperate? Public Goods, Economic Power, and the Montreal Protocol," *The Review of Economics and Statistics* 85 (2), 286-297.

Blum, Andrew, Victor Asal, and Jonathan Wilkenfeld (2005), "Nonstate Actors, Terrorism, and Weapons of Mass Destruction, Editors' Introduction," *International Studies Review* 7 (1), 133–137.

Brack, Duncan (1996), *International Trade and the Montreal Protocol*, London: Royal Institute of International Affairs.

Bunker, Robert (2000), "Weapons of Mass Disruption and Terrorism," *Terrorism and Political Violence* 12 (1), 37–46.

Burrows, Paul (1977), "Pollution Control with Variable Production Process," Journal of Public Economics 8, 357-367.

Burrows, Paul (1979), "Pigovian Taxes, Polluter Subsidies, Regulation, and the Size of a Polluting Industry," *The Canadian Journal of Economics*. 12 (3), 494-501.

Cameron, A. Colin and Pravin K. Trivedi (1998), *Regression Analysis of Count Data*, Cambridge: Cambridge University Press.

Chayes, Abram and Antonia H. Chayes (1995), *The New Sovereignty: Compliance with International Regulatory Agreements*, Harvard University Press: Cambridge, Massachusetts.

Checkel, Jeffrey T. (2001), "Why Comply? Social Learning and European Identity Change," *International Organization* 55 (3), 553-588.

Chertoff, Michael (2005), "Remarks by Secretary Michael Chertoff on the Second Stage Review of the Department of Homeland Security," July 13, 2005 [http://www.dhs.gov/dhspublic/interapp/press_release_0703.xml], accessed November 10, 2005.

Cole, M.A., A.J. Rayner, and J.M. Bates (1997), "The Environmental Kuznets curve: an Empirical Analysis," *Environmental and Development Economics*, 2, 401-416.

Congleton, Roger D. (1992), "Political Institutions and Pollution Control," *The review of Economics and Statistic* 74 (3), 412-421.

Congleton, Roger D. (1992), "Polititcal Institutions and Pollution Control," *The Review of Economics and Statistics* 74, (3), 412-421.

Copeland, Brian R. (2001), "International Trade in Waste Products in the Presence of Illegal Disposal," in A. A. Batabyal, H. Beladi, eds., *The Economics of International Trade and the Environment*, Lewis Publishers, Boca Raton.

Damania, Richard (2002), "Environmental Controls with Corrupt Bureaucrats," *Environment and Development Economics* 7, 407-427.

Damania, Richard, Per G. Fredriksson, and John A. List (2003), "Trade Liberalization, Corruption, and Environmental Policy Formation: Theory and Evidence," *Journal of Environmental Economics and Management* 46, 490-512.

Desai, Uday (1998) *Ecological Policy and Politics in Developing Countries: Economic Growth, Democracy and Environment*, Albany, New York: State University of New York Press.

Dimovski, Mikhail and Rob Glaser (2002), *Environmental Enforcement and Compliance in South Eastern Europe*, The Regional Environmental Center for Central and Eastern Europe, Szentendre, Hungary.

Downs, George W., and David M. Rocke (1995), "Optimal Imperfection? Domestic Uncertainty and Instiotutions in International Relations," Princeton University Press.

Downs, George W., David M. Rocke and Peter N. Barsoom (1996), "Is the Good News about Compliance Good News about Cooperation?" *International Organization* 50 (3), 379-406.

Enders, Walter and Todd Sandler (2000), "Is Transnational Terrorism Becoming More Threatening? A Time-Series Investigation," *Journal of Conflict Resolution* 44 (3), 307–332.

Enders, Walter and Todd Sandler (2006), *The Political Economy of Terrorism*, Cambridge: Cambridge University Press.

Eubank, William L. and Leonard B. Weinberg (1994), "Does Democracy Encourage Terrorism?," *Terrorism and Political Violence* 6 (4), 417–435.

Eubanks, William L. and Leonard B. Weinberg (2001), "Terrorism and Democracy: Perpetrators and Victims," *Terrorism and Political Violence* 13 (1), 155–164.

Finnemore, Martha, and Kathryn Sikkink (1998), "International Norm Dynamics and Political Change," *International Organization* 52, 887-918.

Fisher, Roger (1981), "Improving Compliance with International Law," Charlottesville, VA: University of Virginia Press.

Fleiss, Joseph L., Bruce Levin, and Myunghee Cho Park (2003), *Statistical Methods for Rates and Proportions*, Third Edition Hoboken, NJ: John Wiley & Sons, Inc.

Fredriksson, Per G., and Jakob Svensson (2003), "Political Instability, Corruption and Policy Formation: The Case of Environmental Policy," *Journal of Public Economics* 87, 1383-1405.

Fredriksson, Per G., and Muthukumara Mani (2002), "The Rule of Law and the Pattern of Environmental Protection," Working Paper WP/02/49, International Monetary Fund.

Greene, William H. (2003), *Econometric Analysis*, Fifth Edition Upper Saddle River, NJ: Pearson Education, Inc.

Grossman, Gene M., and Alan B. Krueger (1995), "Economic Growth and the Environment," *The Quarterly Journal of Economics* 110 (2), 353-377.

Gurr, Ted R. (2005), "Which Minorities Might Use Weapons of Mass Destruction?," *International Studies Review* 7 (1), 143-146.

Heyes, A. and N. Rickman (1999), "Regulatory dealing – revisiting the Harrington paradox," *Journal of Public Economics* 72, 361-378.

Hoffman, Bruce (1998), *Inside Terrorism* New York: Columbia University Press.

Hurd, Ian (1999), "Legitimacy and Authority in International Politics," *International Organization* 53 (2), 379-408.

International Country Risk Guide (ICRG) (2005), "About ICRG," [http://www.icrgonline.com/page.aspx?page=icrgmethods], accessed October 31, 2005.

Jaggers, Keith and Ted R. Gurr (1995), "Tracking Democracy's Third Wave with the Polity III Data," *Journal of Peace Research* 32 (4), 469–482.

Jenkins, Brian M. (1985), *The Likelihood of Nuclear Terrorism*, P-7119 Santa Monica, CA: RAND Corporation.

Johnston, Michael (1997) "What Can Be Done About Entrenched Corruption?" Paper presented at the Annual World Bank Conference on Development Economics, Washington, D.C., April 30 – May 1.

Jonsson, Christer and Jonas Tallberg (1998), "Compliance and Post-Agreement Bargaining," *European Journal of International Relations* 4 (4), 371-408.

Kaufmann, Robert K., Brynhildur Davidsdottir, Sophie Garnham, and Peter Pauly (1998), "The Determinants of Atmospheric SO_2 Concentrations: Reconsidering the Environmental Kuznets Curve," *Ecological Economics* 25, 209-220.

Keeler, A., "Noncompliant firms in TDP markets (1991)," *Journal of Environmental Economics and Management* 21, 180-189.

Klitgaard, Robert (1988), "Controlling Corruption," University of California Press, Berkeley.

Knack, Stephen and Philip Keefer (1995), "Institution and Economic Performance: Cross-Country Tests Using Alternative Institutional Measures," *Economics and Politics* 7 (3), 207-227.

Koh, Harold H. (1997), "Why Do Nations Obey International Law?" *Yale Law Journal* 106, 2598-2659.

Koh, Harold H. (1998), "Bringing International Law Home," *Houston Law Review* 35 (3), 181-207.

Kratochwil FriedrichV., and John G. Ruggie (1986), "International organization: a state of the art on an art of the state," *International Organization* 40 (4), 753-775.

Levy, M.A. (1995), "International Co-operation to Combat Acid Rain," Green Globe Yearbook.

Levy, Marc A. (1993), "European Acid Rain: The Power of Tote-Board Diplomacy," in P.M. Haas, R.O. Keohane, and M.A. Levy (eds), *Institutions for the Earth: Sources of Effective International Environmental Protection*, Cambridge, MA: MIT Press, 75-132.

Li, Quan (2005), "Does Democracy Promote Transnational Terrorist Incidents?," *Journal of Conflict Resolution* 49 (2), 278-297.

Lopez, Ramon, and Siddhartha Mitra (2000), "Corruption, Pollution, and the Kuznets Environment Curve," *Journal of Environmental Economics and Management* 40, 13-150.

Malik, A. (1990), "Markets for pollution control when firms are noncompliant," *Journal of Environmental Economics and Management* 18, 97-106.

Marshall, Monty G. and Keith Jaggers (2004), *Polity IV Project*: *Political Regime Characteristics and Transitions, 1800-2003 Dataset User's Manual*, Integrated Network for Societal Conflict Research (INSCR) Program, Center for International Development and Conflict Management (CIDCM), University of Maryland, College Park, MD, 2004, www.cidcm.umd/inscr/polity, accessed November 10, 2005.

Martin, Lawrence, and Arvind Panagariya (1984), "Smuggling, Trade, and Price Disparity: A Crime Theoretic Approach," *Journal of International Economics* 17, 201-217.

Mauro, Paolo (1995) "Corruption and Growth," *The Quarterly Journal of Economics* 110 (3), 681-712.

Mauro, Paolo (1997) "Why Worry About Corruption?" *Economic Issues* 6, International Monetary Fund, Washington, D.C.

Mickolus, Edward F. Todd Sandler, Jean M. Murdock, and Peter A. Flemming (2005) *International Terrorism: Attributes of Terrorist Events, 1968-2004* Dunn Loring, VA: Vinyard Software.

Mitchell, Ronald B. (1994), "Regime Design Matters: International Oil Pollution and Treaty Compliance," *International Organization* 48 (3), 425-458.

Mitchell, Ronald B. (1998), "Discourse and Sovereignty: Interests, Science, and Morality in the Regulation of Whaling," *Global Governance* 4, 275-294.

Monterey Institute of International Studies (2005), *WMD Terrorism Database* Monterey, CA: Monterey Institute of International Studies.

Mookherjee, Dilip, and I.P.L. Png (1995), "Corruptible Law Enforcers: How Should They Be Compensated?" *The Economic Journal* 105 (428), 145-159.

Murdoch, James C., and Todd Sandler (1997a), "The voluntary provision of a pure public good: The case of reduced CFC emissions and the Montreal Protocol," *Journal of Public Economics* 63, 331-349.

Murdoch, James C., and Todd Sandler (1997b), "Voluntary Cutbacks and Pretreaty Behavior: The Helsinki Protocol and Sulphur Emissions," *Public Finance Review* 25 (2), 139-162.

Murdoch, James C., Todd Sandler, and Keith Sargent (1997), "A Tale of Two Collectives: Sulphur versus Nitrogen Oxides Emission Reduction in Europe," Economica, New Series 64 (254), 281-301.

Murdoch, James C., Todd Sandler, and Wim P.M. Vijverberg (2003), "The Participation Decision versus the Level of Participation in an Environmental Treaty: a Spatial Probit Analysis," *Journal of Public Economics* 8, 337-362.

Noble, Ronald (2001) "The Role of the Police in Fostering Political Commitment: Remarks by Ronald K. Noble, Interpol Secretary General," 10th International Anti-Corruption Conference, Prague, Czech Republic, October 8, 2001 [http://www.interpol.org/Public/ICPO/speeches/20011008.asp], accessed on May 15th, 2006.

Olson, Mancur (1965), *The Logic of Collective Action: Public Goods and the Theory of Groups*, Cambridge, MA: Harvard University Press.

Ord, Keith (1975) "Estimation methods for models of spatial interaction," *Journal of the American Statistical Association*, 70, 120-126.

Parachini, Jon (2003), "Putting WMD Terrorism into Perspective," *The Washington Quarterly* 26 (4), 37–50.

Pargal, Sheoli., Muthukumara Mani and Mainul Huq (1996), "Inspections and emissions: puzzling survey evidence on industrial water pollution," *Policy Working Paper* No. 1810, World Bank.

Pitt, Mark M. (1981), "Smuggling and Price Disparity," *Journal of International Economics* 11, 44-458.

Political Risk Services (PRS) Group (2004), *International Country Risk Guide*, East Syracuse, NY: The PRS Group, Inc.

Post, Jerrold M. (2005), "The Psychology of WMD Terrorism," *International Studies Review* 7 (1), 148–151.

Rapoport, David C. (1999), "Terrorism and Weapons of the Apocalypse," *National Security Studies Quarterly* 5 (1), 49–67.

Raustiala, Kal and Anne-Marie Slaughter (2002), "International Law, International Relations and Compliance," in Walter Carlsnaes, Thomas Risse and Beth A. Simmons (eds) *Handbook of International Relations*, London: Sage Publications, 538-558.

Ringquist, Evan J., and Tatiana Kostadinova (2005), "Assessing the Effectiveness of International Environmental Agreements: The Case of the 1985 Helsinki Protocol," *American Journal of Political Science*. 49 (1), 86-102.

Rose-Ackerman, (1975) "The Economics of Corruption," *Journal of Public Economics* 4, 187-203.

Russel, Clifford and William Vaughan, (2003) "The Choice of Pollution Control Policy Instruments in Developing Countries: Arguments, Evidence and Suggestions," In Henk Folmer and Tom Tietenberg, eds. *The International Yearbook of Environmental and Resource Economics 2003/2003*, Cheltenham, UK: Edward Elgar.

Sandler, Todd (1995), "On the Relationship between Democracy and Terrorism," *Terrorism and Political Violence* 7 (4), 1–9.

Sandler, Todd, and Daniel G. Arce M. (2003), "Pure Public Goods versus Commons: Benefit-Cost Duality," *Land Economics* 79 (3), 355-368.

Shafik, Nemat (1994), "Economic Development and Environmental Quality: An Econometric Analysis," *Oxford Economic Papers*, New Series 46, Special Issue on Environmental Economics, 757-773.

Shanon, Vaughn P. (2000), "Norms Are What States Make of Them: The Political Psychology of Norm Violation," *International Studies Quarterly* 44, 293-316.

Shleifer, Andrei, and Robert W. Vishny (1993), "Corruption," *The Quarterly Journal of Economics* 108 (3), 599-617.

Simmons, Beth A. (1998), "Compliance with International Agreements," *Annual Review of Political Science* 1, 75-93.

Simmons, Beth A. (2000), "The Legalization of International Monetary Affairs," *International Organization* 54 (3), 573-602.

Sinai, Joshua (2005), "Forecasting Terrorists; Likelihood to Embark on 'Conventional' to CBRN Warfare," *International Studies Review* 7 (1), 151–153.

Steinbruner, John (2005), "Terrorism: Practical Distinctions and Research Priorities," *International Studies Review* 7 (1), 137–140.

Tallberg, Jonas (2002), "Paths to Compliance: Enforcement, Management, and the European Un ion," *International Organization* 56 (3), 609-643.

Thachuk, Kimberley (2005) "Corruption and International Security," *SAIS Review*, vol. XXV no 1.

United Nations Environment Program, (2001) "Illegal trade in ozone depleting substances: is there a hole in the Montreal Protocol?" OzonAction Program, Division of Technology, Industry and Economics, OzonAction Newsletter Special Supplement, Number 6.

United States Department of Homeland Security (2005), "Budget-in-Brief, Fiscal Year 2006," http://www.dhs.gov/interweb/assetlibrary/Budget_BIB-FY2006.pdf, accessed November 12, 2005.

Van Egteren, H. and M. Weber (1996), "Marketable permits, market power and cheating," *Journal of Environmental Economics and Management* 30, 161-173.

Victor, David G., and Kal Raustiala (1998), "Conclusions," in David G. Victor, Kal Raustiala and Eugene B. Skolnikoff (eds) *The Implementation and Effectiveness of International Environmental Commitments: Theory and Practice*, Cambridge, MA: The MIT Press, 659-708.

Wei, Shang-Jin (2000) "Local Corruption and Global Capital Flows," *Brookings Papers on Economic Activity* 2000 (2), 303-354.

Weinberg, Leonard B. and William L. Eubank (1998), "Terrorism and Democracy: What Recent Events Disclose," *Terrorism and Political Violence* 10 (1), 108–118.

Weisband, Edward (2000), "Discursive Multilateralism: Global Benchmarks, Shame, and Learning in the ILO Labor Standards Monitoring Regime," *International Studies Quarterly* 44, 643-666.

Wilkinson, Paul (2001), *Terrorism versus Democracy*: *The Liberal State Response* London: Frank Cass.

Williams, Rick L. (2000), "A Note on Robust Variance Estimation for Cluster-Correlated Data," *Biometrics* 56 (2), 645–646.

World Bank Group (2006), "World Development Indicators Online," http://devdata.worldbank.org/dataonline, accessed on January 16, 2006.

Young, Oran B. and Marc A. Levy (1999), "The Effectiveness of International Environmental Regimes," in Oran B. Young (ed) *The Effectiveness of International Environmental Regimes: Causal Connections and Behavioral Mechanisms*, Cambridge, MA: The MIT Press.

Appendices

Appendix A

Total differentiation of the system in equations (4) and (5) yields

$$dx = \frac{\alpha\lambda_{\hat{x}}P}{\Delta}d\tau - \frac{\alpha P^2\left[\lambda_{\hat{x}}\mathrm{A} - \lambda(\hat{x})\mathrm{B}\right]}{\Delta}d\alpha - \frac{\alpha^2 PP_\theta\left[\lambda_{\hat{x}}\mathrm{A} - \lambda(\hat{x})\mathrm{B}\right]}{\Delta}d\theta \tag{23}$$

$$d\hat{x} = \frac{\pi_{xx}}{\Delta}d\tau + \frac{P\left[\alpha\lambda_{\hat{x}}P\lambda(\hat{x}) - \pi_{xx}\mathrm{A}\right]}{\Delta}d\alpha + \frac{\alpha P_\theta\left[\alpha\lambda_{\hat{x}}P\lambda(\hat{x}) - \pi_{xx}\mathrm{A}\right]}{\Delta}d\theta \tag{24}$$

where subscripts denote partial derivatives and $\mathrm{A} = \lambda(\hat{x}) - \lambda_{\hat{x}}(x - \hat{x}) > 0$, $\mathrm{B} = 2\lambda_{\hat{x}} - \lambda_{\hat{x}\hat{x}}(x - \hat{x}) < 0$ and $\Delta = \pi_{xx}\alpha P\mathrm{B} - \left(\alpha\lambda_{\hat{x}}P\right)^2 > 0$. Hence,

$$\frac{\partial x}{\partial \tau} = \frac{\alpha\lambda_{\hat{x}}P}{\Delta} \tag{25}$$

$$\frac{\partial x}{\partial \alpha} = -\frac{\alpha P^2\left[\lambda_{\hat{x}}\mathrm{A} - \lambda(\hat{x})\mathrm{B}\right]}{\Delta} \tag{26}$$

$$\frac{\partial x}{\partial \theta} = -\frac{\alpha^2 PP_\theta\left[\lambda_{\hat{x}}\mathrm{A} - \lambda(\hat{x})\mathrm{B}\right]}{\Delta} \tag{27}$$

$$\frac{\partial \hat{x}}{\partial \tau} = \frac{\pi_{xx}}{\Delta} \tag{28}$$

$$\frac{\partial \hat{x}}{\partial \alpha} = \frac{P\left[\alpha\lambda_{\hat{x}}P\lambda(\hat{x}) - \pi_{xx}\mathrm{A}\right]}{\Delta} \tag{29}$$

$$\frac{\partial \hat{x}}{\partial \theta} = \frac{\alpha P_\theta\left[\alpha\lambda_{\hat{x}}P\lambda(\hat{x}) - \pi_{xx}\mathrm{A}\right]}{\Delta} \tag{30}$$

Substituting (25) and (28) in (7) and simplifying, we get (8).

Appendix B

Total differentiation of (8) yields:

$$\begin{aligned}
&\left\{-\left(\pi_{xx}-D_{XX}w^2\right)\alpha P\frac{\partial x}{\partial \tau}+c_{\lambda}\pi_{xxx}\frac{\partial x}{\partial \tau}+c_{\lambda\lambda}\lambda_x\pi_{xx}\frac{\partial \hat{x}}{\partial \tau}\right\}d\tau\\
&+\left\{-\left(\pi_x-D_X w\right)P-\left(\pi_{xx}-D_{XX}w^2\right)\alpha P\frac{\partial x}{\partial \alpha}+c_{\lambda}\pi_{xxx}\frac{\partial x}{\partial \alpha}+c_{\lambda\lambda}\lambda_x\pi_{xx}\frac{\partial \hat{x}}{\partial \alpha}\right\}d\alpha \qquad (31)\\
&+\left\{-\left(\pi_x-D_X w\right)\alpha P_\theta-\left(\pi_{xx}-D_{XX}w^2\right)\alpha P\frac{\partial x}{\partial \theta}+c_{\lambda}\pi_{xxx}\frac{\partial x}{\partial \theta}+c_{\lambda\lambda}\lambda_x\pi_{xx}\frac{\partial \hat{x}}{\partial \theta}\right\}d\theta\\
&+\left(D_{XX}wx+D_X\right)dw+D_{XX}w\,d\tilde{X}=0
\end{aligned}$$

Substituting (25)-(30) in (31), solving for $d\tau$ and substituting the resulting equation in (23) and (24), we obtain

$$\begin{aligned}
dx=&-\frac{1}{\Gamma}P\lambda_{\hat{x}}\left\{c_{\lambda\lambda}\pi_{xx}\lambda+\left(\pi_x-D_X w\right)\alpha P\right\}d\alpha\\
&-\frac{1}{\Gamma}\alpha\lambda_{\hat{x}}P_\theta\left\{c_{\lambda\lambda}\pi_{xx}\lambda+\left(\pi_x-D_X w\right)\alpha P\right\}d\theta \qquad (32)\\
&+\frac{1}{\Gamma}\alpha\lambda_{\hat{x}}P\left(D_{XX}wx+D_X\right)\alpha P dw+\frac{1}{\Gamma}\alpha\lambda_{\hat{x}}PD_{XX}w\alpha P d\tilde{X}\\
d\hat{x}=&\frac{1}{\Gamma}P\left\{-\left(\pi_{xx}-D_{XX}w^2\right)\alpha P\lambda+\lambda c_{\lambda}\pi_{xxx}-\pi_{xx}\left(\pi_x-D_X w\right)\right\}d\alpha\\
&+\frac{1}{\Gamma}\alpha P_\theta\left\{-\left(\pi_{xx}-D_{XX}w^2\right)\alpha P\lambda+c_{\lambda}\pi_{xxx}\lambda-\left(\pi_x-D_X w\right)\pi_{xx}\right\}d\theta \qquad (33)\\
&+\frac{1}{\Gamma}\pi_{xx}\left(D_{XX}wx+D_X\right)\alpha P dw+\frac{1}{\Gamma}\pi_{xx}D_{XX}w\alpha P d\tilde{X}
\end{aligned}$$

where $\Gamma=\lambda_{\hat{x}}\left\{\left(\pi_{xx}-D_{XX}w^2\right)\left(\alpha P\right)^2-c_{\lambda}\pi_{xxx}\alpha P-c_{\lambda\lambda}{\pi_{xx}}^2\right\}$.