Monitoring and Enforcement of Environmental Policy

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Abstract

This article reviews the economics literature on monitoring and enforcement of environmental policy. In the last few years there has been a rapid growth in both theoretical developments and empirical studies of monitoring and enforcement. Various factors have contributed to this growth, including (1) the growth of the law and economics literature and its interest in issues of law enforcement and penalties, (2) increased emphasis on enforcement by EPA and other regulatory agencies, and (3) the availability of data on firm compliance. The economics literature on environmental monitoring and enforcement has closely followed the related field of optimal penalties in the law and economics literature.

The scope of the article includes both public and private mechanisms designed to compel firms (and individuals) to comply with environmental formal regulations and informal rules of conduct or social norms. For purposes of this paper, monitoring and enforcement includes monitoring and inspections by enforcement authorities as well as sanctions, remedial actions, and other mechanisms designed to punish and/or bring a firm into compliance. It also includes non-governmental actions such as citizen suits authorized by the government and informal mechanisms such as public pressure. It does *not* include the role of liability laws (torts, nuisance actions, etc.) in compelling polluters to reduce emissions.

The paper begins with a fundamental question - why do firms comply with environmental laws? Next, I consider the various economic theories of government behavior and how they have been used to help explain observed enforcement behavior. Following these positive analyses, I turn to normative theories of optimal penalties as it relates to environmental regulation, including recent developments that have incorporated the complexities associated with sanctioning both organizations and their employees. The paper continues with an assessment of empirical studies on environmental enforcement. In addition to studies of government enforcement, I examine empirical studies of private enforcement mechanisms (e.g., citizen suits) and the role of market forces in compelling compliance behavior. A concluding section assesses the most critical gaps in our knowledge and contains suggestions for future research.

Monitoring and Enforcement of Environmental Policy

Mark A. Cohen[1]

1. Introduction

This article reviews the economics literature on monitoring and enforcement of environmental policy. Monitoring and enforcement may not be the first things that come to mind when considering policy alternatives. In fact, they are often ignored altogether by both academics and policy makers when discussing environmental policy alternatives. Cropper and Oates (1992: 696) note that "the great bulk of the economics of environmental regulation assumes that polluters comply with existing directives." As a measure of how little attention has been given to this topic, the extensive literature review on environmental economics by Cropper and Oates (1992) devotes less than 2 pages out of 57 and contains only 8 citations out of over 250 to monitoring and enforcement issues.

Despite this general lack of attention, the consequences of ignoring monitoring and enforcement issues can be disastrous for environmental quality and for social welfare. If a regulatory agency imposes a new stricter regulation but noncompliance is rampant, it is possible that the ultimate result will be more pollution– not less pollution.[2] Alternatively, ignoring monitoring and enforcement costs might lead the government to implement a policy that is ultimately more costly (once monitoring and enforcement costs are considered) than one currently in existence. As McKean (1980) points out, high enforcement costs and imperfect compliance make regulations less effective than desired. Thus, monitoring and enforcement concerns "should influence choices about how to regulate, and in some instances, about whether to regulate at all" (McKean, 1980: 289).

In the last few years there has been a rapid growth in both theoretical developments and empirical studies of enforcement.[3] Various factors have contributed to this growth, including (1) the growth of the law and economics literature and its interest in issues of

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[2] This is not just a hypothetical statement. For example, Sigman (1998), discussed in Section 4.1.3, estimates that banning the legal disposal of used oil and requiring instead that it be reused or recycled will result in a significant increase in waste oil being dumped illegally – which is more hazardous than the previously legal method of disposal.

[3] A thorough literature search found nearly half of the citations date from 1990 onward. It may also be instructive to look at the dates of citations in this Article: the bibliography contains 44 citations between 1974 and 1989 (approximately 3 per year), and 82 citations between 1990 and 1997 (an average of 10 per year).

law enforcement and penalties, (2) increased emphasis on enforcement by EPA and other regulatory agencies, and (3) the availability of data on firm compliance.

The economics literature on environmental enforcement has closely followed the related field of optimal penalties in the law and economics literature.[4] Many of the sources cited in this article come from that literature. Some of the law and economics articles cited here never mention the word "environment" and apply to virtually any type of law enforcement activity. Thus, much of this literature may be new to the environmental economist dabbling in issues of enforcement for the first time.

The scope of this article includes both public and private mechanisms designed to compel firms to comply with formal environmental regulations and informal rules of conduct or social norms. Although most of this article – and most of the literature – focuses on pollution control by firms, I also consider individuals who pollute as well as government enterprises such as municipal water or sewer authorities. I consider both "monitoring" activities such as government inspections, and "enforcement" activities such as sanctions, remedial actions, and other mechanisms designed to punish and/or bring a firm into compliance. However, I do *not* consider the role of liability laws (torts, nuisance actions, etc.) in compelling polluters to reduce emissions. [5] In addition, I ignore two other important areas of monitoring and enforcement policy: fisheries and global environmental policies. Both of these topics could be the subjects of their own literature reviews.

This paper is organized as follows. In Section 2, I consider positive theories of behavior, starting with the fundamental question underlying any study of enforcement – why do firms comply with environmental laws? Understanding firm behavior is key toward developing an effective enforcement policy. Since economists are beginning to incorporate social norms into discussions of individual behavior, I also take a brief detour away from economics into the sociology and public policy literature on environmental enforcement. In addition to understanding the behavior of individuals and firms that pollute, it is important to understand the motivation of enforcement agencies. Thus, I also review positive theories of government behavior.

Moving from positive theories to normative theories, in Section 3, I summarize the theory of optimal penalties in the context of environmental enforcement. This theory starts with the simple Becker (1968) model equating the penalty to the harm divided by the probability of detection, and quickly expands in a multitude of directions. Following this growing literature, I consider issues such as: innovations to induce self-reporting behavior and other means of reducing enforcement costs, harm versus gain to the offender, comparison of penalties under various regulatory structures such as emission fees and transferable discharge permits, the effect of uncertain legal standards, and attempts by regulated firms to avoid penalties. Since it is individuals (not firms) that

[4] Polinsky and Shavell (1998) provide a thorough summary of this literature.
[5] See Tietenberg (1992) for a treatment of both enforcement and liability issues. Several of the chapters in that edited volume have appeared elsewhere in journal format and are cited in this article.

ultimately undertake actions that pollute on behalf of their firms, I also review the relatively new addition to the optimal penalty literature that considers who should be sanctioned – the firm, the individual, or both. I also examine the issue of who should sanction employees - the firm or the government.

In Section 4, I consider empirical studies on environmental monitoring and enforcement. Although most empirical studies have focused on the deterrent effect of government monitoring and enforcement policies, government actions are not the only penalty for noncompliance. Thus, I also examine empirical studies of private enforcement mechanisms (e.g., citizen suits) designed to force compliance in the absence of government enforcement, and the role of market forces in compelling compliance behavior. In a final concluding Section 5, I briefly assess the most critical gaps in our knowledge and offer suggestions for future research.

2. Positive Theories of Enforcement, Monitoring and Compliance

In this section, I examine theories that attempt to explain the behavior of either the regulated parties (individuals or firms), or the government agencies that monitor and enforce environmental regulations. Thus, I have distinguished between "positive" theories (this section) and "normative" theories (Section 3). Note that this distinction can sometimes become blurred as one model may have both normative and positive implications. First, I consider economic theories of firm behavior that attempt to answer the question of why firms comply with environmental regulations (Section 2.1). In addition to traditional economic theories, I briefly consider the role of social norms in compliance decisions (Section 2.2). Next, I review the various theories of government behavior (Section 2.3). As shown in that section, an enforcement agency whose goal is to maximize social welfare will choose different policies from an agency whose goal is to maximize compliance or to maximize political support. Finally, I review the literature on enforcement under a multi-layered government systems such as federalism (Section 2.4).

2.1 Economic Theories of Firm Behavior

Any study of optimal government monitoring and enforcement policy should start first with a more basic understanding of firm behavior. After all, there would be no need to study enforcement if all firms complied with the law. Since not all firms do comply with the law, it is interesting to start with a more fundamental question – why do firms comply at all? An obvious economic reason for compliance is that firms respond to both positive and negative incentives. If expected penalties are sufficiently high, the threat of being punished for noncompliance should be an adequate reason. However, as Russell, Harrington and Vaughn (1986) and Harrington (1988) note, government monitoring activities are often quite limited. Moreover, even if discovered to be in noncompliance, fines are low. For example, the median administrative fine imposed by the U.S. EPA in 1995 was $5-10,000, while the average fine was $34,000 (Lear, 1998). Despite these facts, most sources in the U.S. are thought to be in compliance a large fraction of the

time. For example, Magat and Viscusi (1990) report an average level of compliance of 75% in the U.S. pulp and paper industry between 1982 and 1985.[6]

To explain the phenomenon of high compliance in the absence of strict enforcement, Harrington (1988), Harford and Harrington (1991), and Harford (1991) adapted existing models of income tax enforcement.[7] These models have been referred to as "state-dependent" enforcement, since government policy depends on the firm's previous compliance status. The basic idea is that firms are assigned to groups based upon their known compliance history. Ignoring firms that are never monitored, a simple two-group scheme would involve firms found to be in compliance at their last inspection (group 1) and those found to be out of compliance at their last inspection (group 2). Firms placed into group 2 would be subject to some combination of a higher monitoring probability, tougher regulatory standards, or higher fines than would firms in group 1. It has been shown that this type scheme allows the regulatory agency to increase the fraction of firms in compliance for a given level of monitoring or expected penalties. Extra incentives for compliance are created by the threat of being faced with a tougher regulatory regime (i.e., being forced into group 2) if found to be out of compliance. Harrington (1988) calls this added incentive "enforcement leverage." Such a scheme tends to make the level of compliance appear high relative to the fines actually imposed and the average fine threatened.[8]

Although partly used to explain current enforcement policy, these models have an obvious normative component to them as well. I will return to those normative implications – and extensions of the basic model in Section 3.4.2.

Although it is possible that firms comply with environmental laws because of the threat of being placed on the enforcement agency's target list, this is unlikely to be the sole reason for compliance. Downing and Kimball (1982) documented the low penalties for noncompliance and the relatively high compliance rates in the U.S. First, they note that firms receive cost subsidies in the form of tax breaks and special financing. Although a cost subsidy does not provide an incentive for compliance the way a penalty does, it will affect the cost-benefit calculus a firm must undergo when determining the expected cost

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[6] Despite this widely held belief, several U.S. General Accounting Office reports (1979, 1990) suggest that these official estimates may be too high. For example, one study in 1979 found that only 200 out of 921 sources thought to be in compliance actually were. A more recent study in 1990 suggested that EPA's estimate of 86% compliance by major air pollution sources was too optimistic. Nevertheless, the 'stylized fact' that the vast majority of firms are in compliance persists.

[7] Livernois and McKenna (1997) offer a somewhat different reason for compliance based on the fact that the enforcement authority offers a significant incentive for self-reporting violations. See also Section 3.4.1).

[8] Notwithstanding the above discussion, there is no necessary connection between the level of fines actually observed and the level of compliance. For example, Harford (1987b) provides a model in which high compliance rates result from high monitoring rates and no fines being imposed.

of compliance in the presence of noncompliance penalties. Second, they argue that industry might want stringent regulation as an entry barrier to new firms. Although this is plausible, it is not clear how this explains compliance (as opposed to regulation). Third, they note that risk aversion might help explain compliance. The fact that subsequent violations are dealt with more harshly provides an impetus for a risk averse decision maker to comply now instead of risking future monitoring. Finally, Downing and Kimball (1982) raise the possibility that managers care about their corporate image, a hypothesis that they claim is supported by survey evidence. Recent surveys that provide some evidence consistent with this claim can be found in Cahill and Kane (1994), Zerbe (1996), and Doonan, Lanoie and Laplante (1998).

There are other reasons why firms might comply with environmental standards. It is possible, for example, that firms do not realize how low the expected penalty is for violating the law. Hammit and Reuter (1988), for example, cite survey evidence that small quantity generators of hazardous waste significantly overestimate the chance the government will monitor them. Alternatively, it is possible that the expected penalty for noncompliance is not as low as it appears on the surface. For example, there is growing evidence that the relatively low administratively imposed fines noted by previous authors are not the only penalties imposed on firms that fail to comply with environmental laws. As discussed in Section 4.4, firms that violate the law might be sanctioned by market forces.

It is also possible, for example, that managers who make the decisions about compliance simply believe that compliance is the right thing to do. In other words, social norms might operate to yield significant compliance rates – even without the threat of penalties. This is discussed further in Section 2.2. It is also possible that the marketplace rewards firms that comply with environmental regulations if a segment of consumers are more likely to buy their products (Arora and Gangopadhyay, 1995).[9]

Harford (1997) offers an interesting new theory suggesting that large publicly traded firms might be more inclined to comply with environmental standards than other firms. The theoretical argument follows other recent papers in the economics and finance literatures on corporate governance that suggest shareholders of diversified portfolios will want to maximize their portfolio's value – not the share price of any one firm. Thus, if one firm within a diversified shareholder's portfolio creates an externality against another firm, it will be in the interest of that shareholder to internalize the externality and maximize joint share value. To the extent that shareholders own a diversified portfolio of all publicly traded firms that collectively make up a large portion of the nation's

[9] Although Arora and Gangopadhyay (1995) model firms that do better than regulatory standards, there is little difference between their model and one in which firms either comply or violate the law. They model "environmental leaders" as being of some value to a segment of consumers. In a world with only firms that comply or violate the laws, the complying firm could be thought of as an environmental leader. Thus, except for the threat of government-imposed sanctions, the underlying theories of why a firm might comply with regulations and why it might overcomply are virtually indistinguishable.

environmental risks, shareholders will not seek share value maximization, but some modified version that includes their own preference for a clean environment.

Alexander and Cohen (forthcoming) argue that incentives within the firm that align top management with shareholders interests can help explain firm compliance behavior. If it is in the best interest of shareholders to comply with environmental laws, we would expect compliance to be more prevalent in firms where top management incentives are more closely aligned with shareholders. Alexander and Cohen provide empirical evidence that publicly traded firms whose top management incentives are closely aligned with shareholders are less likely to commit corporate crimes. Given the corporate governance literature on managerial incentives, this finding suggests that crimes that are discovered and prosecuted by federal authorities have not generally been crimes that were in the best interest of shareholders. Put differently, many of the environmental violations that occur in large, publicly traded firms, are likely to be caused by negligence or employee shirking – not by deliberate company policy.

The role of community pressure and other forms of informal sanctions are explored in Pargal and Wheeler (1996), Hettige et al. (1996), Arora and Cason (1996), Brooks and Sethi (1997), and Konar and Cohen (1998). These papers generally find support for informal community pressure and social norms as playing an important role in emissions and/or compliance.[10] As Pargal and Wheeler (1996) note, however, the ability of communities to play this role appears to be an increasing function of their income and education level. One problem with analyzing the role of community pressure across different regional areas is the potential for endogeneity of both plant and community location. For example, a firm that wants to build a new plant will likely choose a location that is more receptive to high pollution plants. Similarly, people who choose to live in a neighborhood nearby an existing polluter are likely to have a higher tolerance for pollution.

Finally, an interesting question to ponder is whether noncompliance may be partly explained by ignorance, not willful behavior. Brehm and Hamilton (1996) consider this possibility in the case of new rules requiring certain emitters of toxic chemicals to report their emissions to the U.S. EPA. They develop a model in which violations may occur due to ignorance or evasion. For example, "ignorance" was operationalized by measuring the extent to which a facility had other environmental permits or requirements. It is assumed that firms with other environmental permits were more likely to know about the new reporting requirement. Alternatively, if a firm that failed to report its TRI emissions had a previous violation under other environmental laws, that would suggest evasive activity. Brehm and Hamilton (1996) found considerable support for an "ignorance" explanation for noncompliance, although there was also evidence of evasive activity. Their paper highlights the importance of considering the information set of firms subject to regulations.

[10] Additional studies can be found on the World Bank website: http://www.worldbank.org/nipr/work_paper/index.htm.

2.2 Social Norms and Environmental Compliance Behavior

Although this article is primarily focused on *economic* analysis of environmental monitoring and enforcement, economists do not have a monopoly on theories of compliance. Sociologists and public policy analysts also study regulatory compliance issues. Although their theoretical foundations differ somewhat from economists, they usually include a "deterrence" component in their analysis. However, they also generally assume that some compliance is due to social norms and the fact that individuals generally want to abide by laws they understand. Thus, government enforcement agencies might have two tools at their disposal – "deterrence" and "cooperation." Compliance takes on more of a moral tone in this literature, and is expected to be greater when individuals and firms believe the rules are legitimate and fairly applied.[11] This section provides a brief glimpse into this literature.

Burby and Paterson (1993) provides a good introduction to the non-economic environmental compliance literature. They note that successful enforcement depends on the "capacity" and "commitment" of the regulated parties. "Capacity" refers to having the knowledge of the rules and technologies. To an economist, this is analogous to ensuring that the potential violator has adequate information and the financial ability to comply (i.e., the bankruptcy constraint is not binding). The "commitment" to comply is determined by factors such as deterrence, remuneration, moral reasoning and group identification. To an economist, the first two factors are the incentives (punishments or rewards) facing the decision maker. The second two factors are analogous to a reliance on social norms. That does not mean that sociologists and economists agree on the underlying motivation for individual behavior. To the contrary, few outside economics subscribe to utility maximization as a fundamental paradigm. Whereas the sociologist might argue that the existence of norms is proof that utility maximization is not a reasonable assumption, the economist might retort that adopting social norms is entirely consistent with utility maximizing behavior.[12] Although different disciplines and authors might place differing weights on these various factors, there is clearly some commonality and a lot that can be learned from reading across disciplines.

Social norms have sometimes been explained in a rational utility maximizing framework. For example, Scholz (1984) develops a repeated play game theoretic model in which cooperation can be the equilibrium outcome of a game where firms are not acting altruistically in their compliance behavior. In a 'tit for tat' strategy where the regulated party is concerned about future encounters with the enforcement agency, firms might cooperate even if there is no immediate threat of sanctions.

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[11] Two recommended sources in this literature are Bardach and Kagan (1982) and Hawkins (1984).

[12] There is growing interest in the economics of social norms. For example, Huang and Wu (1994) show how social norms may develop in response to the need to control corruption and maintain order without formal laws. They model a principal-agency relationship, which is analogous to the problem of a regulator-firm. See also Posner (1997) for a brief overview of social norms and economics.

2.3 Positive Theories of Government Behavior

Much of the normative theory and empirical analysis discussed in subsequent sections of this article assume (sometimes implicitly) that the government enforcement agency is interested in maximizing social welfare. This might be appropriate if one is interested in searching for socially optimal solutions. However, to the extent that regulatory agency goals differ from social welfare maximization, any attempt to empirically explain their behavior falls short. For example, why are some firms and/or industries monitored more closely than others? How does an enforcement agency decide whether to use formal penalties or less formal rules? More importantly, if one is interested in making normative policy prescriptions, ignoring the motivations of the enforcement agency might lead to the wrong outcome.[13]

The environmental compliance literature includes a variety of assumptions about enforcement agency behavior. Some of these theories of behavior are based on the general propositions of the political economy or public choice literature, others are based on more detailed interactions between the Congress and the regulatory agency. In this section, I explore several theories of enforcement behavior: (1) net political support maximization, (2) bureaucratic behavior theory, (3) the law enforcement goal of maximizing compliance, (4) maximizing the benefits of compliance without regard to compliance costs, and (5) a median voter model with asymmetric information about enforcement effort and compliance costs.

It is important to note that although different theories might be used to explain government behavior, the empirical implications of those theories might not always be distinguishable. For example, one would expect more stringent enforcement against companies that have a prior history of violating environmental laws under the economic theory of regulation (if the public demands it), compliance maximization (since the agency is most likely to find violations at these firms), and under social welfare maximization (based on the dynamic models discussed in Section 3.4.2). Despite that complication, one can often specify variables that will empirically distinguish one theory from another. For example, one might identify politically powerful industries to see if they have a differential enforcement rate even though firms with a past compliance problem are uniformly dealt with more harshly.

2.3.1 Economic Theory of Regulation/Net Political Support Maximization

The economic theory of regulation posits that agencies wish to maximize net political support (Peltzman, 1976).[14] That is, the agency wants to maximize the difference

[13] Dewees (1983) addressed similar issues in the context of comparing policy instruments (e.g. emission fees versus standards).

[14] Magat, Krupnick and Harrington (1986) operationalize a model of net political support maximization in the context of EPA and the stringency of environmental regulations. However, they do not consider enforcement issues.

between the number of supporters and the number of detractors of its enforcement policy. One way to do this is to impose the least amount of regulatory burden on private interests that are concentrated and well organized. Deily and Gray (1991) model the regulatory agency in this manner. They note that if a firm finds compliance too costly and will otherwise shut down, it is a likely candidate to pressure the agency and to generate political opposition. In particular, that firm's employees and other local citizens who will be hurt from a plant-closing are likely to be vocal opponents of any such stringent regulatory enforcement activity. Thus, they hypothesize that the government will fail to enforce as stringently when the cost of compliance is very high or when the plant is in danger of closing. They also expect to find less enforcement when the plant is a significant employer in the area.[15]

2.3.2 Bureaucratic Behavior Theory

Bureaucratic behavior theory (Niskanen, 1975) is based on the notion that government personnel derive benefits (through higher salaries, perks, and stature) when they have larger budgets. Asymmetry of information between the bureaucratic agency and Congress results in an agency that is driven more by budget maximization than social welfare maximization.

Lee (1983) examines the problem of collecting an emissions fee when the enforcement authority acts as a budget maximizing agency. Not surprisingly, he finds that the agency will spend an excessive amount of resources monitoring for violations. Although the Lee (1983) paper is intuitively appealing and is a nice application of bureaucratic behavior theory, it does not appear to help explain how pollution control laws are enforced in the U.S. As we have shown, an optimal penalty will involve a relatively low level of monitoring, and the empirical evidence suggests that minimal monitoring actually occurs.[16]

The fact that bureaucratic behavior theory does not help us explain enforcement policy should not be viewed as an indictment of that theory. Instead, the Lee (1983) model is too simplistic to capture the important features of political reality. First, I would argue that the theory primarily relates to an entire agency, not its various offices. Thus, even if the enforcement division of EPA lobbied for a larger budget and more monitoring, top EPA officials ultimately decide what budget to present to Congress and how to trade off the numerous internal demands for larger budgets. A much richer theory of bargaining within the agency and the relative importance of different divisions within EPA would be required to determine theoretically how much monitoring we would expect. Second, any theory of bureaucratic behavior must consider the fact that the agency is merely one player in a principal-agency relationship where its principal (Congress) might attempt to reduce this budget-maximizing tendency through appropriate incentive compatible

[15] See Section 4.1.2 for a discussion of Deily and Gray's empirical results.
[16] Harford (1985) makes this same point and corrects some errors in the Lee (1983) formulation. However, the basic result that budget maximization leads to excessive monitoring still holds.

enforcement mechanisms of its own through the budgetary process. This latter possibility is explored empirically by Wood (1988), in Section 4.1.1 of this paper.

Gūth and Pethig (1992) develop an interesting variant of bureaucratic behavior theory in which the regulatory enforcement agent is of unknown quality. The enforcement agent cares about increasing compliance since higher compliance will likely enhance his career. At the same time, however, the enforcement agent is an employee of a government bureaucracy and thus might try to shirk, might be incompetent, or otherwise engaged in utility maximization that is not conducive to effective law enforcement. The regulated firm does not know if it is confronted with an effective or ineffective enforcement agent. Thus, Gūth and Pethig set the stage for an interesting and complex game theoretic model of firm-regulator interaction. For example, the firm might engage in an "exploratory pollution accident" to test the monitoring agent's proclivity to undertake a thorough investigation. Thus, the firm hopes that this minor incident will cause the monitoring agent to reveal its type. Although this sequential game might result in such a signaling equilibrium, depending on the parameters chosen, it might also result in a pooling equilibrium where the monitoring agent does not reveal its type.

2.3.3 Maximizing Compliance with the Law

The enforcement arm of a regulatory agency often has more in common with police or other law enforcement agencies in government than with the regulatory agency itself. In the U.S., EPA enforcement officials work closely with the Department of Justice and some EPA officers even have criminal arrest powers and carry guns. Thus, an alternative view of enforcement is that it is a pure law enforcement function designed to achieve the highest possible level of compliance. In contrast to "maximizing social welfare," which would require the agency to balance the cost of compliance against the benefits of compliance, "maximizing compliance" ignores costs altogether. Keeler (1995) adopts this somewhat apolitical view of the enforcement agency, and assumes a limited enforcement budget that must compete with other agency functions. As long as the agency does not fully account for the cost of compliance in its decision process, Keeler's model thus predicts an excessive amount of enforcement relative to the socially desired level and relative to the other functions of the agency (e.g., writing new regulations, research, etc.).

Garvie and Keeler (1994) also assume the enforcement agency's goal is to achieve the highest level of compliance given their enforcement budget. Thus, the agency must take into account the fact that if it tries to impose a very steep penalty, it will incur additional enforcement costs as firms attempt to evade, challenge enforcement actions in court, etc. In such a setting, Garvie and Keeler's model predicts relatively low penalties and more frequent contact with enforcement officials and less formal negotiations when the regulated industry has a lot of political power or when there is a high probability of judicial leniency due to unclear regulatory standards. On the other hand, we expect low monitoring/probability of detection and high penalties when the activity is judged to be especially damaging and the regulator can be certain of legal and public support for

prosecution. Examples of the latter are midnight dumping of hazardous wastes. To my knowledge, there have been no empirical tests of these testable implications.

2.3.4 Maximizing Environmental Benefits of Enforcement

If we allow the goals of the regulatory agency and its enforcement arm to be somewhat more closely aligned, it might be reasonable to assume that the enforcement goal is to maximize the environmental benefits of compliance. This is different from maximizing compliance, which would involve focusing on 'easy' enforcement targets even if they yield little environmental benefits. Maximizing environmental benefits would focus the enforcement agency on those facilities that have the highest environmental payoff per dollar of enforcement effort. It is also different from maximizing the *net* benefits of compliance, which would explicitly consider the firm's compliance cost.

Given the reluctance of Congress and the Courts to allow environmental regulations to explicitly balance social costs and benefits or to consider the cost of compliance as a factor in regulation, "maximizing environmental benefits" is a plausible agency goal. Jones and Scotchmer (1990) examine this case in the context of enforcing uniform regulatory standards when firms have different compliance costs. They show that maximizing the benefits of compliance yields compliance rates that differ across firm type. Even though the enforcement authority is not told to differentiate between high and low cost firms, it is more difficult (and hence more costly for the enforcement agency whose budget is limited) to obtain compliance from a high cost firm. Of course, we would expect to see a similar differential compliance rate if the enforcement agency's goal was net social benefit maximization. Nevertheless, we would not expect these two goals to yield equivalent social benefits. Jones and Scotchmer (1990) argue that limiting an enforcement agency's budget is one way to induce an enforcement strategy that is closer to the socially optimal one of net benefit maximization. By limiting the agency's enforcement budget, Congressional appropriations committees force the agency to shift its enforcement resources away from high cost firms.

2.3.5 Median Voter Model

Casual observation suggests there is often an asymmetry between the letter of the law and its application. Although stringent environmental regulations might be on the books, one cannot necessarily assume that compliance and enforcement will take place. Selden and Terrones (1993) formalize this notion by adopting a median voter model where the legislature and voters have asymmetric information about the costs of pollution control and enforcement zeal. The voters demand and are "given" very stringent environmental legislation since they are less readily able to see the cost of these rules. However, the voters are also less able to observe the extent to which the government is enforcing its environmental standards. Thus, we expect more stringent regulations than might be socially optimal, and we expect less than stringent enforcement to compensate. Note that if this model is realistic, one should be cautious about allowing private citizen suits (see

Section 4.3) to enforce when the government does not. In this context, citizen suits would only cause over deterrence.

2.3.6 The Role of Federalism and Multi-level Enforcement Agencies

An interesting question that has only seldom been discussed in the literature is the extent to which enforcement and compliance differs with the level of government in a federal system. Should monitoring and enforcement be delegated to a state or local jurisdiction, or remain with the Federal enforcement agency? The scarcity of literature on this topic reflects both the difficulty in obtaining sound data that would allow for such a study, and the lack of definitive theoretical models of federalism that yield strong predictions of enforcement behavior. Thus, the little empirical literature devoted to this topic tends to be focused on policy implementation issues.

A good example of this type of research is Burby and Paterson (1993), who study compliance under two different enforcement agencies, a state-level enforcer and a local enforcement authority. Burby and Paterson are interested in whether delegating enforcement authority to the local level will result in more or less compliance. The theory is ambiguous on this issue. On the one hand, a decentralized enforcement agency might be overly concerned with local job losses or zoning restrictions. Thus, we would expect less stringent enforcement and compliance with local government monitoring. On the other hand, a local enforcement agency has the advantage of being familiar with the facilities and individuals within the firm, and is more likely to gain the cooperation of local managers. Burby and Paterson develop a unique data set of inspections in North Carolina, where some local jurisdictions voluntarily enforce state law, with the remaining jurisdictions allowing the state to enforce. They find some evidence of increased compliance by firms subject to local enforcement. Given the fact that local jurisdictions self-selected into the enforcement program and the fact that this is only one program in one state, one should be reluctant to generalize from these findings.

3. Normative Theories of Monitoring and Enforcement

Moving from positive theories to normative theories, in Section 3.1, I begin with the simple Becker (1968) model equating the penalty to the harm divided by the probability of detection. Although this theory has been expanded considerably over the years, its basic insight is intact. One way in which the theory has been expanded is by taking into account numerous constraints on the actors – in this case firms and regulatory agencies. Firms might declare bankruptcy and might be run by managers who are risk averse (Section 3.2). Imposing sanctions costs the enforcement agency resources that need to be taken into account (Section 3.3). More complex penalty structures might be designed to reduce these government monitoring and enforcement costs (Section 3.4). Another issue that is often debated in policy arenas is whether the optimal penalty should be based on the “harm” caused by the violation or the “benefit” to the firm from not complying

(Section 3.5). Since the legislature might set a fixed enforcement policy, one can also study the best response of enforcement agencies under such constraints (Section 3.6).

The environmental economics literature has long touted the use of market-based incentives and other innovative regulatory approaches. In Section 3.7, I consider whether or not firms will comply with these forms of regulatory policies and how the enforcement agency can induce compliance. Despite the fact that most models of enforcement assume perfect knowledge on the part of both the firm and the regulator, uncertainties abound. In Section 3.8, I consider the consequences of uncertain legal standards and errors in the enforcement process. In Section 3.9, I consider the possibility that firms may deliberately attempt to evade detection or spend resources challenging an administrative order. Finally, in Section 3.10, I expand the theory to consider the fact that regulatory violations are caused by people within firms. Thus, an optimal penalty policy might consider the incentives facing both the firm and its employees. This has important implications for both wage contracts and government law enforcement policy.

3.1 Optimal Penalties and Optimal Monitoring – The Becker Model

The optimal penalty literature begins with Becker's (1968) economic analysis of crime. The basic insight of that seminal article is that potential criminals respond to both the probability of detection and the severity of punishment if detected and convicted. Thus, deterrence may be enhanced either by raising the penalty, by increasing monitoring activities to raise the likelihood that the offender will be caught or by changing legal rules to increase the probability of conviction. Becker's model ultimately leads to an "efficient" level of crime, whereby the marginal cost of enforcement is equated to the marginal social benefit of the crime reduced per unit of enforcement. Thus, given individual preferences and enforcement technologies, both the crime rate and the level of monitoring and enforcement activities are determined by this model.

The earliest variants of the Becker model that appeared in the environmental arena are Downing and Watson (1974), Harford (1978), and Storey and McCabe (1980), all of whom investigate firm behavior in response to penalties. Downing and Watson (1974) describe the model in general terms and conduct a simulation exercise comparing various combinations of penalties and monitoring for both an emission fee and a control standard. Harford (1978) presents a formal model of firm response, also comparing enforcement of emission fees to regulatory standards.

As noted in the environmental economics review article by Cropper and Oates (1992), there are generally two sources of environmental violations. First, a firm might intentionally violate the law by not complying with a regulatory standard or by not paying the appropriate emission fee. That is the type of violation envisioned by Harford (1978), where the firm explicitly chooses an output-emission combination. Second, pollution may be of a stochastic nature, in which case it may not be obvious a priori whether the existence of pollution is due to a willful violation of the law, some form of negligent behavior, or a random act of nature. Beavis and Walker (1983), Beavis and

Dobbs (1987) and Cohen (1987) examine stochastic pollution. As Cohen (1987) notes, the Becker (1968) model can be written as a special case of a more general model of firm behavior that takes into account the random nature of pollution. Although Becker is primarily interested in *ex post* penalties, his model can easily be adapted to include *ex ante* penalties for not taking proper care to prevent a crime from occurring. This section closely follows the model in Cohen (1987) in order to investigate the role of *ex ante* versus *ex post* monitoring and incentives. In Becker's model, crime is unambiguously "caused" by the criminal, whereas in stochastic pollution, the extent to which a polluter took adequate care in preventing the externality is often an important issue to be resolved.

We begin with the firm's problem. The firm is assumed to produce pollution as a byproduct of its production process. In its most general form, pollution (x) is a function of the level of output (o), the level of effort expended by the firm to reduce pollution (e), and a random component. Thus, pollution is a random variable with distribution function F(x,e). To simplify, we ignore the firm level of output, which obviously affects the expected level of pollution. It can be thought of as a control variable for most of the analysis.

Under a command and control regime, the government requires a certain minimum level of effort, which might include installing and properly maintaining certain pieces of equipment, properly training employees, etc. With probability $P_I(m_1)$, the firm will be inspected for compliance, where m_1 is the level of government resources devoted to compliance monitoring. If inspected and found to be in noncompliance (i.e., $e < e^*$), the government will impose a penalty $T_I(e)$. This is an *ex ante* penalty, as it is based on the level of effort devoted by the firm to prevent pollution.

If pollution occurs, the government may devote resources to detect and punish the firm that caused it. Let m_2 be the level of government resources devoted to detecting stochastic pollution. Then, the probability of detection will be $P_D(x,m_2)$, where the detection probability is increasing in both the level of government detection resources and the size of the externality (larger emissions are presumably easier to detect). If the pollution is detected and attributed to its generator, the government imposes a penalty, $T_D(x,e)$. Note, however, that the government does not directly observe the level of effort by the firm. Thus, if the government wants to condition its penalty on the level of effort (a negligence standard), it must expend additional *ex post* monitoring resources, m_3, to determine the culpability of the stochastic polluter. Finally, in some cases (e.g., spills of valuable inputs to a production process), the existence of a stochastic externality may involve a private loss to the polluter, v(x), the value of lost resources.

The firm's expected profit from polluting can be written as:

$$EU(e) = R(o) - K(o,e) - P_I T_I(e) - \int_x [v(x) + P_D(x) T_D(x,e)] f(x,e)\, dx - e \quad [1]$$

Revenue, R, and production costs, K(o,e) are included in this more general formulation.[17] Note that this formulation easily converts to a nonstochastic framework. For example, Harford (1978), has a similar formulation, where (using the notation in this paper), profit is $R(o) - K(o,x) - P_D T_D(x)$ plus a term allowing for a government subsidy.[18] In this case, the penalty is based on observed pollution, i.e., the government enforces a performance standard. For our purposes, we assume that production costs depend only on output level and are separable from the pollution prevention decision.[19] Thus, K(o,e) can be written as K(o) and e is chosen independently. In that case, we can examine the pollution control decision in isolation:

$$EU(e) = - P_I T_I(e) - \int_x [v(x) + P_D(x) T_D(x,e)] \; f(x,e)\, dx - e \qquad [2]$$

The government is assumed to be a social welfare maximizer.[20] It has numerous choices to make, including the level of monitoring expenditures. As such, it wants to minimize the sum of cleanup or recovery costs, C(rx), where r is the fraction of pollution that is cleaned up; environmental damages, D[(1-r)x]; private resource loss, v(x); prevention expenditures, e; and government enforcement expenditures m_1, m_2, and m_3.

$$EW(e, m_1, m_2, m_3, r) = \int_x \{D[(1-r)x] + C(rx) + v(x)\} f(x,e)\, dx - e - m_1, m_2, m_3 \qquad [3]$$

Implicit in this formulation is the indifference of the government to the level of the fine paid by the firm, since the fine is a transfer payment. The government has control over the level of monitoring, m_1, m_2, m_3, and can either mandate some level of recovery/cleanup or clean up the damage directly itself. However, level of effort cannot be observed directly and can only be inferred or imperfectly observed *ex post*. Thus, the government imposes a penalty to induce the firm to take the optimal level of effort. That penalty is:

$$T_D(x) = \frac{D[(1-r)x] + C(rx)}{P_D(x)} \qquad [4]$$

Substituting [4] into [2], the polluter's problem becomes one of social welfare maximization, [3] where m_1, m_2, and m_3 are set equal to zero with no need for

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[17] Cohen (1987) ignores this part of the firm's decision, as that paper is primarily interested in oil transfer operations where one can generally separate out the decision about how much oil to transfer and what pollution prevention/control technologies to adopt.

[18] A recent paper by Stranland (1997) argues that a subsidy targeting technological innovation in pollution control might be a viable substitute for more stringent enforcement policies as firms receiving the new technological innovation will have a lower expected marginal benefit of noncompliance.

[19] The results of these models generally hold even if production is explicitly included; this just adds unnecessary notation and complexity.

[20] This assumption is discussed further is Section 2.3, where I examine alternative assumptions of government behavior.

government monitoring. This penalty is just Becker's optimal penalty equal to the harm divided by the probability of detection, which induces the socially optimal level of effort. Harford (1978) obtains a similar result under the simplifying assumption that pollution is not cleaned up (r=0). In that case, the optimal penalty is simply the harm divided by the probability of detection.

The optimal penalty [4] varies with the probability of detection, a key parameter in the enforcement agency's tool kit. Since increasing the probability of detection requires some expenditure on government monitoring, Becker's policy prescription is to set $P_D(x)$ arbitrarily low, thus raising the penalty. However, there may be limits on how high a penalty is feasible – for political reasons, wealth constraints of polluters, and for purposes of preserving marginal deterrence (Polinsky and Shavell, 1979).

In addition to determining the probability of detection, the optimal penalty [4] requires that the government decide whether to require cleanup of any harm caused by illegal pollution. As Cohen (1987) shows, the optimal recovery/cleanup rule equates marginal damages to marginal cleanup costs, $D'[(1-r)x] = C'(rx)$. The cleanup rule is independent of either the level of care taken by the firm or mandated by the government, and is independent of the optimal penalty. Note, however, that this rule can be endogenously determined through an optimal penalty that incorporates cleanup. As Polinsky and Shavell (1994a) show, if the polluter is made responsible for cleanup and held strictly liable for any residual damage, it will determine the optimal level of cleanup by equating marginal cleanup costs to marginal damages.

Note that the optimal penalty [4] does not depend on the level of effort undertaken by the firm. Thus, it is a strict liability standard, whereby the polluter is held liable without regard to his state of mind or to the fact that the polluting incident might have been beyond his control. If penalties are not constrained, such a penalty is best because it economizes on government resources (m_3) that might otherwise be devoted to an *ex post* investigation and potential adjudication or litigation costs associated with determining what level of care the firm actually took (Cohen, 1987). However, one could also specify a technology-based standard and impose a penalty $T_D(e)$, when $e < e^*$. In the parlance of the law and economics literature, instead of a strict liability standard, this would be a negligence-based penalty. A negligence-based penalty is one that is imposed only when it is shown that the polluter did not take an appropriate level of care in preventing the emissions.

The choice between using a strict liability standard versus a negligence standard is the subject of much discussion in the law and economics literature (see e.g., Shavell, 1980). If one is concerned about the cost of enforcement, a strict liability standard will generally be less expensive to enforce, as a negligence standard requires additional resources to determine the cause (and perhaps to litigate over the cause). In addition, a negligence standard results in a lower expected penalty to potential violators of stochastic pollution. Hence, a negligence standard has an advantage over strict liability when regulating stochastic pollution in the presence of risk aversion or a wealth constraint (Cohen, 1987).

Thus far, I have limited my analysis to *ex post* penalties and mandates to clean up after an illegal polluting incident has occurred. However, recall that the government might monitor *ex ante,* m_1, to determine the level of effort undertaken by the firm and impose a penalty only if found to be in noncompliance with some optimal standard of care.[21] In theory, either approach can achieve the same level of deterrence. However, we can distinguish instances when *ex ante* monitoring is preferable to an *ex post* penalty and vice versa (see Shavell, 1993). If solvency of the polluter is a problem, *ex ante* monitoring has an advantage, since the optimal penalty for taking an action that increases the probability of harm will be smaller than if that harm has actually occurred. In other words, there is a lower probability of insolvency – thereby preserving the incentive effects of penalties. If the polluter is risk averse, *ex ante* monitoring also has an advantage, since the polluter can predict with virtual certainty whether or not she will pass the government's standard as opposed to the uncertainty of being penalized only if some random event occurs.

In some instances, it will be easier (less costly) to apply one type penalty over the other. For example, consider the difficulty in determining the responsible parties for a Superfund site or who is responsible for contaminating a drinking water source. As the cost of determining the responsible party increases, *ex ante* monitoring becomes a more attractive alternative. On the other hand, it might be more difficult to estimate the expected harm from *ex ante* monitoring. Thus, an *ex post* penalty might be more likely to be calculated properly.

3.2 Costly Sanctions

Thus far, I have assumed that if the enforcement agency detects a violation, it is always able to impose a sanction and there is no cost in doing so. However, in reality, the agency will incur additional investigation costs and may even have to drop enforcement actions against a violator due to procedural problems or lack of evidence. In addition, there may be a cost associated with imposing the sanction itself. For example, there might be paperwork associated with assessing and collecting a fine, or additional follow-up monitoring to ensure that a remedial cleanup or compliance program has taken place. Assuming risk neutrality and that the wealth constraint is not binding, it can be shown that the optimal penalty is:

$$\frac{D[(1-r)x] + C(rx)}{P_D(x)\,q} + s/q + k \qquad [5]$$

where q is the probability of a fine actually being imposed after it is detected, s is the cost of the investigation and prosecution stage, and k is the cost of imposing the sanction.[22] Thus, the "variable enforcement costs" need to be taken into account in order to impose

[21] If the government is enforcing a regulatory standard that requires certain equipment be installed or other prevention activities occur, and does not regulate actual emission levels, all monitoring is "*ex ante,*" and the only relevant penalty is $T_I(e)$.

[22] This is taken from the penalty derived in Polinsky and Shavell (1992), with the addition of cleanup costs as discussed in equation [4].

an optimal sanction (Polinsky and Shavell, 1992). The variable enforcement costs, s and k, are social costs imposed by the violator, unlike the monitoring costs, m_1 , m_2 , m_3. Monitoring costs are "fixed enforcement costs" that do not vary with the number of violations. However, as Polinsky and Shavell (1992) note, the optimal probability of detection varies with both types of enforcement costs.

As Becker noted, one can save government enforcement resources by increasing the penalty and lowering the probability of detection. At the extreme, one could continue to make this tradeoff until very few violators are punished, but those that are caught are punished severely. In reality, however, we do not observe such high penalties and low detection rates.[23] As discussed in the following sections, among the reasons for not imposing a high sanction are limited wealth of the offender, risk aversion, and an exogenously imposed maximum (due to legislation or social norms of fairness). Polinsky and Shavell (1979) explicitly examine the tradeoff between the probability of detection and the optimal fine.

3.3 Risk Aversion and Wealth Constraints

Although I have thus far assumed that the polluter is risk neutral and able to pay the optimal fine, neither risk aversion nor ability to pay are assumptions that necessarily hold in the real world. If risk averse, an individual (or firm) facing a range of uncertain negative payoffs, would prefer to pay the expected dollar value of the payoff possibilities as an insurance premium rather than face the uncertain situation. Hence, potential violators would be better off if they were monitored more frequently and received a lower penalty if found to be in violation of environmental laws than if they were seldom detected and paid a high price for the rare finding of noncompliance (Shavell, 1979; Cohen, 1987).[24] Of course, monitoring is costly to society. Thus, one must trade off the efficiency gains to the violator from lower sanctions/higher monitoring versus the higher cost of monitoring. To the extent that the penalty is higher than optimal to save on monitoring costs, the government will overdeter violations.

A somewhat different problem arises when the optimal penalty is so high that it bankrupts the environmental violator. In that case, we can view the risk neutral offender as being risk-loving. If the polluter is able to declare bankruptcy in some of the worst case scenarios (e.g. an extremely large stochastic pollution incident or unexpected compliance inspection, it has an incentive to take too much risk and thus less than optimal level of care (Cohen, 1987: 33-4). Polinsky and Shavell (1991) show that if wealth varies across individuals, the optimal penalty is less than the wealth of the wealthiest individual and may be smaller than most individuals' wealth. Alternatively, as indicated in Section 3.1, this limit on the size of the penalty might force the government to increase their *ex ante* monitoring, or to impose an *ex post* negligence standard (instead of a strict liability standard).

[23] See Section 2.1.

[24] Similarly, one could adopt a negligence-based standard and only apply the penalty when the polluter is found to be in violation of a minimum level of care. See Section 3.1 for a discussion of negligence versus strict liability standards.

An alternative approach to dealing with insolvency is to impose nonmonetary sanctions on the offender. Following Becker (1968), it is generally noted that the imprisonment alternative is socially costly (as opposed to monetary fines that are generally considered transfer payments). Thus, imprisonment is seen as a last resort. For example, an individual offender might be placed in jail if the optimal penalty is so high that it would bankrupt the offender. Imprisonment might also be called for when the firm cannot afford to pay its share of a penalty. Shavell (1985: 1236-7) identifies five factors that have a bearing on whether or not imprisonment is needed: (1) size of assets of the offender, (2) probability of detection and conviction, (3) size of private benefits from illegal activity, (4) probability that an act will cause harm in the case of ex ante penalties, and (5) size of the harm if it occurs.

Incarceration is not the only form of nonmonetary sanction. Individuals convicted of a crime may be placed on probation, forbidden from engaging in certain lines of business or professions, or may have certain restrictions placed on their rights (e.g., ownership of firearms or voting rights). Similarly, organizations might be placed on "probation" whereby the court or regulatory agency monitors their future compliance or remediation activity. They might also lose certain rights such as the right to sell goods or services to the government. These nonmonetary sanctions might be more or less punitive than fines. As we have noted above, there are many reasons why the optimal penalty might not be feasible or desirable, including risk aversion, uncertain legal standards, limited wealth, and exogenous limits on the size of penalties. Thus, from the enforcement agency's perspective, nonmonetary sanctions such as negotiated agreements without monetary penalties may be important enforcement tools.

3.4 Innovations to Reduce Government Monitoring Expenses and Increase Deterrence

Under the most simplistic optimal penalty model, decreased monitoring coupled with higher penalties is always beneficial. Indeed, absent externally imposed constraints on penalties, the optimal penalty is arbitrarily high and the optimal expenditure on monitoring approaches zero. As noted above, however, risk aversion and insolvency – not to mention fairness – precludes the use of such draconian policies. Thus, we are left with a government enforcement policy that requires a significant amount of monitoring expenditures. Several innovations have been suggested to reduce the need for expensive government monitoring. In this section, I consider two such innovations: (1) self-reporting induced by the government, and (2) differential penalties based on prior compliance history. In some instances, these innovations serve other goals – such as increasing deterrence. This is not surprising, since increasing deterrence for a given level of enforcement expenditures is conceptually no different from decreasing enforcement expenditures without decreasing the deterrent effect of government enforcement.

3.4.1 Inducing Self-Reporting Behavior

Self-reporting is a substitute for government monitoring efforts that may reduce enforcement costs without compromising deterrence. Polluters are told they must report any violation of pollution standards or any realization of stochastic pollution. The magnitude of any penalty they receive will depend on whether the violation is reported voluntarily or if government enforcement authorities discover it when no self-report has been made. If the latter, the penalty is considerably higher. Many environmental laws have such self-reporting requirements. In some instances, failure to report and submitting a false report are criminal offenses punishable by imprisonment. In other cases, self-reporting is rewarded with more lenient treatment by prosecutors who might agree not to bring criminal charges or to reduce the severity of the sanction.[25]

Harford (1987a) first studied self-reporting and characterized the firm's optimal level of emissions under such a scenario. Under some plausible assumptions about the shape of the fine function, he finds that tougher enforcement of self-reporting requirements will generally cause pollution to fall. However, that is not always the case. It is possible that increasing the penalty for failure to report will have the perverse effect of increasing actual emission levels. Whether or not this problem arises will depend on the magnitude and limitations of the various penalty functions. The recent growth of "environmental auditing" by firms that want to ensure they are complying with environmental laws highlights the importance of this issue. One of the key questions being raised recently in policy debates is whether information obtained through an audit should be made available to the public.[26] Many firms have argued that if these audits are not treated as proprietary, they will actually do less audits than they might otherwise have conducted. If that is true, compliance might be lower with "mandatory" self-disclosure than under a regime where voluntary audit results are kept private. However, a recent article by Mishra, Newman and Stinson (1997) argues that allowing the government to have access to these self-audits and to use them in enforcement procedures actually increases compliance. The reason for this counter-intuitive result is that the authors assume the regulator will adjust its inspection and enforcement policies in response to any law allowing or prohibiting access to environmental audits.

Of course, self-reporting does not entirely remove government enforcement costs. Instead, the government enforcement authority now has a new type of monitoring to consider – auditing self-reports and imposing a penalty if the polluter is found to be lying. Malik (1993) considers the effect of self-reporting on enforcement costs. He finds that for a given level of firm effort, a self-report scheme involves less government monitoring (auditing), but more frequent imposition of sanctions. Self-reporting is found to reduce costs when (1) the cost of monitoring/auditing is high, (2) the maximum feasible fine is

[25] Proposed Sentencing Guidelines for organizations convicted of environmental crimes in the U.S. would provide such a reward for self-reporting (Bureau of National Affairs, 1993). For a critique of that proposal see Cohen (1996).

[26] Most of this discussion has taken place outside the economics literature. See for example, Shweiki (1996).

low, or (3) the desired effort level is high (Malik, 1993: 253). Self-reporting is likely to increase costs if (1) the cost of collecting penalties is high (since the government is now more likely to impose penalties than to monitor pollution directly), or (2) the regulator's monitoring technology is extremely accurate. As Malik notes, although many environmental regulations involve self-reporting, the extent to which this mechanism is used varies considerably by program, with self-reporting being a common requirement in water regulations and toxic/hazardous chemical spills, but seldom being used in air regulation. It would be interesting to try to explain these differences.

Kaplow and Shavell (1993) provide a model of self-enforcement that is similar to Malik's, but they assume that the cost of imposing sanctions is zero. With that assumption, self-reporting always dominates, as it lowers the cost of government monitoring/auditing. In addition to decreasing monitoring costs, self-reporting is beneficial to polluters who are risk averse, as they can predict the penalty they will receive and have it imposed with certainty. If self-reporting speeds up the process by which victims are notified, it might also help reduce the damages ultimately caused by the environmental hazard as mitigating actions can be taken sooner to avoid further harm.

As Livernois and McKenna (1998) note, penalizing a firm for polluting has the offsetting effect of providing an incentive for firms to evade detection. Thus, while setting a very high penalty for noncompliance will deter violations, it may also reduce the accuracy of self-reported emissions. By lowering fines, the regulator may trade off some compliance for more reliable self-reporting. In other words, by lowering the expected fines for noncompliance, the regulator buys information on the true compliance status of the firm.

A similar argument is made by Heyes (1996), in the context of accidental discharges. Heyes (1996) notes that there is a time dimension associated with most pollutants. That is, some pollutants persist in the environment longer than others. Moreover, cleanup does not occur automatically even if it is mandated. The fact that a firm voluntarily cleans up an accidental discharge is likely to tip off enforcement authorities that a polluting incident has occurred. As time passes, the chance of being able to assess blame decreases as the pollution dissipates, other pollutants mix with it, etc. Thus, assessing a penalty on polluters has two effects – it deters firms from polluting in the first place, but it also reduces the incentive for firms to clean up pollution that has occurred. Thus, Heyes proposes reducing the penalty below the maximum level suggested by [4]. In addition, he proposes to save the maximum fine for firms that do not self-report. Thus, the differential penalty for self-reporting is not motivated by a desire to reduce enforcement expenses, it is precipitated by the need for "marginal deterrence," whereby firms have an incentive to reduce the damages caused by pollution before they become worse. The degree to which the penalty for self-reported pollution is reduced from the maximum penalty will depend on the "persistence" of the pollutant. At one extreme, if the pollutant has virtually no lasting impact, there is no need to reduce the penalty. If pollution has no lasting impact, the fact that there is a reduced incentive to clean up is not relevant. Conversely, if the impact is very long, there needs to be an incentive to clean up.

Throughout most of this article (and most of the literature), I have assumed that the regulatory authority can observe and regulate each firm's emissions – even if imperfectly. However, suppose instead that the regulatory authority can only observe aggregate emissions or ambient air or water quality. In that case, enforcement authorities may not be able to assign an individual emission fee or penalty for emitting more than the regulated standard. Meran and Schwalbe (1987) show that the enforcement agency may be able to employ a "collective penalty." The enforcement agency identifies all polluters in a region and determines whether aggregate environmental quality conforms with the regulated level. If not, a collective penalty is assessed, whereby the firms within the group bargain amongst themselves for the allocation of the penalty. Relying on game theory, Meran and Schwalbe (1987) show that a Nash Equilibrium solution exists whereby the optimal level of pollution will be achieved. However, the distribution of pollution and penalties across firms is indeterminate due to multiple equilibrium. Although theoretically interesting, implementation of this idea would likely raise legal/constitutional concerns. It might involve costly rent seeking behavior on the part of firms subject to the bargaining game and high transactions costs as legal fees mount up during the inevitable legal battle between polluters.[27]

3.4.2 Dynamic Models of Monitoring and Enforcement

Another innovation from the basic optimal penalty model relies upon a dynamic model of firm-regulator interaction. Previously, authors assumed a static framework where government monitoring was based on the expected reaction of firms. Of course, we do not live in a static world, and there is no reason why the government enforcement agency must treat all firms alike. Instead, one can envision differential monitoring rates – and differential penalties – depending on the enforcer's expectations based on each firm's prior compliance history or other exogenous information. As discussed earlier, Harrington (1988) and Harford (1991), have modeled the enforcement agency's policy allowing for differential monitoring rates and penalties. These positive models also have important normative implications, as they offer a mechanism to achieve the same level of compliance (or higher) and yet yield lower social costs. Although most of these authors adopt compliance maximization as the goal, Harford (1993) considers a similar model in the context of social welfare maximization.

Moving into the normative world (and ignoring how enforcement policy is actually implemented), Harrington (1988) offers a variation of these models that includes a third group of firms. The third group is meant for second time violators, with their punishment being banishment to eternal monitoring. The threat of being in that third group ensures compliance at a dramatic reduction in government monitoring costs. However, as Harrington (1988) notes, it is not a very realistic alternative. If there is any positive probability of a false positive, all firms will eventually be placed in group 3, and the cost of monitoring becomes astronomical. Thus, some modified version of this policy would have to be implemented. Russell (1990) provides one such solution, by offering an "escape probability" from group 3 that guarantees a long enough stay for the negative

[27] A similar approach to emission fees was advocated by Segerson (1988) in the context of nonpoint sources of pollution.

consequences of being in group 3 to make a difference, but short enough to keep costs down.

Hentschel and Randall (1996) offer a more recent innovation to these dynamic enforcement models. They propose a combination of a self-reporting requirement (see Section 2.4.1), and differential inspection rates and penalties based on the firm's reputation for truthful reporting.

3.5 Harm versus Gain to the Offender

The optimal penalty derived in equation [4] above is based on the harm caused by the environmental violation. The fact that the offender gained by violating the law is not relevant to our analysis. Nevertheless, offenders generally do benefit from violating the law – otherwise, they would not risk being penalized. Moreover, the government took account of that gain as an increase in social welfare when determining the optimal penalty. Note that social welfare maximization [3] includes v(x), the value of resources lost if there is an accident, and e, the cost of the firm's preventive measures. These terms drop out in the optimal penalty calculation because they are privately included in the firm's decision [2]. Since firms already minimize these costs in their own private calculation, there is no need to include them in the penalty calculation – which is based on external costs not taken into account by the polluter.

There is an ongoing debate between economists and criminal justice policy makers about whether the penalty should be based on the harm, gain, or both. A penalty based on the gain to the offender would replace the term D[(1-r)x] in equation [4] with a term such as (e*-e), to account for the difference between the mandated pollution prevention effort and the amount of effort actually expended. However, if the penalty differs from [4] the polluter will exert too little or too much effort/compliance relative to the social optimum. If we want to be certain to deter every violation of the law, we could impose a penalty equal to the gain divided by the probability of detection. Then it would never be in the firm's interest to violate the law. However, pollution is a byproduct of a socially beneficial activity. In the jargon of the law and economics literature, pollution is a "conditionally deterred" offense – one that we only want to prohibit when its social costs exceed its social benefits. Some offenses – like violent assaults and rapes – are "unconditionally deterred" offenses that society would never condone regardless of the private benefit to the offender. In those cases, we simply ignore the offender's benefits, and the optimal penalty would be based on the private gain divided by the probability of detection.

In practice, many government penalties are based on either gain or some combination of harm and gain. The U.S. EPA, for example, calculates its civil penalty based on a combination of gain and harm. It first imposes a "gain" based penalty that is designed to take away any benefit from noncompliance, and then adds a "gravity" component based

on the harm from the offense.[28] The gain-based component of the penalty calculates the amount of money the violator saved by not complying with the law. The harm-based component is not as precise. This component of the EPA penalty is based on qualitative descriptions of harm and is not directly related to any quantitative measure of harm. Recently enacted Sentencing Guidelines for organizations convicted of federal crimes computes the monetary penalty based on the *maximum* of gain or harm.[29] One reason that is often mentioned for using gain is that it is easier to estimate than harm – especially for nonmonetary harms such as environmental hazards. However, that rationale may be less valid than it used to be. I would argue that the growing literature on contingent valuation and other methods used to value environmental harms has made the task of estimating harm no more difficult than estimating gain. Moreover, as Polinsky and Shavell (1994b) show, any underestimate of gain will make it beneficial to violate the law. Thus, gain-based penalties are more susceptible to underdeterrence than harm-based penalties. In contrast, if harm is underestimated, the offense is still likely to be deterred if it is very harmful.

3.6 Standard Setting with Fixed Enforcement Policy

In its more general formulation, the optimal penalty model yields an optimal mix of regulatory standards and enforcement expenditures. Since enforcement is socially costly, the agency must trade off enforcement expenditures for the level of environmental protection society ultimately obtains. This trade-off may be expressed in terms of the regulatory standard and/or the level of compliance. However, for some purposes, it is useful to consider holding enforcement policies fixed and asking what level of environmental protection will arise. For example, the legislature might impose a fixed (or maximum) penalty, firm insolvency constraints might make higher penalties inappropriate, and enforcement budgets might be limited.

Viscusi and Zeckhauser (1979) consider the case of an enforcement agency with a fixed budget and limits on the monetary penalty they can impose. They show that if some firms might decide not to comply, the optimal standard is below that which would be optimal in the absence of noncompliance. The intuition for this result is that imposing a stricter standard causes some firms to stop complying. Unlike the usual case, the agency cannot increase monitoring or penalties in response. All it can do is lower the standard. However, as Jones (1989) notes, even with a fixed budget and penalty, the *expected* penalty for noncompliance may increase with the severity of the offense. Even with a fixed budget, enforcement agencies can target their monitoring efforts, and very serious violations are likely to be detected more easily. Thus, Jones (1989) argues that the standard does not necessarily need to be lowered.

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[28] See U.S. Environmental Protection Agency, "Policy on Civil Penalties," February 16, 1984 reprinted in 17 Environmental Law Review 35083 (October 1987).

[29] The fine provisions of the Sentencing Guidelines that became effective in 1991 do not apply to environmental violations. One reason cited by the Commission in postponing writing Guidelines for environmental offenses was the fact that it is difficult to quantify harm.

Bose (1995) and Lear and Maxwell (1998) take a somewhat different approach. They consider the problem of a social planner (Congress) who sets a fixed penalty policy that the regulator must follow. The regulator is assumed to minimize the cost of monitoring net of penalties, an objective function that looks a lot like budget maximization (see Section 2.3.2) The crucial assumption in both models is that the regulator either keeps the fine or is somehow rewarded for higher fines. As Lear and Maxwell (1998) show, if the social planner increases the penalty, this provides an incentive for the regulator to increase monitoring to collect more fine revenue. Thus, the equilibrium to this game may yield too high a level of firm compliance expenditures. Lear and Maxwell conclude that the optimal penalty will be either the maximum the violator can afford to pay or zero. It is possible, therefore, that in some cases it is better to not regulate at all than to risk this socially costly spending. However, this policy prescription crucially depends on the existence of an enforcement agency with such an objective function.

3.7 Optimal Enforcement Structure under Alternative Regulatory Structures

Until now, I have considered the problem of optimal penalties in the context of a regulatory standard. However, economists have long argued that command and control regulation is dominated by more flexible "market-based" regulatory structures such as emission fees or marketable permits. Thus, it is not surprising that the literature on monitoring and enforcement has also compared optimal policies under varying regulatory approaches. Since market-based incentives lower the cost of compliance, it might be natural to assume that lower compliance costs will result in higher compliance rates and hence less of a need for costly government monitoring expenditures. However, as Malik (1992) shows, this is not necessarily the case and will depend on the characteristics of firms' abatement cost functions. This section reviews the literature on monitoring and enforcement of these alternative regulatory structures.

3.7.1 Emission Fees

Harford (1978), Linder and McBride (1984), and Malik (1992) compare monitoring and enforcement of emission fees to regulatory standards. Harford (1978) analyzes a pollution tax that is imposed on each unit of reported wastes. If the firm underreports wastes and it is detected, a penalty is imposed on the underreported amount in addition to the tax that should have been paid in the first instance. Somewhat surprisingly, Harford finds that the actual level of wastes generated by the firm does ***not*** depend on either the size of the penalty or the probability of detection. The reason for this result is that the profit maximizing firm will equate the marginal cost of abatement to the emission fee.[30]

[30] As Harford (1978: 37) notes, one might be tempted to infer that it therefore does not matter if the probability of detection is very low and/or the penalty for nonreporting is

Thus, penalties for underreporting affect only the decision to report – not the actual level of emissions.

A deposit-refund system might help alleviate some of the problems associated with costly monitoring. Swierzbinski (1994) proposes a deposit-refund system whereby firms are first asked to self-report their emissions and pay the emission fee. With some known positive probability, the firm's report is monitored. If the firm is found to be telling the truth, they receive a reward, while if it is found to be underreporting emissions, the firm is fined an amount in addition to the emission fee. This proposal reduces the cost to the enforcement agency by shifting some of the monitoring costs onto firms. If monitoring can be more cheaply performed by firms (which is certainly plausible), this is also a socially desirable shift.[31]

In some cases, the cost of monitoring emissions can become so prohibitive that taxing output is considerably less expensive to the enforcement authority than taxing emissions (see Cropper and Oates, 1992: 680). Schmutzler and Goulder (1997) consider the enforcement implications of placing the fee on firm output instead of emissions.[32] They characterize the conditions under which monitoring costs are sufficiently high to make output taxes (or a combination of emission fees and output taxes) more desirable.

Although enforcement issues seldom drive the choice of regulatory instruments, that might not be true in developing countries where monitoring and enforcement resources are scarce. As Eskeland and Jimenez (1992) point out, if the cost of monitoring and enforcing environmental damages or emissions are too high, it might be better to apply indirect instruments instead of either emission fees or direct controls. Indirect pollution taxes are levied on fuels such as coal or gasoline or on products that are inherently polluting such as automobiles. Subsidies might be given to substitutes such as public transportation. Other proposals include selective use of command and control over subsectors that can be better monitored (e.g., taxis and minibuses instead of private automobiles). To date, virtually no literature exists examining the efficacy of these alternatives, ways in which they might be utilized more effectively, or how they might cause other distortions in the economy. Given the fact that the environmental concerns in developing countries are growing, this seems to be a fruitful area for further research.

Finally, Heyes (1994) offers a less than optimistic view of emission fees in the case where some firms are able to evade or underreport the tax. Although his paper is primarily concerned with the problem of imposing an emission fee when the government does not have jurisdiction over a neighboring country or state, the model generalizes to the case where some firms within the enforcement agency's jurisdiction are able to evade

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very high. However, these factors may affect long-run profits and thus entry and exit decisions.

[31] This is similar in spirit to inducing self-reporting by the firm (discussed in Section 3.4.1), and to shifting the burden of monitoring employees onto the firm (discussed in Section 3.10).

[32] Eskeland and Jimenez (1992) note that this approach might be of special benefit in developing countries with limited enforcement resources.

the tax. Inability to collect from all firms raises the possibility that emissions will actually go up – especially if the firms that can evade are the dirtiest. Although this might be more likely in the case of cross national boundaries, it is at least theoretically possible.

3.7.2 Transferable Discharge Permits

Malik (1990) examines monitoring and enforcement of transferable discharge permits (TDP). Under a TDP system, firms are allocated an initial right to pollute that may be transferred to other firms. Although the enforcement agency might know how much pollution each firm is allowed to emit, it can only observe actual emission levels with costly monitoring. Thus, there is an incentive for firms to pollute more than their permitted amount. Given that scenario, the marginal valuation of a permit now depends not only on the marginal cost of pollution reduction, but it also depends on the probability of being audited and the penalty for emitting more than the permitted amount. This distorts the equilibrium price of permits.

Although intuition would tell us that the equilibrium price of permits would be lower than in the case of costless enforcement (since firms that do not comply need fewer permits), Malik finds that it is also possible that the price will be higher. Indeed, given the fact that firms trade off permits and noncompliance, it is possible that increased government monitoring will also have a perverse effect. Firms that believe they are more likely to be caught if noncompliant are now likely to increase their demand for permits, thus raising the equilibrium price of permits. This higher price of permits might have the offsetting effect of reducing compliance as other firms find noncompliance to be more cost effective. Although this paper provides evidence that TDP markets will not be efficient in the face of costly enforcement, it does not propose an alternative penalty or monitoring scheme to overcome this problem.

A recent paper by Mrozek (1997) finds a different anomaly when implementing a TDP system. As Mrozek notes, differences in the probability of detection across firms are likely to cause the expected penalty from violating a permit to vary across firms. Thus, the firm that is most able to avoid detection (and hence has the lowest expected penalty) will set the permit price. This lower permit price might increase aggregate emissions. Unlike Malik (1990), however, these emissions will be legal. Mrozek (1997) does offer a solution to this problem, but it involves differential penalties based on the probability of detection, a policy that might be difficult to implement. Mrozek (1995) explores targeted enforcement under TDP policies in more detail.

3.8 Uncertain Legal Standards and Errors in Enforcement

Thus far, the models presented here assumed that both the regulator and the firm know the required regulatory standards. It has also been assumed that if the government monitors and detects a violation, it can do so without error and can always impose a

sanction without being challenged by an appeal to a court of law by the firm. Put differently, although I have allowed for uncertainty about whether or not a firm that pollutes will be detected, thus far, I have assumed that once "detected," there is no uncertainty about liability. In reality, however, many uncertainties about liability arise. For example, the regulatory authority might agree to a permit that allows 1 part per million of a certain pollutant based on an expectation by both the firm and the regulator that the proposed piece of equipment to be installed will bring the firm into compliance with that standard. Yet, there is no guarantee that this equipment will achieve the desired permit level. Thus, even if the firm installs the equipment it thinks will solve the problem, it might ultimately be liable for exceeding the regulatory standard. As a second example, consider a regulation that calls for "state-of-the-art" oil spill cleanup training of personnel by oil transporters. From the firm's perspective, it is uncertain as to whether or not their employee training will satisfy the regulator in the event of an accident.

Calfee and Craswell (1984) analyze the case where legal standards are uncertain. Without specifying the exact form of the probability distribution of the standard, it is difficult to make strong predictions. However, one key insight follows from their model: even a firm that is behaving in a socially optimal fashion will face some chance of being penalized for an environmental violation. This firm can reduce the expected penalty by over complying with the regulatory standard. One possible solution to this problem is that the government could reduce the penalty below the otherwise optimal penalty. However, lowering the penalty reduces the deterrent value of the penalty and might provide an incentive for other firms to violate the standard. Another possibility is to reduce the uncertainty. For example, instead of specifying a 1 part per million standard, a permit might be stated in terms of average parts per million over a week long period.

A similar problem arises when the enforcement agency falsely accuses a firm of violating an environmental law. Errors in enforcement have been studied in the law and economics literature (see Polinsky and Shavell, 1998 for a summary). For example, lower penalties (and thus higher enforcement expenditures for a given level of deterrence) are generally called for if individuals are risk averse. Bose (1995) considers the case of an enforcement agency with a fixed penalty structure and concludes that regulatory error will result in overdeterrence. Firms will likely go beyond the standard in order to reduce the likelihood of being falsely accused. To compensate for this problem, the regulator must fix the penalty below the "optimal penalty."

3.9 Evading Liability

Throughout most of this Article, we have assumed that there is a predetermined probability of detection based on government enforcement efforts. Furthermore, if the government detects a violation, it will automatically punish the polluter.[33] In reality, however, a firm that violates the law might expend resources attempting to evade liability. For example, records might be falsified and monitoring equipment might be

[33] An exception is in Section 3.2, where the optimal penalty formula is shown to depend on the probability of actually imposing the sanction, not just detecting the violation.

tampered with. Firms that are accused of a violation might try to evade punishment by challenging the government enforcement agency in court or bribing officials not to bring charges. These evasive activities complicate the basic optimal penalty result and challenge the efficacy of raising the probability of detection or increasing the penalty. Garvie and Keeler (1994) discuss this problem in the context of a positive model of government enforcement behavior (see Section 2.3.3).

Lee (1984) considers the problem of a government enforcement agency that desires to lower the actual level of emissions by increasing an emission fee. Traditional optimal penalty theory would conclude that raising the penalty provides an incentive for firms to reduce emissions. However, instead of reducing emissions, it might be more profitable for the firm to expend resources evading taxation. Thus, by raising emission fees in the hope of producing a positive environmental impact, the enforcement agency might actually harm the environment. The probability of detection and size of the fine are no longer perfect substitutes once evasive activity is possible. Instead, to increase compliance, the policy prescription is to lower the emission fee and increase government monitoring efforts.[34]

Raising penalties or increasing the stringency of a regulation has two effects (Kambhu, 1989; Kadambe and Segerson, 1998). The direct effect is to improve environmental quality as the expected penalty from noncompliance increases. The indirect effect, however, is that there will be an incentive for the regulator and regulated party to affect the probability of detection. Thus, the firm that faces a higher penalty for noncompliance might challenge the fine in court or take other measures designed to reduce the probability that the fine will actually be imposed. Unless these indirect effects are small or zero, one cannot unambiguously state that stricter enforcement results in improvements in the environment. Kambhu (1990) argues that the existence of evasive activities tips the balance in favor of command and control regimes over emission fees.

The problem of evasive activities is somewhat different in the context of illegal dumping activities. Nowell and Shogren (1994) consider the problem of illegal dumping when firms can challenge their liability in court. They are able to mitigate Kambhu's concern over incentive-based regulations, by prescribing a reduction in the cost of legal disposal (i.e., mandate a subsidy instead of a tax). Reducing the cost of legal disposal lowers the marginal benefit of evasion, while increasing the penalty for illegal disposal increases the marginal benefit of evasion. Depending on the type of waste, a deposit-refund scheme might be used to finance the subsidy program. As Nowell and Shogren (1994) point out, however, subsidizing legal disposal is not necessarily the correct solution to the problem of evasive activities. Subsidizing legal disposal lowers the cost of the pollution generating activity itself, thus distorting relative prices in the output market and increasing the quantity of hazardous wastes that need to be disposed of in the first place. Nowell and Shogren (1994) thus conclude that subsidies might be preferable only in industries where there are ample opportunities to evade enforcement (i.e., where it is

[34] Polinsky and Shavell (1992: 143, note 14) have a similar result, where they show that if the cost of evasive activity increases with the size of the penalty, the optimal fine is less than it would be in the absence of these costs.

difficult to prove who illegally disposed of the waste) *and* where there is restricted entry, regulated prices, or inelastic demand.

A similar result is shown in Oh (1995) and Huang (1996). When evasive activities are possible, raising the emission fee might actually *raise* emissions. On the other hand, if the government raises the probability of detection, the value of a given level of avoidance activity is reduced. Thus, Oh (1995) concludes that in the context of emission fees, raising fines will not be effective unless the probability of detection is increased. He contrasts his results to the Harford (1978) finding that the actual level of wastes generated by firms is invariant to either the probability of detection or penalty for underreporting emissions. In the presence of avoidance behavior, raising the probability of detection will have the effect of reducing the marginal valuation of evasion; hence lowering the firm's optimal emission level.

3.10 Monitoring and Enforcement within the Firm

Most of the literature on environmental enforcement has considered the firm as a monolith, with decisions made by management being implemented as directed. Thus, the government enforcement agency can simply impose an optimal penalty on the company that is generating the emissions and not worry about the individuals involved.[35] In reality, however, corporate managers have their own enforcement problem when trying to convince employees to act on the company's behalf. For example, suppose corporate policy includes a strong policy in favor of compliance with hazardous waste regulations. A local manager whose bonus depends on his unit's profitability might decide to dispose of some hazardous wastes illegally in order to boost his bonus. Thus, employee shirking is always a possible source of emissions that are not only against the law but may also be against firm policy. Recent literature has focused on this principal-agency relationship within the firm and its effect on environmental compliance. This literature has addressed three issues: (1) whether the employee or the firm should be punished for an environmental violation, (2) how the firm should structure its incentive system to ensure individual compliance with company policy, and (3) how optimal penalty theory can be used to encourage the corporation to monitor its own employees.

Segerson and Tietenberg (1992) and Polinsky and Shavell (1993) address the first question in the context of a principal-agent model. They consider the case of an employee who commits a law violation on behalf of a corporation. From the persepctive of the government enforcement agency and social welfare, corporate and individual penalties are found to be perfect substitutes if the employee can bear the full cost of the optimal penalty. In that case, it does not matter if the individual or the company is fined, as the company can always pass the cost back onto the individual through its wage contract. Employee and employer sanctions may also be substitutes if the employer can observe the level of effort of the employee and use that knowledge to set wages. Once

[35] An exception (noted in Section 3.3) is the case that the firm is judgment proof, in which case imprisonment for culpable individuals might be warranted.

again, the firm can induce the individual to take the optimal level of care in preventing emissions beyond the legally allowable amount. If employees and employers are perfect substitutes, the government can arbitrarily decide how to allocate the optimal penalty between the two parties.

In many cases, however, the employer and employee will not be able to shift penalties between themselves. In that case, employers and employees are no longer perfect substitutes. If (as is most likely) the employee cannot bear the full burden of the optimal penalty, the government might still be able to impose the optimal penalty on the company. Since the penalty cannot be shifted to the employee, however, an alternative mechanism must be found. Either the firm spends more on *ex ante* monitoring of the employee's behavior, or the government will be needed to impose incarceration.

Gabel and Sinclair-Desgagne (1993) address the second question. They adapt the multi-task principal-agent framework (see citations therein) to the question of competing goals within the firm to increase profits and comply with environmental laws. The employee who is charged with both tasks has only a finite amount of resources (including her own time and cognitive capabilities to deal with so many issues at one time). The model focuses on stochastic externalities such as environmental accidents. Employees have private information about their level of effort and the employer can only observe some measure of performance without directly observing effort. Top management is assumed to desire compliance. Because of these competing interests, it is difficult to specify an optimal enforcement policy other than to distinguish its characteristics. Thus, we find that incentive pay should be linked more closely to environmental risk reduction as the employer is more interested in environmental risk reduction (relative to profits) and as the monitoring technology becomes more accurate. Put differently, when the level of risk reduction reaches the firm's optimal level, it makes little sense to provide incentive pay for further risk reductions. In addition, when monitoring is very costly, incentive pay for risk reductions become less attractive.

Finally, Gabel and Sinclair-Desgagne (1993) discuss an alternative arrangement whereby the two functions are separated, so that employees responsible for environmental protection are on a fixed salary, while those with responsibility for profitability are paid under an incentive contract. Of course, it is not always possible to make such fine distinctions in job descriptions. Another alternative is for the firm to explicitly adopt a policy of punishing employees who are liable for environmental accidents. Thus, the threat of firing and/or refusal to indemnify the employees from the cost of a lawsuit, serves as an incentive mechanism to curtail illegal activities.

Arlen (1994) and Arlen and Kraakman (1997) address the third question - how to structure penalties so that the company has an incentive to monitor its own employees. Arlen (1994) notes that the conventional optimal penalty– harm divided by the probability of detection – might create a perverse incentive for firms that would otherwise monitor their own employee's conduct. In Arlen's model, it is assumed that the company will honestly report to the government any (or some) violations it uncovers. This assumption is an important one, but one that is plausible for many types of

environmental violations. For example, it is a violation of criminal laws to fail to report an oil spill or accidental discharge of a hazardous waste, and the penalty for failure to report may include jail time for individual managers. The implication of this model is that the optimal penalty should be lower than harm divided by the probability of detection. Alternatively, as Arlen and Kraakman (1997) propose, one could start with the conventional optimal penalty and offer a reduction if the firm effectively monitors, investigates and reports any violations to the government. Thus, the Arlen and Kraakman (1997) approach is very similar in spirit to the self-reporting models discussed in Section 3.4.1.

4. Empirical Analysis of Environmental Enforcement

Until recently, there have been surprisingly few empirical studies of environmental enforcement. Diver (1980) suggests that the reason is that enforcement is so difficult to study. Agencies are reluctant to reveal their enforcement policies and many decisions are made at relatively low levels within the agency and without formal proceedings. Data on compliance and enforcement are often impossible to obtain. Until recently, the U.S. EPA did not have comprehensive compliance data available themselves, let alone make it available to researchers. Thus, the few studies that have been published focused either on oil spills (where the Coast Guard maintains a comprehensive data set), or on specific industries such as the pulp and paper industry, where EPA funded and/or assisted researchers in their data collection efforts. Outside the U.S., data appear to be even scarcer. Data availability is rapidly changing as EPA has integrated all of its enforcement and monitoring data by facility and is beginning to make facility-level data freely available to the public on their website.

In Section 4.1, I review studies of monitoring and enforcement by government regulatory agencies. These constitute the bulk of empirical studies. Partly for convenience, but also generally following the sequence of studies over time, I have grouped these empirical studies into: oil spills (Section 4.1.1), manufacturing industries (Section 4.1.2), illegal waste disposal (Section 4.1.3), and studies outside the U.S. and Canada (Section 4.1.4). In Section 4.2, I examine criminal enforcement of environmental regulation. Moving from government enforcement to the private sector, I review the empirical literature on private enforcement in Section 4.3 and the role of information and market penalties in Section 4.4.

4.1 Government Monitoring and Enforcement of Environmental Regulation

Empirical studies of enforcement generally ask two questions: (1) How does the regulatory agency enforce its regulations? and (2) Does more enforcement lead to an increase in compliance or improvement in the environment? Although the first question is primarily descriptive, it provides insight into whether the enforcement authority targets its efforts and whether it acts as if it is interested in an efficient enforcement scheme. The second question often leads to policy implications such as whether monitoring or penalties should be increased or decreased.

Although empirical studies have demonstrated the effectiveness of government activities such as inspections and monitoring, one must take care in drawing strong policy implications from these studies. Each empirical study is necessarily limited by the scope of the data and choices made by regulatory authorities. Further, few studies have attempted to characterize the social costs and benefits of government monitoring or enforcement activities. Thus, a finding that increased monitoring leads to increased compliance, for example, does not tell us if the marginal cost of increased monitoring is outweighed by the benefits of increased compliance. It also does not tell us if there are other less costly methods of monitoring and enforcement or more productive methods that could be employed for the same level of government expenditures. A few studies have attempted to answer these latter questions and are highlighted below.

4.1.1 Accidental Oil Spills by Tankers and Vessels in the U.S. and Canada

The earliest empirical analysis of environmental monitoring and enforcement activities appears to be Epple and Visscher (1984), who examine the U.S. Coast Guard's enforcement of oil spill regulations. Their theoretical model assumes that the enforcement agency's policies are fixed and firms react to that policy. Empirically, they estimate the volume of oil spilled in U.S. waters as a function of Coast Guard monitoring activities – which vary by port and over time. Data limitations preclude estimation of the probability of spilling oil. However, they find that increased monitoring activity results in lower oil spill volume. In Cohen (1986, 1987), I extend the Epple-Visscher analysis by incorporating the enforcement agency's decision calculus into the model and empirically comparing the effectiveness of different types of Coast Guard activities to deter oil spills. To examine the effectiveness of Coast Guard monitoring in reducing oils spills, I estimated the following regression equation:

OIL SPILLED = F (Price of Oil, Vessel Size, Inspections, Monitoring Transfer Operations, Patrolling Ports)

The last three variables are the three different types of government monitoring activities employed by the Coast Guard. Although the results are consistent with Epple-Visscher, Cohen (1987) also finds that the effectiveness of different monitoring activities varies considerably. Monitoring oil transfer operations and random port patrols designed to detect spills are found to be effective. However, routine inspections that are designed to determine if vessels are in compliance with oil spill prevention regulations has no significant effect on spill size.[36]

[36] Anderson and Talley (1995) conduct a similar analysis for accidents occurring during an oil *transport* operation and obtain virtually identical results. Like Cohen (1987), they find *ex ante* monitoring of vessels to be ineffective at the margin, while pollution detection activities are effective in reducing barge accident spill sizes (but not tanker accident spill sizes).

Changes in Coast Guard enforcement and data collection policies have provided important new tests of the theory. The most important data collection improvement is the ability to estimate the frequency of spills relative to the number of oil spill transfer operations. Thus, Viladrich-Grau and Groves (1997) estimate the probability of (detected) oil spills as well as oil spill volume. They find that the Coast Guard enforcement activities have an even larger effect on oil spill frequency than they have on spill size. Average penalties in the prior period have no effect on oil spills. However, this may be attributable to the fact that Coast Guard penalties are only a small fraction of the cost of mandatory cleanup. Perhaps the most interesting part of their study, however, examines the Coast Guard's newly implemented monitoring policy of classifying ships into 'low risk' (infrequently monitored) and 'high risk' (always monitored). This is reminiscent of the two tiered enforcement model discussed in Section 3.4.2 (e.g., Harrington, 1988). Viladrich-Grau and Groves (1997) find that this two-tiered enforcement policy is effective in reducing the cost of enforcement without having a negative effect on the environment.

In Cohen (1987), I also model and estimate the Coast Guard's *ex post* enforcement activities: required cleanup and monetary penalties. A penalty function is estimated based on the actual fines that are meted out for detected oil spills:

PENALTY = F(Vessel Size, Spill Size, Monitoring, Percent Cleaned Up, Location of Spill, Type of Oil, Cause of Spill, Year, Season)

Estimation of the penalty function serves two purposes. First, it addresses the question of whether or not the Coast Guard uses a negligence or strict liability standard in its penalty calculus. Several "causes" are included as dummy variables, including improper maintenance, personnel error, equipment failure, intentional discharge, and natural causes. All of these variables are found to have significant power in the penalty regression equation. For example the monetary penalty increases with personnel error, intentional discharges, and improper maintenance, but decreases with natural causes. Thus, the Coast Guard uses a negligence-based standard in its discretionary penalty assessment.

The second reason for estimating the penalty function is to investigate the optimality of the Coast Guard cleanup and penalty policy. Combined with data on the probability of detection, the cost of cleaning up a spill, and the environmental damage caused by a spill, I estimate the optimal cleanup costs and penalty as a function of the size of the spill. The current Coast Guard policy appears to require excess cleanup for very small spills (which are costly on a per gallon basis and cause little environmental harm). In addition, statutory maximum penalties are too low for large spills. Despite these inadequacies, I also conclude in Cohen (1986), that the current enforcement policy passes a cost-benefit test – both in the aggregate and at the margin. That is, the estimated cost to society (Coast Guard monitoring expenses, industry prevention expenses and opportunity cost of time spent by industry responding to Coast Guard inspections) is outweighed by the social benefits (reduced natural resource damage, cleanup costs and the value of oil not spilled).

4.1.2 Manufacturing Industry Emissions in the U.S. and Canada

Whereas the first empirical studies of environmental monitoring and enforcement focus on a stochastic externality, Magat and Viscusi (1990) focus on more traditional forms of regulation.[37] They study the impact of government inspections on water pollution levels and compliance with standards in the pulp and paper industry in the U.S. Their regression model is similar to that in Cohen (1987) with a few minor exceptions:

POLLUTION = F (Lagged Pollution, Inspections, Capacity, Location, Type of Output, Season)

Magat and Viscusi model pollution as being a function of firm-specific and location specific variables. They also include a measure of government inspections. Unlike Cohen (1987), Magat and Viscusi (1990) know the name of the company being inspected. Thus, they use actual inspections on the plant instead of aggregate inspections in the region as an explanatory variable. However, since there might be a lag between the time of an inspection and the time it takes to install new pollution control equipment, they use lagged inspection terms instead of contemporaneous inspections. They also include a variable for the prior period's pollution level to account for the firm's abatement technology and history of compliance. Unlike Cohen (1987), Magat and Viscusi (1990) do not include variables to measure culpability or negligence.

Like their predecessors, Magat and Viscui (1990) document the fact that higher levels of enforcement activity result in lower levels of pollution.[38] They are able to document a "specific" deterrent effect with a one quarter lag.[39] However, Magat and Viscusi (1990) are less sanguine about whether current enforcement policy passes a cost-benefit test.

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[37] An earlier study by Fuller (1987) attempts to estimate the effect of enforcement on the electric utility industry. However, since Fuller does not have direct measures, he measures enforcement as the ratio of actual to regulated pollutants within a state. Although this might be a proxy for enforcement, it might also be a proxy for other factors such as age and type of plant, quality of coal, etc. Nevertheless, his proxy for enforcement is shown to be a significant explanatory variable in terms of actual emissions.

[38] Magat and Viscusi (1990) estimate current pollution levels as a function of last period's inspection rate. One reason for ignoring current period inspections is that they are endogenous. Indeed, one would expect and hope that enforcement authorities determine their enforcement priorities based on prior experience with each company, current market conditions that might affect compliance, etc.

[39] A "specific" deterrent effect is one that applies to a specific person or firm that has been reprimanded for a past activity and subsequently refrains from that activity. Because of the difference in data availability, Cohen (1987) does not test for a specific deterrent effect, but instead finds a "general" deterrent effect – whereby the monitoring activities of the Coast Guard have an effect on the aggregate volume levels of oil spills.

Although they show that the estimated value of benefits exceed the cost of inspections, it is not clear that they exceed the cost of regulatory compliance.

Liu (1995) replicates the Magat and Viscusi (1990) study with updated data and more complete information on monitoring activity. Unlike Magat and Viscusi, Liu finds that increased monitoring does *not* reduce the number of known violations. However, Liu explains this result by noting that during the more recent time period, EPA undertook two types of inspections– discretionary and routine. Routine inspections designed to detect reporting violations are likely to increase the number of known violations. On the other hand, discretionary inspections are targeted towards firms known to be out of compliance and those with previous violations. Discretionary inspections are expected to deter both false reporting and noncompliance. The combination of these two inspection mechanisms thus has an indeterminate effect on the number of observed violations. Liu's empirical analysis confirms this hypothesis about the differential impact of inspections, thus helping to explain the observation of no "deterrent" effect at the aggregate level. This is an important lesson for future researchers to keep in mind when conducting an empirical analysis of enforcement and deterrence.

Monitoring of pollution at pulp and paper mills has also been studied in Canada (Laplante and Rilstone, 1996). Their empirical model of pollution is nearly identical to the model estimated in Magat and Viscusi (1990). However, instead of using past inspections directly in their empirical model, Laplante and Rilstone (1996) note that government inspections are not exogenous.[40] For example, smaller plants are less likely to be inspected, firms that are inspected once are less likely to be inspected again soon, and those that make changes to their productive capacity are more likely to be inspected. Thus, Laplante and Rilstone (1996) estimate a probit equation where the dependent variable is the probability of being inspected. The predicted value of this equation for each firm thus becomes the "expected inspection" rate for that firm. Consistent with previous studies using actual inspection rates, Laplante and Rilstone find that the threat of inspections (or "expected inspection rate") also induces compliance. They also find that inspections are effective at inducing more frequent self-reporting.

Nadeau (1997) conducted another study of EPA enforcement effectiveness, but extended the analysis to include the length of time of violation. Thus, Nadeau explicitly models the fact that firms are usually out of compliance for more than one day at a time. He also studies the U.S. pulp and paper industry, and finds that a 10% increase in monitoring activity leads to a 0.6 to 4.2% reduction in violation time. A 10% increase in enforcement (eg. fines) is more effective, resulting in a 4.0-4.7% reduction in violation time.

Having established that monitoring and enforcement deters regulatory violations, Helland (1998) turns to a different question – whether or not government monitoring and enforcement policies are consistent with the 'targeting' approach described by Harrington (1988) and others. In other words, do firms that have been found to be in violation of the law have a significantly higher probability of being inspected in subsequent periods? The

[40] This approach was first used by Deily and Gray (1991), discussed below.

answer, according to Helland (1998), is a qualified yes. Firms found to be out of compliance are more likely to be inspected in subsequent periods. These firms are also more likely to self-report a violation, consistent with the view that they are trying to regain credibility with the government so that they are taken off the 'target' list. However, Helland also finds that other "political" factors help explain inspections, including the per-capita level of pollution, the affluence of the community, and the probability that a plant will close if it is forced to comply.

Moving from the pulp and paper industry to the steel industry, Deily and Gray (1991) examine the government's enforcement policy during the years 1977-1986. They employ a two-stage model where the first stage is the level of government enforcement and the second stage uses this "expected enforcement" variable as a predictor in the plant closing decision. The government is assumed to be a net political support maximizer (see Section 2.3.1). Thus, they estimate a regression model of inspections that depends on many political pressure variables:

INSPECTIONS = F (Prior pollution, Region, Likelihood of Plant Closure, Percent of City Residents working at Plant, Local Unemployment, Cost of Compliance, Year, State).

Consistent with theory, they find that plants with a higher probability of closing have lower inspection rates. A lower inspection rate is also prevalent when a plant's workers are a large fraction of the local labor market. However, they are unable to explain the contrary finding that plants in high unemployment areas are found to have a higher risk of inspections.

A subsequent paper by Gray and Deily (1996) examines steel industry behavior and government inspections in a simultaneous model. They not only ask the question of whether increased monitoring and enforcement leads to increased compliance, but they also ask if increased compliance by firms yields reduced levels of government activity. To operationalize political support maximization, Gray and Deily hypothesize that the public will demand that past violators be inspected more often. Note that this is also consistent with other theories of regulation including the social welfare maximizing models of targeted enforcement discussed in Section 3.4.2. However, other assumptions are more peculiar to the political support model enforcement behavior. For example, they suggest that the public wants larger emitters (who presumably are more visible) to be more frequently inspected – even if they were in compliance in the past. They also expect differences by geographic location as public demand for environmental quality varies across regions of the nation. On the other side of the political spectrum, they expect fewer inspections and enforcement actions for plants that have a high cost of compliance – since those plants are more likely to spend money fighting the enforcement action. They also expect less government activity where the labor force is a larger percentage of the local population, since workers will be concerned about losing their jobs if a plant must shut down.

The empirical results are suggestive but mixed. Consistent with most of the other published empirical papers, Gray and Deily (1996) find that increased monitoring and enforcement leads to higher compliance in subsequent periods. They also find that firms who were found to be in compliance in prior periods were less likely to be inspected in subsequent periods. Plants that had higher emissions had higher inspection rates – even controlling for compliance in prior periods. At the firm level, larger companies had lower enforcement rates, which they note is consistent with "regulatory sensitivity to firms' political power". One interesting finding is that there appears to be a pattern of compliance or noncompliance across plants owned by the same firm, and multi-plant firms are more likely to be in compliance than single-plant firms. This suggests that corporate policies on environmental compliance might be important, and that enforcement authorities might target plants whose owners have been known to be out of compliance elsewhere. Note that financial status of the firm did not affect compliance, which rules out a purely financial explanation for the last result.

A similar study of enforcement in the pulp and paper industry in Canada confirms some – but not all - of the findings by Deily and Gray (1991) and Gray and Deily (1996). Dion, Lanoie and Laplante (1998) employ a virtually identical model of government monitoring and find similar results that past compliance history explains enforcement activity. They also have a measure of environmental damages and find that monitoring is concentrated where damages are largest. Unlike Deily and Gray (1991), they find that a plant with a larger share of local employment is *more likely* to be inspected. They posit that the difference between the two studies lies in their measurement of government enforcement. Deily and Gray (1991) measure government activity as the number of actions taken – including inspections, remedial orders and penalties. In contrast, Dion, Lanoie and Laplante (1998) measure only inspections. Thus, it is possible that enforcement agencies are more likely to inspect more visible plants, but if found to be in noncompliance, they are less likely to impose remedial actions or punitive sanctions. Contrary to Deily and Gray, they also find that areas with higher unemployment are likely to have *lower* enforcement levels. This is certainly an area that could benefit from further empirical research.

Finally, a recent study by Lear (1998) examines newly released data by the U.S. EPA on administrative penalties imposed on polluting facilities. Previously, data on fines had been available primarily for oil spills (from the Coast Guard) and criminal violations (from the Sentencing Commission). As discussed in Section 3.5, EPA's penalty policy calls for both a "harm" and "gain" component. It also allows for some consideration of ability to pay. Lear finds that EPA penalties increase with firm size (for firms over 50 employees), and with the expected gain from the violation (for firms under 50 employees). However, she also finds a "deep pockets" effect with higher fines for larger firms. This finding must be qualified, however, since the EPA data does not provide a measure of the severity of the harm. To the extent that larger firms have more serious violations, size of firm is simply serving as a proxy for harm. Lear (1998) also estimates regional monitoring and enforcement expenditures and compares these measures to the magnitude of fines imposed. Under optimal penalty theory, we would expect monitoring expenditures (which affect the probability of detection) to be negatively correlated with

the size of penalties. Indeed, for firms over 50 employees, Lear finds this relationship holds.

Studies by Wood (1988) and Wood and Waterman (1991) remind us that enforcement policy cannot be viewed in a vacuum. Although "bureaucratic behavior theory" might be used to partly explain the motivation of an enforcement agency, that theory presumes the existence of a higher level of government authority (e.g., legislature or chief executive) that desires a certain action from the bureaucracy. Although the EPA determines who will be monitored, what violations will be brought forward to an administrative proceeding, and what ultimate penalty will be imposed, it is constrained both formally and informally by political institutions such as the courts and Congress. This principal-agency relationship suggests that under some circumstances, the higher level authority should be able to control the actions of the EPA. To test this proposition, Wood (1988) collected data on the number of EPA monitoring and enforcement activities on a monthly basis from 1977-1985. He finds that monitoring activities *increased* significantly following the Reagan election. After Reagan took office and the Republicans won over the House of Representatives, EPA's 1982 budget was cut. To compensate, EPA *increased* their enforcement activities (i.e. a higher percentage of inspections resulted in notice of violations, fines, etc.). Coupled with other such changes, Wood's study illustrates how the EPA responded to reduce the external control by Congress and the President. As Wood (1988) notes, "the EPA bureaucracy bucked the administration and used its slack resources to substantially increase surveillance of pollution sources" (p. 224), providing further evidence that the budget maximizing bureaucrat is a useful model in thinking about enforcement policy.

Finally, Harrison (1995) is one of the few cross national studies of enforcement. She compares the different approaches to enforcement policy existing in the U.S. and Canada, once again focusing on the pulp and paper industry. Harrison characterizes the strategy in Canada to be "cooperative" relative to the more stringent approach adopted in the U.S. Canadian enforcement officials are more willing to negotiate and revise compliance programs instead of forcing compliance or imposing a sanction. Empirically, Harrison finds that Canadian pulp and paper mills are not in compliance as much as in the U.S. Moreover, she shows that U.S. enforcement is more even handed across plants – suggesting that Canadian officials are more likely to give in to plants that face higher control costs.

4.1.3 Illegal Disposal of Wastes in the U.S. and Canada

Illegal disposal of wastes presents a somewhat more complicated problem than normally encountered in the study of enforcement policies. Unlike most areas of environmental regulation, this inherently involves a new policy parameter – the cost of *legal* disposal. Not only does the government decide how to "price" noncompliance (through a monetary penalty) and how much effort to expend on monitoring, but now the government also

needs to price "compliance" by setting the price of legal disposal.[41] As Sullivan (1987) shows, if the price of legal disposal is too high, the government actually encourages illegal disposal. Conversely, one way to encourage legal disposal is to subsidize it. Thus, the government has a third policy option available when determining optimal enforcement against illegal disposal – subsidizing legal disposal. See Section 3.9 for a related discussion and policy recommendation in the context of costly evasive activities.

Sullivan (1987) provides an initial estimate of the optimal subsidy and enforcement budget for hazardous waste disposal and determines the conditions under which a subsidy is preferable to increased enforcement and vice versa. Similar analyses are conducted by Fullerton and Kinneman (1995) in the context of household garbage, and Sigman (1998) for used oil disposal. All of these studies highlight the tradeoff between raising the cost of legal disposal and the amount of illegal disposal that is observed. For example, Sigman (1998) estimates that a ban on used oil disposal (requiring instead that used oil be recycled or reused) will result in 34% of the waste previously disposed legally being illegally dumped. Since illegal dumping is likely to be worse than the previous method of legal disposal, one cannot say a priori whether a ban on used oil disposal is socially beneficial. This is an excellent example of how enforcement concerns can make an otherwise socially desirable policy change counter productive.

Finally, returning to a model of bureaucratic behavior, Hamilton (1996) examines EPA data on administrative fines imposed on hazardous waste violators and finds that political pressures affect the magnitude of sanctions imposed. Fines are higher in regions where key Congressional Committee members reside and where there are higher levels of environmental group membership. Hamilton also finds that fines are significantly higher when EPA does not resort to the use of a "formal" rule and instead negotiates an informal settlement. He suggests that this is partly due to the fact that regulators are more likely to have strong environmental preferences and thus impose higher sanctions when they are not constrained by the regulatory process.

4.1.4 Government Enforcement Outside the U.S. and Canada

Most of the empirical work on environmental enforcement has focused on the U.S. and Canada. One exception is the U.K., where sociologists and political scientists have studied regulatory enforcement for quite some time. Fenn and Veljanovski (1988) employ an economic approach to study enforcement in the U.K. They model government enforcement authorities as having discretion over whether or not to prosecute offenders who have violated the law. In that case, bargaining, selective enforcement and negotiated agreements without penalties become important enforcement tools. However, only credible threats of punishment and credible promises of compliance will make an informal system like this work. If firms know that they are always able to negotiate a

[41] In many ways, this is analogous to setting the regulatory standard itself. By requiring a more costly pollution control standard, the government raises the marginal value of noncompliance and hence affects enforcement. See Section 3.6 for a discussion of setting the regulatory standard with a fixed enforcement budget.

compliance agreement without further penalty, they will take a 'wait and see' approach to compliance. Fenn and Veljanovski (1988) argue that in reality there is uncertainty about the enforcement agency's strategy. Although they might agree to a negotiated settlement involving no penalties, there is no guarantee they will do so. In a repeated game, they find that if the cost of compliance is less than the social harm, it is possible to find a cooperative solution involving negotiated compliance. Employing data from health and safety inspections at factories in the U.K., they find evidence in support of their model. For example, inspectors are more likely to negotiate when compliance costs are very high and there are significant employment concerns.

Several recent studies have moved beyond these highly developed capitalist countries to consider enforcement in other institutional contexts. Availability of data has been the most significant barrier to researchers interested in other countries. Lack of systematic government data often requires the researcher to engage in raw data collection exercises in addition to data analysis.

Dietrich Earnhart has collected a unique data set of environmental mishaps and associated penalties in the Czech Republic – both before and after its transition from a socialist to capitalist regime. This data set has been used to test some of the positive theoretical implications of the economics of enforcement literature as well as expand on that literature by specifying alternative government objective functions and legal constraints under the two regimes. In Earnhart (1997), he examines penalties for violations of water pollution laws under both regimes, and finds evidence that remediation rules shifted from a negligence-based standard under socialism to a strict-liability standard under capitalism. The latter is consistent with an optimal penalty framework (see Section 3.1). Other findings relate to the liability rules used in each regime and to political influence implicit in enforcement decisions. In Earnhart (1998), he examines the relationship between the sanctions imposed on firms and their employees based on the theoretical model of Segerson and Tietenberg (1992).

Recently, the World Bank has conducted a series of studies in developing countries. Since many of these studies involve innovative programs designed to overcome the paucity of government enforcement budgets, many of them are discussed below in Section 4.4. A recent study in India highlights the difficulty that developing countries have had in enforcing environmental regulations. Pargal, Mani and Huq (1997) conduct a two stage least squared regression of enforcement and compliance. They find that although increased emissions prompts government inspections, those inspections have no effect on subsequent emissions. Among possible reasons cited is the low probability of inspections, low penalties for noncompliance, and low pay for inspectors, which might encourage bribery.

4.2 Criminal Enforcement of Environmental Laws in the U.S.

Virtually every environmental law in the U.S. includes criminal provisions (Cohen, 1992). Some of these criminal provisions are designed to ensure truthful self-reporting

(see Section 3.4.1), while others apply to the polluting activity itself. Economic theory does not generally distinguish between criminal law and civil or administrative law. A penalty is a penalty regardless of who imposes it. All of the goals of punishment – except incapacitation (holding an offender in prison so they cannot commit a new offense) - can be realized with either a criminal or civil sanction. Yet, criminal laws have different legal procedures, standards of proof, and enforcement personnel. In general, it is thought that imposing a criminal sanction is more costly to the government than imposing a similar sanction through the administrative process.[42] Most economists have thus argued that criminal sanctions should be reserved for cases in which the optimal penalty is too high to be collected (Cohen, 1992: 1061-2). In that case, one might mandate a period of incarceration for the individual violator. An alternative view of criminal sanctions is that they help educate or shape preferences of the public who are potential violators (Dau-Schmidt, 1990). Given these competing theories, there is a need for future empirical research on the distinction between civil and criminal enforcement.

While the U.S. EPA has a civil penalty policy that systematically assesses penalties, there is no comparable policy for environmental crimes. Judges are free to assess any monetary sanction as long as it is not greater than the statutory maximum.[43] Cohen (1992) examines criminal sanctions imposed on companies that have violated U.S. environmental laws and compares the penalty structure implied by these sanctions to that which we would expect under an optimal penalty. One of the difficulties with this type of analysis is the lack of comprehensive data on harm. In the absence of such data, Cohen (1992) used monetary harm – any known restitution or payments for direct losses suffered by victims plus cleanup costs. Both criminal fines and total monetary sanctions are found to increase with this measure of harm. Sanctions are also higher for hazardous waste violations. However, Cohen (1992: 1090, Table 6) finds that sanctions are higher for larger firms and are higher when individuals are convicted along with their firms. These findings appear to be inconsistent with optimal penalty theory. There is no economic reason to increase fines for larger firms – only for larger harms. However, since large firms are less likely to have individuals convicted for the same offense, the larger penalties might simply reflect the inability to trade-off individual for corporate sanctions. That is, judges might be increasing the monetary penalty to companies when there is no individual to sanction. This is a plausible explanation, since in a restricted sample of small, privately held firms convicted of environmental crimes, monetary fines are found to be negatively related to the likelihood of an individual going to jail (Cohen, 1992: 1095, Table 8).

[42] However, this may not always be true. In the U.S., for example, charging a corporation with a crime makes it easier for the government to obtain documents that might provide evidence against corporate officials who were involved in the criminal activity.

[43] In 1991, the U.S. Sentencing Commission issued mandatory guidelines for judges to follow in the case of organizations convicted of federal crimes. However, it did not include environmental crimes in the penalty provisions of these guidelines. Thus, judges are still free to impose any monetary penalty they see fit (up to the statutory maximum).

4.3 Private Enforcement of Environmental Law

Although enforcement is ultimately the government's responsibility, the government does not necessarily initiate all enforcement activity. In some instances, private parties are given the right to initiate enforcement actions through the administrative agencies or the courts. There are several reasons why governments might adopt this dual enforcement approach. Private citizens who are directly affected by pollution might be better situated to detect environmental violations in their neighborhoods and can be a good judge of whether or not they are concerned enough about this pollution to take some action. It is also possible that private enforcement is less costly as private enforcers are not subject to the inefficiencies of government bureaucracies. Finally, the government enforcement agency might simply lack the funds to adequately enforce, and instead would have to rely upon private enforcement agents to fill in the gaps.

Despite these apparent benefits, private enforcement might also serve the less noble goal of enhancing private interests at the expense of public interests. As Landes and Posner (1975) show, private enforcement might lead to too much enforcement, i.e., over deterrence. This is especially a concern if private enforcement is allowed as an adjunct to public enforcement and the public agency does not take private enforcement into account when setting their enforcement policy. For example, recall from Section 3.1 that it may be optimal for the government to set a high fine and low probability of detection. Assuming that such an enforcement policy is set optimally, allowing private enforcement would yield a higher expected penalty than is optimal. This might lead to too much enforcement and overdeterrence – a situation whereby the firm spends more than is socially optimal to prevent pollution. As Tietenberg (1996) shows, if the regulatory standard is too stringent (but not enforced), private enforcement can lead to excessive regulations. Polinsky (1980) argues just the opposite, however, if the optimal enforcement scheme involves high monitoring costs. In that case, relying on private enforcement might lead to under deterrence. Thus, if the government is to allow private enforcement, it should take into account the level of enforcement expected from private parties in determining the correct penalty level to impose.

Cohen and Rubin (1985) propose an alternative approach to private enforcement, whereby EPA turns all of its monitoring and enforcement activities over to private parties. The payment the private enforcer receives is based on the net social benefit of enforcement. In theory, their proposal would overcome both of these objections. However, even in an era of privatization, the practical and political difficulties of implementing this proposal appear to be insurmountable.

In the U.S., private enforcement largely takes the form of citizen suits. Although fines imposed by the court go directly to the government, lawyers who represent the citizens in a successful lawsuit collect significant legal fees. Although the 'citizens' who bring the lawsuit do not receive any compensation, penalties are sometimes earmarked for local cleanup efforts, community parks, or other programs that directly affect the citizens on

whose behalf the lawsuit is filed. The conclusions one can draw from studies of citizen suits are mixed. Naysnerski and Tietenberg (1992) provide a simple model of the supply and demand for private enforcement. Nonprofit groups form whose members prefer a higher level of public goods than currently supplied by the government. Although one possible role of the nonprofit group is to lobby to pass more stringent environmental legislation, an alternative is to pass laws allowing private parties to enforce when the government does not. To the private enforcer, the problem of when to seek legal remedies is one of private utility maximization. If the private enforcer is a nonprofit group whose sole objective function is to maximize the utility of its members, then the problem becomes one of trading off the cost of litigation against the net benefits to the members from improved environmental quality. As Naysnerski and Tietenberg (1992) note, this suggests that the amount of private enforcement will be inversely related to the amount of public enforcement. That is, when government enforcement budgets are tight, we would expect to see more private enforcement. Empirically, they show this is exactly what happened in the U.S. in the early 1980s when EPA enforcement fell and private citizen suits grew.

However, there are other reasons why private enforcement might increase. Consistent with Naysnerski and Tietenberg's model, we would expect an increase in private enforcement anytime the costs of private enforcement decrease or the benefits increase. Naysnerski and Tietenberg (1992) and Greve (1992) argue that the huge increase in private enforcement in the early 1980s was largely due to a reduction in the cost of obtaining information for Clean Water Act cases. EPA regulations mandated record keeping that enabled student volunteers to scan records and immediately identify violations. "They also created economies of scale: Large numbers of companies can be served with identical, form-letter notices of intent, on which only the dates, names, and a few specifics have to be changed" (Greve, 1992: 109). Greve (1992) further notes that the large increase in citizen suits was primarily for Clean Water Act cases, while there is no reason to believe that EPA enforcement reductions were felt any less in the case of other media. As Naysnerski and Tietenberg (1992) note, this bias towards Clean Water Act cases was at the expense of other violations that might have been causing more damage.

Naysenerski and Tietenberg (1992) also argue that private enforcement is particularly useful in filling a gap in enforcement against public polluters. They note that public polluters (e.g., municipal water or sewage facilities) are seldom the target of enforcement actions by public enforcement agencies. Private enforcers are apparently less reluctant to file lawsuit against public agencies.

Heyes (1997) offers a more formal model of private enforcement that takes into account the fact that public and private interests diverge not only when the firm decides to pollute, but also when the private enforcer decides to sue.[44] His model recognizes the fact that the private enforcer might not only care about a cleaner environment, but also is influenced by the possibility of collecting a reward for its effort. In this highly stylized

[44] Baik and Shogren (1994) also consider a formal model of private enforcement with qualitatively similar results.

model, the firm and private enforcer bid for the outcome they deem favorable. The winner of this contest is based on the effort expended on winning. It is assumed that the environmental benefits of the contest are known to all, but the cost of compliance to the firm is private information. Suppose the government wishes to encourage such lawsuits and subsidizes them. In that case, the public enforcer might win some socially beneficial as well as socially costly decisions. Discouraging lawsuits through taxation has the same mixed result. Heyes concludes that it is not possible to devise a tax/subsidy scheme that sorts out the good from bad decisions. Thus, private enforcement will always lead to some inefficient decisions.

4.4 Information and Market Forces as Enforcement Tools

Information that a firm has been sanctioned for violating environmental laws (fines, cleanup costs, damage compensation, etc.) may be of interest to shareholders or lenders of that firm. To the extent that the monetary sanction reduces the expected value of the firm, this will affect the share price and/or bond rating of the firm. It may also give lenders pause about risking more capital on that particular firm. In addition to the direct monetary sanctions and cleanup costs associated with the enforcement action, the firm may incur additional costs in the future. For example, if being convicted of an environmental crime automatically causes a firm to be barred from doing business with the government (as it oftentimes does in the U.S. – even though this is a temporary suspension), then investors may take this additional information into account. Similarly, if the government enforcement agency follows the suggestion of Harrington (1988) and others (see Section 3.4.2), and implements a targeted enforcement strategy, the threat of future sanctions may now be higher. It is also possible that this environmental law violation will result in the loss of goodwill to employees or customers, thus reducing the long run profitability of the firm. Some socially conscious investors might even shun the firm's stock, thereby depressing its value. Finally, it is possible that investors will update their assessment of the quality of management in the firm and take this environmental law violation as a signal that the firm is not as well managed as they thought.

The role of non-regulatory enforcement tools such as the impact of information disclosure on firm behavior is an important emerging topic in the economics of enforcement. One impetus for this growing interest appears to be the experience in the U.S. with the "toxic release inventory" (TRI) information disclosure requirements. Firms emitting more than a certain amount of chemicals in to the air, water or land are required to report the type and amount of emissions to the EPA – even for emissions that are legal. Hamilton (1995) estimates that the first such disclosure had a significant effect on the market value of publicly traded firms - a negative abnormal return of –0.3% for the average firm. However, the distribution of abnormal returns varied considerably, with some firms receiving stock price reductions of several percentage points, and others actually receiving positive abnormal returns. Hamilton's analysis does not provide a means of determining the underlying reason for the stock price decline. We do not know, for example, whether these stock price effects reflect investor expectations of future targeted enforcement scrutiny of high emitters (which has been hinted at by EPA).

Another potential explanation for the stock price decline is the expectation that public pressure would cause firms to voluntarily reduce emissions. It is also possible that investors simply take this information as a signal of an inefficient production process and/or bad management. Regardless of the reason, we know that firms have dramatically reduced their TRI emissions following the initial disclosure. Konar and Cohen (1997) compared the firm-specific reductions to the abnormal returns estimated by Hamilton (1995), and find that the firms with the largest negative abnormal returns upon the initial announcement of TRI emissions are the firms that reduced their emissions the most.

It is important to keep in mind that information disclosure under the TRI program is about legal emissions. Mandatory disclosure programs such as TRI are best thought of as substitutes for regulatory programs that attempt to use community or other external pressures to encourage firms to reduce emissions voluntarily. In contrast, information disclosure about law violations is best thought of as another form of penalty in addition to any direct government imposed monetary fine. Thus, to the extent that information disclosure about *legal* emissions had an effect on firm valuation and subsequent *legal* emissions, we would expect similar if not greater effects for information disclosure about *illegal* emissions. Several recent studies have focused on bad environmental news in the U.S. and Canada, such as oil or chemical spills or the announcement of civil or criminal enforcement actions (Muoghalu, Robison and Glascock, 1990; Lanoie and Laplante, 1994; Klassen and McLaughlin, 1996; Badrinath and Bolster, 1996; Lanoie, Laplante and Roy, 1998). Although most of these studies involve one-time announcements, Lanoie, Laplante and Roy (1998) find that capital markets in Canada continue to react to subsequent announcements every six months. Recent studies in developing countries have found similar capital market effects in both Korea (Jeon, 1998), and in Argentina, Chile, Mexico and the Philippines (Dasgupta, Laplante and Mamingi, 1998). In some cases, positive stock price effects have even been demonstrated following announcements of superior environmental performance or awards.

However, these studies have not compared the loss in stock value to the cost of penalties, cleanup, etc. To the extent that a firm sanctioned $1 million by the government incurs a market value decline of $1 million, for example, these studies would be of little interest to those interested in environmental enforcement. In that case, the market value decline is only one alternative way to measure the full cost of the penalty. However, it is possible that the decline in market value of a firm exceeds the combined cost of the sanction plus collateral payments required by the law. If so, the additional market value drop can be considered to be a penalty itself that the environmental violator must bear. Thus, we do not know if these market losses reflect the full value of expected past and future out-of-pocket costs, or if there is some additional penalty imposed by the market.[45] Future studies focusing on this issue would be of interest.

[45] One study of the Exxon Valdez incident estimated the total market value loss to be $10.1 to $11.3 billion (Jones, Jones and Phillips-Patrick, 1994). This is $1.2 to $2.4 billion more than the $8.9 billion in direct costs I have estimated Exxon paid including cleanup costs, fines, and civil settlements. If insurers paid a significant portion of those costs, the direct cost to Exxon might have been considerably less. Thus, it is possible that Exxon received an additional "market" penalty from all of the bad publicity surrounding

Several recent experiments with information disclosure as an enforcement tool have yielded promising results. Most of these efforts are being promoted by the "New Ideas in Pollution Regulation" (NIPR) program of the World Bank, and are reported on at their Internet site, http://www.worldbank.org/nipr. Although some of these experiments are designed to fill a void where no regulations are in place, others have explicitly used the power of information disclosure as a method of pressuring firms to comply with government regulations. This is particularly useful in countries where government enforcement resources are limited. For example, a program in Indonesia rated firms by their level of compliance with existing regulations and gave the firms six months advance notice of the rating that would be made public unless they changed their compliance behavior. Afsah, Laplante and Wheeler (1997) report considerable improvements in compliance status both before the initial public announcement (which allowed firms to change their status before the announcement) and following the public announcement.

5 Summary and Future Research Needs

It has long been recognized that enforcement is an important element of regulatory policy design. Yet, the economics literature on environmental enforcement is highly fragmented and not easily accessible. I had two main goals in writing this article: (1) to bring this diverse literature together in a format that provides researchers and policy makers with a laundry list of enforcement issues to consider when evaluating environmental policy, and (2) to provide researchers with new and interesting topics for further study.

Over the past 25 years, we have learned a lot about the effect of monitoring and enforcement on firm behavior. We know that increased monitoring and inspections can increase compliance. We also know that enforcement does not occur in a vacuum and that understanding the motivations and incentives of both polluters and enforcement agencies should be an important component of any study of enforcement. However, there is a lot yet to be learned.

We probably know the least about the most important and fundamental topic in enforcement – why firms comply with the law. Two promising areas of research on this topic appear to be developing: (1) incorporating social norms, community pressure and firm reputation into the analysis, and (2) opening up the "black box" of the firm and incorporating incentives within the organization. These are both complex topics that require an understanding of a diverse set of literatures – including topics such as corporate governance, principal-agency theory and economic models of social norms. This is also an area where economists can learn from other disciplines and from other empirical studies outside economics. Although recent attempts to empirically estimate the factors that cause firms to voluntarily reduce emissions have been promising, they

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the Valdez incident. However, a recent study by Karpoff et al. (1999) finds no significant evidence of a market penalty in a sample of publicly traded firms that had an environmental violation and penalty.

have often been unable to substantiate the theoretical models that others have proposed. Further empirical and theoretical work in this area could be beneficial.

Another significant gap in our knowledge relates to the interaction of the various institutions that affect compliance behavior. Are citizen suits a substitute or a complement to government enforcement? What role do firm reputation and market forces play in the enforcement equation? Does organizational structure affect a firm's propensity to comply? If so, how should this be taken into account in designing appropriate enforcement policies? Is "information" really an enforcement tool that government agencies can use at a very low cost? If so, what are the social costs and benefits of providing information to the public in an effort to affect firm behavior? How can a diverse set of institutional actors with their own agendas (e.g., EPA, Sentencing Commission, courts, private enforcement activities, market forces) coordinate so that the outcome at least approximates optimality? These are just a few of the questions that arise when we look beyond the simple question of designing an optimal penalty when there are only two actors – a polluter and enforcement agency. Opening up the model to account for real world complexities make our task much more difficult – but also much more interesting.

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