The Economics of Environmental Monitoring and Enforcement

Jay P. Shimshack

Frank Batten School of Leadership and Public Policy, University of Virginia, Charlottesville, Virginia 22904; email: shimshac@gmail.com

Annu. Rev. Resour. Econ. 2014. 6:339–60

First published online as a Review in Advance on July 7, 2014

The *Annual Review of Resource Economics* is online at resource.annualreviews.org

This article's doi: 10.1146/annurev-resource-091912-151821

JEL codes: K32, K42, Q53, Q58

Keywords

inspections, sanctions, penalties, deterrence, pollution

Abstract

Without monitoring and enforcement, environmental laws are largely nonbinding guidance. Although economists and philosophers have thought seriously about the broader public enforcement of law since at least the eighteenth century, environmental monitoring and enforcement remain both understudied and controversial. This article reviews what we do and do not know about the subject. I review common environmental enforcement institutions, prescriptive and descriptive theories, empirical evidence on regulator behavior, and empirical evidence on deterrence effects.

1. AIMS AND SCOPE

Without monitoring and enforcement, environmental laws are largely nonbinding guidance. Scholars regularly cite traditional enforceable regulation as a leading motivator for environmental performance (Kagan et al. 2003, Doonan et al. 2005, May 2005, Delmas & Toffel 2008). Government agencies spend billions of dollars monitoring and enforcing pollution regulations each year, and firms spend billions complying and paying penalties.

Economists and philosophers have thought seriously about the public enforcement of law since, at the latest, Bentham (1789). Yet, environmental monitoring and enforcement remain both understudied and controversial. Environmental economists most often ignore or assume away monitoring and enforcement issues. Other scholars and policy makers regularly call for transitions away from traditional enforcement toward cooperative, voluntary, or information-based approaches.[1]

This article reviews what we know about environmental monitoring and enforcement and concludes with a discussion of what we do not yet know. The review builds on, and draws from, existing surveys (Cohen 1999, Heyes 2000, Gray & Shimshack 2011, Stranlund 2013). It contributes in two ways. First, the article updates Cohen (1999). Second, it addresses a broader set of issues than do Heyes (2000), Gray & Shimshack (2011), and Stranlund (2013).

The article proceeds as follows. Section 2 reviews common environmental enforcement institutions in the United States. Section 3 surveys both prescriptive theory and descriptive theory. Section 4 reviews empirical evidence on how environmental regulators behave and on how regulated entities respond to regulator actions. Section 5 concludes with key lessons and knowledge gaps.

2. UNDERSTANDING MONITORING AND ENFORCEMENT IN PRACTICE

How do environmental monitoring and enforcement work? How common are inspections and sanctions in the United States? How are environmental monitoring and enforcement changing over time? This section takes up these issues.

The discussion below emphasizes activity falling under the umbrella of the Environmental Protection Agency (EPA) and especially the regulatory setting under the three acts receiving the bulk of US monitoring and enforcement resource allocations. These acts are the Clean Air Act (CAA), the Clean Water Act (CWA), and the Resource Conservation and Recovery Act (RCRA). The discussion below also loosely describes institutions under the Safe Drinking Water Act (SDWA); the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); the Toxic Substances Control Act (TSCA); the Emergency Planning and Community Right-to-Know Act (EPCRA); and the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Institutions for environmental rules managed by agencies other than EPA, as well as institutions in other developed countries, are often similar in some respects and different in others.[2]

2.1. Basic Structure

Legislation guiding environmental policy in the United States is set largely at the federal level. In contrast, primary monitoring and enforcement responsibility is typically decentralized to states' departments of environmental protection and to local authorities. When states or localities have primary authority, dubbed primacy, they are still required to regularly provide key activity metrics to

[1]Harrison (1995) reviews early arguments.

[2]Scarlett et al. (2011) and Deily & Gray (2007) compare institutions across agencies. Harrison (1995), Rousseau (2007), Almer & Goeschl (2010), Telle (2013), and Billiet & Rousseau (2014) discuss institutions in selected developed countries outside of the United States.

EPA regional and federal offices. EPA offices regularly review state operations, and regional and national authorities also conduct their own inspections and issue their own sanctions. EPA actions most often occur when and where decentralized enforcement is perceived as insufficiently rigorous or when and where potential environmental impacts from specific violations are unusually large. The EPA retains the right to revoke a state's primacy under any given specific environmental statue, although such revocations are rare. States may decline primacy for resource or political economic reasons. The EPA typically maintains primacy for newer and smaller environmental regulatory programs.

Executive oversight of environmental monitoring and enforcement is primarily indirect. The executive branch appoints the EPA administrator, the deputy administrators, and the assistant administrator for enforcement and compliance assurance. These individuals strongly influence enforcement intensity via budget negotiations with Congress, via within-agency resource allocations, and via impacts on bureaucratic culture. Although direct executive office interventions in specific enforcement cases has been rare, presidential administration staffers have periodically been heavily involved in crafting policy initiatives that can impact monitoring and enforcement (Bressman & Vandenbergh 2006; Mintz 2012, pp. 182–83). A high-profile example from the mid-2000s was executive efforts to modify new source review policies for power stations while several EPA cases on the matter were ongoing.

Legislative oversight of environmental monitoring and enforcement is also mostly indirect. Congress designs and passes the overarching environmental laws that specify enforcement authority and process. Legislatures authorize EPA budgets and can indirectly influence all EPA activities via budgeting choices. Congress must approve executive nominations for EPA leadership positions. Legislative authorities can also publicly express their collective preferences regarding enforcement intensity. For example, Congress publicly advocated for more aggressive aggregate environmental enforcement in the early 1980s and, as part of a growing antiregulatory platform, advocated for less aggressive aggregate environmental enforcement in the early 1990s. According to Mintz's (2012) extensive interviews, however, the prevailing wisdom among enforcement officials is that individual congressional committees or members are rarely directly involved in specific enforcement cases beyond routine requests for information.

2.2. Personnel and Instruments

Almost all state, regional, and federal monitoring and enforcement staff members are engineers and attorneys. Managers at both state and federal agencies are commonly internally promoted attorneys or engineers. Because enforcement resources are consistently scarce, because environmental conditions at facilities are often complex, and because regulations can be vague and flexible, authorities at all levels have high levels of discretion regarding the frequency and severity of interventions. This discretion, in turn, can sometimes result in contentious interactions between enforcement authorities at different levels of government (Mintz 2012).

Nearly all pollution monitoring and enforcement activities in the United States are conducted on a media-specific or statute-specific basis. Technical and legal complexities make other strategies challenging. The pulp and paper industry's integrated cluster rule is a notable exception, as it was designed to coordinate water and air regulation for more efficient facility compliance through process modifications. Other exceptions include multiple-media monitoring and enforcement activities targeted toward industries or sources periodically identified as EPA national priorities or national enforcement initiatives. Priority industries from 2011 to 2013 included animal feeding, minerals processing, energy extraction, coal-fired utilities, and cement.

Common environmental instruments include self-reporting and continuous emissions monitoring. For large facilities regulated under the CWA, several provisions of the CAA, and the

EPCRA, self-reported pollution data are the primary source of compliance monitoring information. Self-reporting is common under many other statutes as well. In most cases, facilities self-report pollution snapshots or longer-term pollution summary measures at the pollutant-point source level. Continuous emissions monitoring systems, applied on the largest scale under the CAA's Title IV acid rain program for power stations, achieve approximately the same goals with real-time measurements and with automatic reporting.

Regulator inspections help confirm the accuracy of self-reported data. Also, for statutes or facilities without extensive self-monitoring requirements, inspections are the dominant source of compliance monitoring information. Evaluations vary substantially in scope and scale across facilities, industries, statutes, states, and time. Low-intensity inspections may involve visual inspections of emissions and abatement equipment. Medium-intensity inspections may involve reviews of facility operations, maintenance, sampling, and reporting procedures. High-intensity inspections may typically involve extensive sampling by the regulator.

Inspections are conducted at specific facilities "for cause" or, more commonly, for administrative reasons under the auspices of "neutral selection." For-cause inspections are typically associated with compliance history, citizen complaints, anonymous employee complaints, or facility characteristics correlated with frequent violations or significant damages. Neutral-selection inspections are based on time since last inspection and regulator cost factors, such as geographic proximity to other facilities scheduled to be inspected. Monitoring guidelines set inspection frequency targets for facilities, but these targets are generally not legally binding. Three features of the environmental inspection process are noteworthy to many economists. First, purely random inspections do not fall under most definitions of neutral selection or for cause. Second, the agency increasingly uses environmental justice as a targeting consideration, as the natural vulnerability of populations near environmental justice facilities indicates the potential for significant environmental harm. Third, facilities are typically notified by authorities in advance of impending inspections, so on-site inspections are often not a surprise to facilities.

When pollution violations are disclosed or detected, authorities have several enforcement options. Informal sanctions include warning letters, telephone calls, and notices of violation. These actions are most frequently carried out by the lowest-level authority with primacy. Formal sanctions may include field citations, but the vast majority are administrative orders issued by state authorities or by the administrative law judges associated with state and regional offices. Significant enforcement actions may also include state, regional, or national civil litigation. A small number of egregious violations are referred to state attorneys general or to the Department of Justice (DOJ) for criminal prosecution.[3]

Enforcement guidelines vary by statute. However, as a general rule, the frequency and severity of environmental sanctions are a function of one or more of the following: the extent of damages from the violation, the penalized facility's financial gain from the violation, the facility's compliance and enforcement history, the economic impact of the penalty on the violator, and the violator's intent. Fairness and the strength of the legal evidence can also influence sanction magnitudes. In practice, authorities typically pursue the minimum sanction necessary to achieve a return to compliance and some longer-run deterrence objective. Maximum penalties allowable under the law are rarely assessed, if ever.[4] Administrative penalties are strongly prioritized over

[3]Facilities may appeal all types of sanctions. Penalized facilities may appeal administrative penalties to state administrative appeals boards or to the independent Environmental Appeals Board (EAB) in Washington, DC. Facilities facing civil or criminal penalties may appeal to state or federal courts.

[4]The most common statutory maximum is $25,000 per day in violation. A high-profile environmental defense attorney referred to these maximums as "off the charts" (Mintz 2012, p. 16).

civil penalties. All else equal, enforcement attorneys try to avoid time-consuming and costly litigation. Criminal referrals are especially rare and occur for cases with demonstrable attempts at falsification and evasion, cases with deliberate attempts to sidestep the regulatory environment altogether, or cases with extreme environmental damages (Uhlmann 2009).

Environmental authorities' general approach to pollution monitoring and enforcement has remained largely constant for decades. However, the EPA is now investigating, promoting, and beginning to implement programmatic changes dubbed next-generation compliance. Next-generation environmental compliance exploits recent technological advances and more holistic rulemaking to increase the efficacy and efficiency of monitoring and enforcement. The paradigm has five key pillars: rules in which compliance is the default, advanced pollution monitoring, electronic reporting, enhanced information disclosure, and innovative enforcement strategies such as third-party certifications (Giles 2013).

2.3. Levels and Trends

Oversight of federal environmental monitoring and enforcement was consolidated in 1994 into the EPA's Office of Enforcement and Compliance Assurance (OECA). In the first year of operation, OECA received an ~$690 million budget (~$436 million in 1994 dollars, adjusted to 2013 dollars). **Figure 1** shows that real budgets, however, steadily declined for the next several years. Real OECA budgets then leveled off in the ~$600–620 million range, where they remain. The budgets in **Figure 1** represent lower-bound estimates of federal environmental enforcement expenditures because OECA regularly partners with other offices and agencies that have their own resources. Moreover, although the enforcement budgets in **Figure 1** include federal grants to states for enforcement and compliance assurance, they do not include resource allocations from the states.[5]

Between 1994 and 2011, the EPA conducted approximately 19,850 inspections per year. This estimate does not include state-led inspections and thus significantly understates total inspection counts.[6] Total EPA inspections steadily increased from approximately 14,500 in 1995 to 23,200 in 1998 and then generally leveled off to a steady-state level of between 18,000 and 22,000 per year. **Figure 2** shows that inspection levels and trends vary significantly across statute. After a sharp increase in the mid-1990s, CWA inspections generally fluctuated in the 3,500 to 4,500 range. The EPA conducted approximately 3,100 RCRA inspections between 1994 and 2001 on average, but levels sharply increased and then sharply decreased over the period. EPA carried out approximately 2,800 CAA inspections per year, but levels fell to less than 1,000 in 2002 and almost reached 4,000 in 2006. The greatest number of federal inspections for any major environmental statute between 1994 and 2001, approximately 7,200 per year, were conducted under the auspices of the SDWA.

Administrative penalty orders are formal requirements to return to compliance that are accompanied by financial penalties. Federal and regional EPA offices levied nearly 1,800 administrative penalty orders per year, on average, between 1994 and 2011. This estimate, however, does not include state administrative penalty orders or EPA complaints unaccompanied by monetary sanctions. It therefore understates total administrative action counts. **Figure 3** shows that EPA administrative penalty orders varied significantly across time and statute. EPA-led administrative penalties under the CWA increased between 1991 and 2005, and administrative penalties under

[5]I am unable to locate systematic estimates of state expenditures on environmental enforcement and compliance assurance. Informal estimates tend to suggest that incremental state enforcement expenditures across all states may be of similar magnitude as total federal enforcement expenditures.

[6]Systematic data on inspection type and inspection intensity over time are not immediately available.

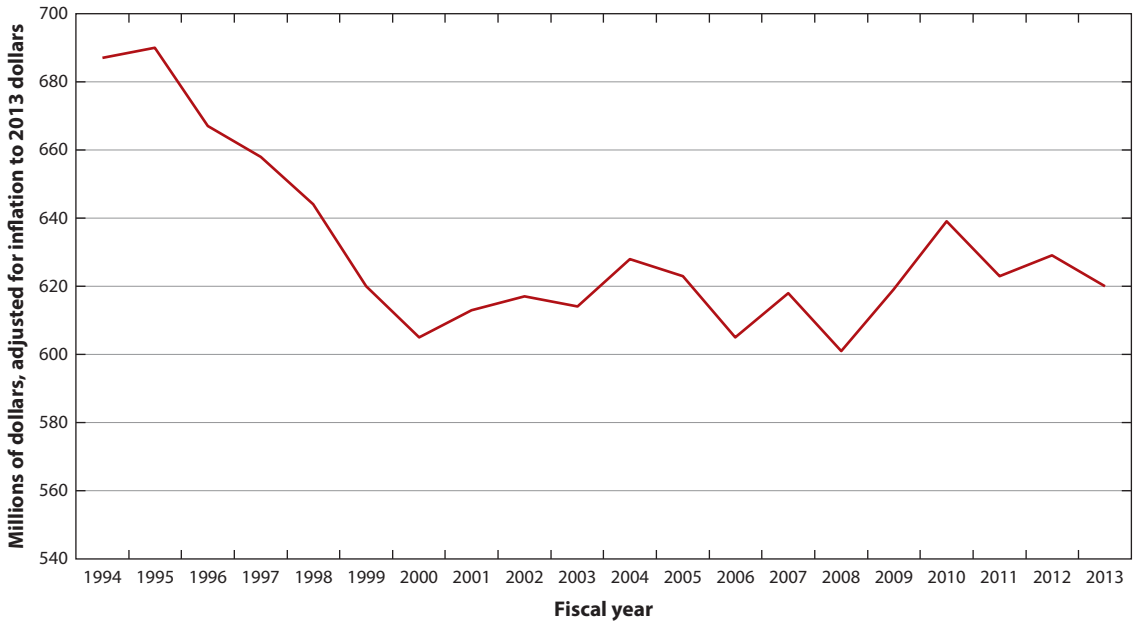

Figure 1

Inflation-adjusted EPA budget allocations for enforcement and compliance assurance, in 2013 dollars, fiscal years 1994 through 2013. Data from EPA historical planning, budget, and results reports (**http://www2.epa.gov/planandbudget/archive#BudgetSummary**).

the RCRA and the CAA increased between 1998 and 2008. Penalty magnitudes also varied significantly across statute and time. The mean (nominal) EPA administrative penalty over all statutes between 1991 and 2005 was approximately $17,500. Median penalties were far lower.[7]

As noted above, civil and criminal referrals to the DOJ for pollution violations are infrequent. Between 1994 and 2011, EPA referred, on average, 288 cases per year to the DOJ for civil litigation. The bulk of these referrals were for CERCLA, CAA, and CWA violations. Civil judicial case numbers trended downward over time, with the total number of EPA civil referrals generally varying between 300 and 400 in the mid-1990s and between 200 and 300 in the late 2000s. Total penalty amounts from civil judicial cases averaged approximately $95 million per year. Between 1998 and 2011, EPA referred, on average, 420 cases per year to the DOJ for criminal litigation. Criminal judicial case numbers also trended downward over time, with the total number of EPA criminal referrals generally varying between 400 and 500 in the late 1990s and between 300 and 400 in the late 2000s. Financial penalties from criminal cases averaged approximately $85 million per year, with accompanying average annual jail sentences totaling approximately 134 years.

Fully characterizing levels and trends of state-led pollution monitoring and enforcement is beyond the scope of this article. **Figure 4**, however, highlights significant heterogeneity across states. **Figure 4** presents basic data on state-led compliance evaluations of CAA facilities, state-led formal enforcement actions levied against CAA facilities, state-led inspections of CWA major facilities, and state-led enforcement actions levied against CWA major facilities. To highlight some

[7]Gray & Shimshack (2011) report that median administrative penalties between 2001 and 2008 were approximately $7,850 under CERCLA, $3,000 under CWA, $7,200 under EPCRA, $600 under RCRA, and $3,600 under TSCA. Gray & Shimshack's (2011) median penalties are calculated from data that include state administrative penalties.

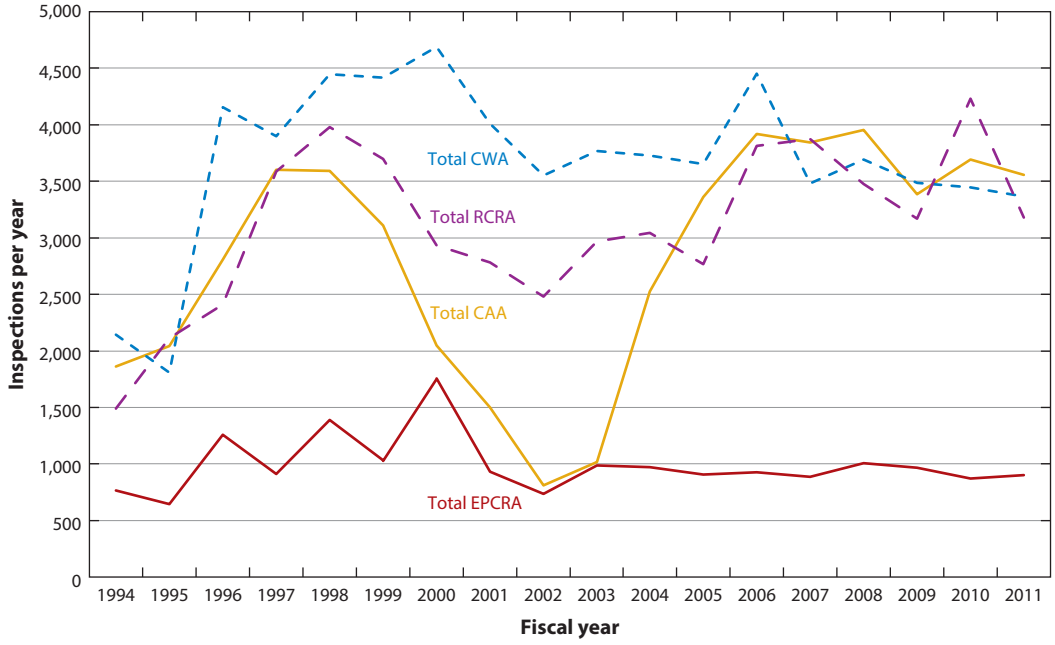

Figure 2

Inspections by major statute, fiscal years 1994 through 2011. Abbreviations: CAA, Clean Air Act; CWA, Clean Water Act; EPCRA, Emergency Planning and Community Right-to-Know Act; RCRA, Resource Conservation and Recovery Act. Data from EPA national enforcement trends (**http://cfpub.epa.gov/compliance/resources/reports/nets/**).

differences, consider that in 2011, North Carolina led compliance evaluations at more than 95% of its CAA facilities, whereas New York led compliance evaluations at only slightly more than 10% of its CAA facilities. Pennsylvania led inspections at more than 90% of its CWA majors, whereas New York led inspections at less than 15% of its CWA majors. Texas issued enforcement actions at more than 50% of its CWA majors, whereas Pennsylvania issued enforcement actions at less than 10% of its CWA majors. Readers are cautioned not to overinterpret **Figure 4**, as cross-state differences are attributable to many possible factors. Such factors include, but are not limited to, differences in industrial composition, facility characteristics, regulatory severity, regulatory action history, and data quality.

2.4. Private Monitoring and Enforcement

Nearly every major environmental statute allows for citizen suit enforcement (Naysnerski & Tietenberg 1992). In this context, private groups like the Natural Resources Defense Council and Riverkeeper initiate lawsuits against polluters or government authorities to promote compliance and reduce pollution.[8] Citizen suits are typically permitted only when public regulators fail to pursue noncompliance. Furthermore, statutes require that cases targeting polluters be preceded by a 60-day notice of intent to both authorities and polluters (Langpap & Shimshack 2010). During this period, public agencies are often able to preempt the suit with their own actions.

[8]Community organizations, and especially watershed groups, also regularly informally alert authorities of unusual discharges, raise community awareness of local pollution, and work with facilities to improve environmental performance. See Grant & Grooms (2012) and Grant & Langpap (2013) for more discussion of this informal monitoring and enforcement sector.

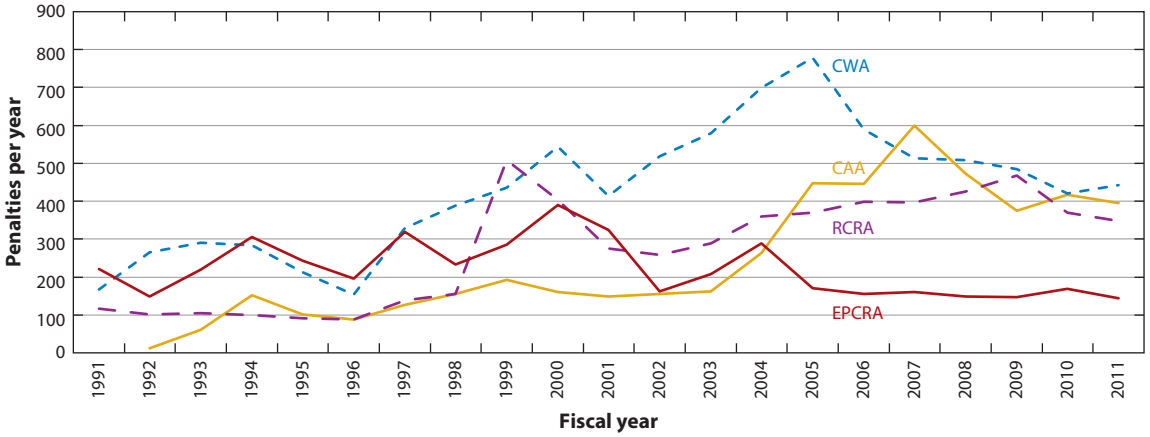

Figure 3

Administrative penalties by major statute, fiscal years 1991 through 2011. Abbreviations: CAA, Clean Air Act; CWA, Clean Water Act; EPCRA, Emergency Planning and Community Right-to-Know Act; RCRA, Resource Conservation and Recovery Act. Data from EPA national enforcement trends (**http://cfpub.epa.gov/compliance/resources/reports/nets/**).

During the 1980s and 1990s, approximately 50–150 citizen suits were prosecuted per year. Citizen suits related to CWA violations were, and continue to be, far more common than suits under other statutes. For example, Smith (2004) suggests that approximately 88% of suits between 1995 and 2000 were filed under the CWA provisions. Extensive self-reporting under the CWA allows citizen groups to regularly observe compliance at the facility level.

3. ECONOMIC THEORIES OF MONITORING AND ENFORCEMENT

What do optimal environmental monitoring and enforcement look like? Why might monitoring and enforcement in the real world differ from optimal monitoring and enforcement? This section takes up the theoretical account. The reader should note that much of the theory of environmental monitoring and enforcement is developed as part of the broader theory of the public enforcement of law. Polinsky & Shavell (2000) and Shavell (2004) survey this literature in depth, so the present article focuses on key insights and influential citations.

Justifications for public enforcement, in lieu of private tort and contract law, are the natural theoretical point of departure. Becker & Stigler (1974), Landes & Posner (1975), and Polinsky & Shavell (2000) review the key arguments. Three reasons favor the public enforcement of law, and perhaps especially so in the context of environmental enforcement. First, identifying the source of the harm may be difficult for victims due to information asymmetries. Second, there may be economies of scale and natural monopolies in monitoring and enforcement technologies. Third, positive externalities may arise from harm reduction, or negative externalities may arise from private monitoring.

Before proceeding further, this article reviews the standard utilitarian view of individuals' compliance motivations in the presence of enforcement. This framework has been understood since at least Bentham (1789), although the theory was formalized in the seminal work of Becker (1968). Here, a rational, risk-neutral agent considers a privately beneficial action that may also generate harm to third parties. The agent compares the expected benefits of the action with the expected cost of that action. In a setting with public enforcement of law, the expected cost of the action is related to the probability of detection and to the magnitude of the sanction if detected. Under strict liability, in which a penalty is imposed for realized harm regardless of intent or care,

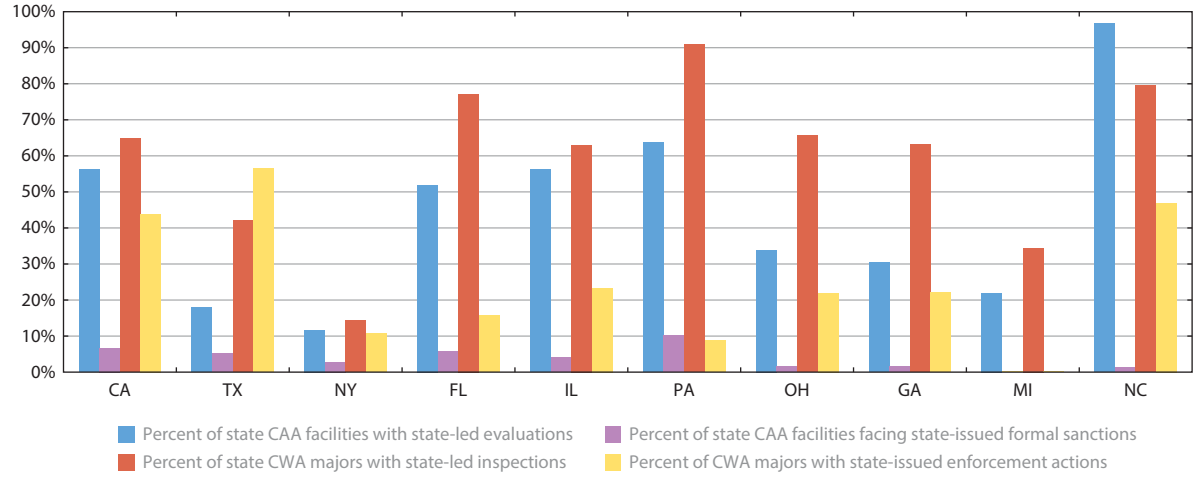

Figure 4

Basic Clean Air Act (CAA) and Clean Water Act (CWA) inspection and enforcement metrics across the ten largest US states, fiscal year 2011. Data from EPA ECHO state dashboards (**http://echo.epa.gov/air_dashboard** and **http://echo.epa.gov/water_dashboard**).

a risk-neutral agent commits the harmful act if the expected benefits exceed the expected penalties. Under fault-based liability, in which a penalty is imposed for realized harm only if the act is socially undesirable, a risk-neutral agent commits the harmful act when the expected gains are high enough to avoid fault.[9] Obvious extensions follow for act-based analogs to both strict liability and fault-based liability; in such analogs, penalties are based on ex ante expected harm rather than on ex post realized harm. Act-based liability is an especially appropriate framework when harm is treated as stochastic.[10]

3.1. Prescriptive Theory

The most fundamental law and economic theories of enforcement explore various features of a social welfare–maximizing enforcement system. The most common baseline models assume costly monitoring and apprehension, costless imposition of monetary sanctions, and certain imposition of monetary sanctions conditional on detected violation. Common baseline models also assume Becker-style rational agents who have no wealth constraints and who make binary decisions over a single course of action.

The simplest starting point is a model assuming that the probability of detection is fixed at one. With strict liability or its act-based analog, an optimizing enforcement agency imposes an expected sanction equal to the expected harm. With fault-based liability or its act-based analog, an optimizing enforcement agency imposes an expected sanction equal to the expected harm, provided that the action is socially undesirable. In all cases, socially undesirable acts are deterred, and socially desirable acts are left undeterred. A natural extension to the simplest model assumes that the probability of detection is fixed at some probability greater than zero but less than one. Optimal sanctions are now based on expected harm divided by the probability of detection.

[9]Socially undesirable in this context refers to a net or aggregate concept, i.e., when social harm exceeds private gain.

[10]Shavell (2004) reviews the advantages and disadvantages of the various liability rules, including those related to agency enforcement costs, agent risk-bearing costs, and Coasian transaction costs (Coase 1960).

Beyond the identification of optimal sanction rules, two insights arise from simple models with fixed detection probabilities (Shavell 2004). First, when agents are risk averse, optimal penalties will be lower than the optimal sanctions when agents are risk neutral. The intuitions are that risk bearing is costly and that risk-averse agents are more easily deterred. Second, optimal sanctions may bear little resemblance to sanctions perceived as fair or reasonable. Sanctions for acts when the probability of detection is low can be very high, even when harm is relatively low. For example, a minor pollution violation that is unlikely to be detected is deterred only with optimal penalties that may seem extreme to the casual observer.

More nuanced models assume that a welfare-maximizing regulator chooses both the probability of detection and the magnitude of the sanction conditional on violation. Here, an optimizing enforcement agency chooses a low probability of detection and a high sanction. Indeed, one implication of Becker (1968) is that the optimal sanction with risk-neutral agents is often at or near its maximum allowable level.[11] The intuition is that the regulator saves monitoring resources without sacrificing deterrence. An optimizing enforcement agency will also choose a probability of detection that leads to some underdeterrence. In other words, the regulator chooses a monitoring probability that is lower than the monitoring probability necessary to equate the expected sanction with the expected harm. The intuition is that allowing some socially undesirable activities to save enforcement resources is beneficial.

Some models allow for both monetary sanctions and nonmonetary sanctions. Nonmonetary sanctions include incarceration but may also include penalties like reputation damage. Under the assumptions that nonmonetary sanctions are costly to impose and that monetary sanctions are costless (or nearly costless) to impose, an optimizing regulator will issue maximum monetary sanctions before issuing any nonmonetary sanctions. Stated differently, an optimizing regulator will resort to nonmonetary sanctions only when monetary sanctions are unlikely to achieve deterrence.[12] In practice, these conditions typically arise when monetary penalties are constrained, when the probability of detection is limited, when agent wealth is constrained, and/or when the private gains from committing the harmful act are unusually high (Shavell 2004).

3.2. Extensions to Prescriptive Theory

Extensions to the basic prescriptive theory include models allowing for errors in liability, imperfectly observable enforcement parameters, costly monetary sanctions, and multiple harmful actions. In models with errors in liability, all errors reduce deterrence. Type I errors reduce the expected sanctions of noncompliance, and type II errors reduce the gap between the expected benefits of compliance and the expected benefits of noncompliance. Optimal sanctions with errors are therefore higher than optimal sanctions without errors. In models with imperfectly observable enforcement parameters, changes in perceived detection probabilities and perceived sanctions impact deterrence more than do changes in actual detection probabilities and sections. In models with costly sanctioning, optimal sanctions need to be higher than optimal sanctions with costless monitoring.[13] The intuition is that expected penalties need to reflect both expected harm and expected imposition costs. In models in which agents may choose multiple harmful acts, the key insight is the notion of marginal deterrence. Marginal deterrence across acts with different levels of

[11]Maximum legal penalties may be defined in statutes, or penalties may be politically constrained. Marginal deterrence, discussed below, may also lead to constrained penalties for many actions with lower levels of harm.

[12]Segerson & Tietenberg (1992) consider more nuanced agency trade-offs between monetary and nonmonetary sanctions when principal-agent issues within the firm complicate compliance incentives.

[13]Sanctioning may be costly for documentation, negotiation, litigation, political backlash, or other reasons.

harm requires optimal sanctions that rise with damages. One complication is that maintaining sufficiently steep penalty schedules may require artificially low sanctions and underdeterrence for lower-level harm (Mookherjee & Png 1994).

One extension that has received particular attention in the environmental context involves the possibility of avoidance activities. Malik (1990a) models the implications of agents trying to lower the probability of being sanctioned by engaging in evasion, lobbying, or concealment efforts.[14] Because larger penalties increase incentives for avoidance activities, an optimizing enforcement agency may not choose the highest possible sanction. Heyes (1994) expands these ideas to a case in which a regulator chooses between more frequent inspections and more thorough inspections. More frequent inspections provide incentives for concealment activities, whereas more thorough inspections provide incentives for transparency. Heyes (1994) argues that an optimizing enforcement agency should emphasize thoroughness.

Another relevant extension addresses self-reporting. Enforcement systems with self-monitoring can be incentive compatible while lowering enforcement costs and enhancing regulator efficiency. Malik (1993) shows that regimes with self-reporting can be welfare improving if less frequent regulator inspections are coupled with more frequent regulator punishment. Kaplow & Shavell (1994) demonstrate that regimes with self-reporting can be implemented without affecting agents' incentives. The intuition is that equivalent deterrence can simply be achieved with penalties for self-disclosed violations equal to (or, in some cases, somewhat less than) the certainty equivalent of expected penalties without self-reporting. Kaplow & Shavell (1994) also note that an additional advantage of self-reporting is a reduction in agents' risk-bearing costs. Innes (1999a,b; 2001) shows that the welfare-enhancing effects of self-reporting may be especially high if agents are expected to engage in ex ante avoidance activities and/or in ex post remediation effects.

A third pertinent extension in the environmental context involves the monitoring and enforcement of market-based pollution control instruments. Under a pollution tax or a cap-and-trade system, the marginal benefit of noncompliance is typically the per-unit pollution price (Stranlund & Dhanda 1999).[15] Because the pollution price and therefore the marginal benefits of noncompliance do not vary across facilities, compliance decisions may be independent of abatement costs. Implications for enforcement targeting follow. See Stranlund (2013) for further discussion.

3.3. Descriptive Theory

In the environmental context, several features of observed regulator behavior are broadly consistent with prescriptions of the optimal enforcement models discussed above. Environmental sanctions are frequently a function of harm or damages. Underdeterrence may be widespread. Monetary penalties are common relative to incarceration, and criminal sentences are typically reserved for only those cases in which deterrence with monetary sanctions may be especially difficult. Statutes have penalty schedules that often reflect the general notion of marginal deterrence. Self-reporting is common. Market-based regulatory systems are enforced differently from command-and-control regulatory systems.

[14]Linder & McBride (1984) also discuss the possibility of concealment activities in an environmental context. However, that paper is ultimately concerned with enhancing enforcement performance in a decentralized regulatory setting.

[15]Under additional conditions described in Stranlund & Dhanda (1999), the expected penalty may have little direct influence on the true level of the harm, and expected penalties impact only incentives for truthful reporting. Under a tradable permits system, the expected penalty may have only an indirect influence on the level of harm via impacts on permit prices. These indirect impacts, however, can have important implications for the stability and efficiency of transferable discharge permit markets (Malik 1990b). See Stranlund (2013) for greater discussion.

However, other features of observed regulator behavior may be largely inconsistent with prescriptions of traditional law and economic theory. A broad descriptive literature attempts to explain these departures from economically optimal behavior in several ways. Many descriptive theories consider public enforcement agencies as captured regulators, in the spirit of Stigler (1971) and Peltzman (1976). Other theories conceptualize enforcement bureaucracies as conflict minimizing or attention avoiding, along the lines of Hilton (1972), Joskow (1974), and Leaver (2009). Some theorists model enforcement agencies as budget maximizers, in the spirit of Niskanen (1971). Yet others consider enforcement agencies as maximizing compliance subject to strong institutional constraints or as minimizing enforcement costs subject to target compliance rates (see, for example, Garvie & Keeler 1994).

An especially frequent motivation for descriptive theories of environmental enforcement is a common belief that static law and economic models would predict compliance rates that are well below those observed in real-world pollution control contexts. Observed inspection rates, sanction probabilities, and penalty magnitudes seem too low to generate high compliance. In an attempt to rationalize this apparent puzzle, Harrington (1988) proposes a dynamic repeated game between a regulated firm and an environmental enforcement authority facing highly constrained penalties.[16] Harford (1991, 1993), Harford & Harrington (1991), Friesen (2003), and others refine the basic model. The essence of regulator behavior in these studies is a state-dependent strategy in which the regulator adjusts inspection frequency and/or sanction intensity on the basis of agents' past performance. Generally compliant agents face infrequent inspections and/or low sanctions for violations, and generally noncompliant agents face frequent inspections and/or high sanctions for violations. The expected penalties of noncompliance therefore include both immediate sanctions and additional sanctions for violations that otherwise would have been undetected or lightly punished in future periods. This dynamic enforcement leverage may be used to enhance compliance, in many cases cost effectively, beyond what might be achieved with static enforcement.

Other descriptive theories attempting to explain simultaneously high compliance rates and low enforcement intensity include Livernois & McKenna (1999) and Heyes & Rickman (1999). Livernois & McKenna study the sanctioning policy of a cost-minimizing regulator managing an enforcement regime with self-reporting and with an exogenous goal of achieving a fixed compliance rate. They show that increasing sanctions for violations lowers the incentive for truthful reporting, and therefore lower penalties may increase compliance in some circumstances. Heyes & Rickman study regulator-firm interactions in the presence of multiple compliance domains. Here, a regulator may enhance overall compliance by allowing some noncompliance in one domain in exchange for compliance in another domain. As noted in Heyes (2000), the regulatory dealing of Heyes & Rickman (1999) can be thought of as a cross-sectional analog of dynamic enforcement leverage games.

Other prescriptive theories and descriptive theories going beyond simple Becker-style models emphasize jointness in pollution production. In the general spirit of Heyes & Rickman (1999), Shimshack & Ward (2008) illustrate that compliance for a given pollutant is influenced by expected penalties for different pollutants generated in the same production process. Becker-style models typically consider pollutants individually. With pollution jointness, optimizing agencies should design and implement permitting, inspection targeting, and enforcement strategies holistically.

Other theories, typically drawing from noneconomic disciplines or behavioral economics, explore both prescriptive and descriptive aspects of monitoring and enforcement when agents are motivated to comply for reasons beyond rational utilitarian calculations (Ayres & Braithwaite 1992, Thornton et al. 2005). One insight is that observed compliance may be motivated by moral

[16]Harrington (1988) is an application and extension of Landsberger & Meilijson (1982).

or ideological beliefs and values (Burby & Paterson 1993). Under these conditions, an optimizing agency may use carrots as well as sticks, regularly provide services, and impose sanctions widely seen as fair and prompt. A second insight is that observed compliance may be motivated by social norms (Scholz 1984, Winter & May 2000). Under these conditions, an optimizing agency may foster long-term personal relationships and may work to promote a culture in which compliance is seen as the norm. A third insight is that some observed noncompliance may emerge because agents do not fully understand complex and changing requirements (Spence 2001, Stafford 2006). Here, an optimizing agency may offer extensive compliance assistance.

A final strand of the descriptive theory literature focuses on relationships between public enforcement and private citizen suit enforcement. Heyes & Rickman (1999) predict that citizen suits may crowd in or crowd out public monitoring and enforcement, depending on the presence and extent of regulatory dealing. Langpap (2007) explores endogenous relationships in more detail. A key result is that citizen suits with high expected penalties are likely to crowd out public enforcement, and in many cases this crowding out will enhance the efficiency of public agency behavior.

4. THE EMPIRICAL ACCOUNT

How do environmental authorities determine inspection probabilities and sanction magnitudes in the real world? Do environmental monitoring and enforcement interventions enhance compliance? Do environmental inspections and sanctions reduce pollution? This section takes up the empirical account.

4.1. Empirical Determinants of Enforcement Agency Behavior

Empirical evidence suggests that environmental enforcement authorities regularly consider benefits and costs. Regarding benefits, higher emissions and damages are frequently associated with increased inspection probabilities (Dion et al. 1998, Stafford 2002, Gray & Shadbegian 2004). Administrative, civil, and criminal penalty magnitudes typically increase with harm (Epple & Visscher 1984, Cohen 1992, Kleit et al. 1998, Oljaca et al. 1998). CAA enforcement actions may be more common in nonattainment areas (Gray & Deily 1996). Regarding administrative costs, states with higher-paid employees conduct lower-intensity CWA inspections on average (Helland 1998c). Facilities recently inspected under the CWA are less likely to be immediately inspected again (Helland 1998b, Shimshack & Ward 2005). Storage tank inspections are more likely when nearby facilities are also inspected (Eckert & Eckert 2010). Regarding compliance costs, the EPA and states direct fewer monitoring and enforcement actions toward facilities that are important local employers or that have especially high probabilities of shutdown (Deily & Gray 1991, Gray & Deily 1996, Helland 1998c).

Other observed determinants of enforcement intensity may be consistent with direct agency benefits and costs, but overall welfare effects are more ambiguous. First, facilities' compliance history is typically an important determinant of monitoring and enforcement activity (Kleit et al. 1998, Oljaca et al. 1998, Stafford 2002, Eckert & Eckert 2010). The presumed intuition is that recent violators may be more likely to violate again. Second, although authorities are more likely to inspect facilities with a higher threat of private citizen suits, they are less likely to penalize these facilities (Langpap & Shimshack 2010, Ashenmiller & Norman 2011).[17] This enforcement crowd-out effect is consistent with theory and may reflect shifting resource allocations away from settings where private interventions are already influencing deterrence. Third, regulators respond to enforcement conditions in other jurisdictions. Federal CWA inspections are more common after

[17]Earnhart (2000) explores citizen suits and public enforcement in the Czech Republic but does not explore the extent of crowding in or crowding out between them.

state CWA inspections, and vice versa (Earnhart 2004c). Surface mining regulators lower enforcement intensity in response to lower enforcement intensity in nearby states, a result that may be consistent with an enforcement race to the bottom (Woods 2006). Somewhat similar strategic interactions are observed for CAA, CWA, and RCRA enforcement (Konisky 2007).

Regulator actions that are wholly inconsistent with direct benefit and cost comparisons are also readily observed. CWA and CAA inspection propensities are related to congressional representatives' voting scores and committee memberships, perhaps suggesting the importance of bureaucratic interest (Helland 1998b, Innes & Mitra 2011). Highly corrupt states pursue more lax environmental oversight, relative to less corrupt states, after receiving enforcement primacy (Grooms 2012). Many authors find that both inspection probabilities and enforcement probabilities are closely related to community characteristics. Most notably, characteristics associated with political activism, such as income, education, voter turnout, and environmental group membership, appear to be especially influential for state-level interventions (Helland 1998c; Earnhart 2004a,c).

4.2. Empirical Investigations of Deterrence

The evidence from environmental settings indicates that monitoring and enforcement actions get results. Most directly, requirements of administrative compliance orders and judicial resolutions help reduce immediate environmental harm. For example, the EPA asserts that its 2011 federal actions resulted in 3.6 billion pounds of hazardous waste treated and 1.6 billion pounds of air and water pollution reduced.[18]

More importantly, the empirical deterrence literature consistently finds that regulated facilities adjust subsequent environmental behavior following inspections, sanctions, or increased threats of inspections and sanctions. Environmental monitoring and enforcement actions generate specific deterrence, meaning that they improve future performance at the evaluated or sanctioned facility. Environmental monitoring and enforcement actions also generate general deterrence, meaning that they spill over to improve future performance at facilities other than the evaluated or sanctioned facility. Finally, environmental monitoring and enforcement actions appear to even generate beyond-compliance behavior, meaning that they can induce facilities to reduce pollution well below legally allowable levels.

4.2.1. Empirical investigations of specific deterrence. The empirical literature finds relatively consistent evidence for specific deterrence under air quality regulations. EPA enforcement actions were followed by enhanced compliance with CAA regulations in the steel industry during the 1970s and 1980s (Gray & Deily 1996, Deily & Gray 2007). EPA and state monitoring and enforcement actions reduced both the duration of noncompliance and the rate of noncompliance in the pulp and paper industry during the 1980s (Nadeau 1997, Gray & Shadbegian 2005). In the late 1990s and early 2000s, coal-fired power plants facing threats of new source review lawsuits reduced emissions relative to those plants not facing similar threats (Keohane et al. 2009). EPA air compliance evaluations reduced aggregate Toxic Release Inventory–reported emissions across several manufacturing industries in the 1980s, 1990s, and early 2000s (Hanna & Oliva 2010).

The empirical literature also consistently finds evidence of specific deterrence under water quality regulations. Both inspections and increased threats of inspections enhanced compliance with water quality regulations in the US and Canadian pulp and paper industries during the 1980s

[18]See EPA Compliance and Enforcement Annual Results: 2011 Fiscal Year (**http://www.epa.gov/compliance/resources/reports/endofyear/eoy2011/index.html**).

(Magat & Viscusi 1990, Laplante & Rilstone 1996). Sanctions, and especially federal fines, were associated with subsequent pollution reductions at wastewater treatment plants during the 1990s and at chemical facilities during the late 1990s and early 2000s (Earnhart 2004b,c; Glicksman & Earnhart 2007). Formal enforcement actions with monetary penalties impacted compliance and pollution at pulp and paper plants during the 1990s and 2000s (Shimshack & Ward 2005, 2008).

Evidence for specific deterrence arises in many other environmental settings as well. Three seminal papers find that some monitoring activities resulted in reduced oil spill frequency and oil spill size (Epple & Visscher 1984, Cohen 1987, Grau & Groves 1997). Although some enforcement interventions failed to significantly impact gas and liquid pipeline operation during the late 2000s and early 2010s, federal cases initiated against operators may have improved many aspects of environmental performance (Stafford 2014). Deterrence effects of inspections under Canadian petroleum storage regulations appear to be small but positive (Eckert 2004). Rule changes increasing liability or penalties significantly reduced hazardous waste violations and toxic releases in the late 1980s and 1990s (Alberini & Austin 1999, 2002; Stafford 2002, 2003).[19]

Empirical evidence for specific deterrence is not restricted to US and Canadian contexts. Plants facing regulatory inspections in Mexico self-reported increased compliance during the 1990s (Dasgupta et al. 2000). Although evidence on deterrence in European contexts is surprisingly rare (Tosun 2012), increased enforcement appears to have reduced environmental crime and waste dumping in Germany during the 1990s and 2000s (Almer & Goeschl 2010, 2013). The probability of detection strongly influenced Danish farmers' compliance with agro-environmental regulations during the late 1990s (Winter & May 2001). Inspections reduced subsequent air and water pollution emissions at manufacturing facilities in China in the 1990s (Dasgupta et al. 2001).

Despite a strong consensus in favor of specific deterrence, a handful of empirical studies find that some interventions reduce environmental performance. Although this finding may be consistent with some noneconomic theories of deterrence, the more likely explanation is that these studies fail to adequately address the nonrandom nature of environmental inspections and sanctions. Gray & Shimshack (2011) discuss endogeneity challenges arising in observational deterrence investigations, as well as possible empirical solutions to these challenges.

Observational endogeneity also suggests a promising and growing role for experimental evidence. Lab-based experiments of basic deterrence theory find that increasing the probability of detection or the sanction for noncompliance increases compliance (e.g., Anderson & Stafford 2003, Friesen 2012). Murphy & Stranlund (2006) demonstrate that enforcement pressure reduced emissions in laboratory permit markets, but only via changes in the allowance prices as predicted by theory.[20] Telle (2013) provides compelling evidence from a natural experiment in Norway that inspections raised environmental compliance. Duflo et al. (2013) find that reformed incentives for third-party auditors reduced false self-reports and reduced pollution at plants in the Indian state of Gujarat.

4.2.2. Empirical investigations of general deterrence and beyond-compliance behavior. Scholars and regulators have long believed that monitoring and enforcement actions spill over to enhance compliance for agents other than the inspected or sanctioned agent. The intuition is that monitoring and enforcement actions enhance the regulator's reputation for toughness, and plants update their beliefs in response to new perceptions of regulatory stringency. In a qualitative survey of regulated companies in Oregon, Carlough (2004) finds that 10–40% of respondents reported

[19]Sigman (2009) demonstrates that liability rule changes for toxic pollution can have important consequences for property markets.

[20]Stranlund (2011) and Friesen & Gangadharan (2013) more completely discuss the laboratory evidence on enforcement in environmental markets.

making changes in response to hearing about inspections or penalties at other Oregon facilities. Percentages were higher for larger facilities. Thornton et al. (2005) survey US industrial facilities and find that nearly 90% of respondents were aware of at least some enforcement actions at other firms. Sixty percent of respondents reported making changes in response to hearing about other facilities' penalties. However, recall about specific signal cases at other facilities in the same state and sector was often imperfect.

Shimshack & Ward (2005) provide early quantitative evidence for general deterrence. The deterrence effects of monetary penalties for violations in the pulp and paper industry during the 1990s were almost as strong for other facilities as they were for the sanctioned facility. Furthermore, these general deterrence effects had significant effects on aggregate compliance. The statewide noncompliance rate for conventional water pollutants fell by nearly two-thirds in the year following a fine on any plant in the state. Gray & Shadbegian (2007) also find that interventions at manufacturing plants during the late 1990s enhanced compliance both at the evaluated facility and at facilities located nearby. Spillover effects, however, were limited by jurisdictional boundaries. Facilities located nearby, but across state lines, did not increase compliance in response to others' inspections.

General deterrence may also stem from private enforcement actions. Langpap & Shimshack (2010) find that violations at all wastewater plants in a state fell significantly following citizen suits against a wastewater treatment plant in that state. This general deterrence effect, however, was attenuated by the net crowding out of public enforcement. In other words, citizen suits enhance compliance, but direct deterrence effects are overstated because citizen suits in a state and sector reduce public enforcement in that state and sector.

Economists typically view all types of enforcement as a means of achieving compliance. Recent evidence suggests that public enforcement actions may also increase beyond-compliance or overcompliance behaviors. Shimshack & Ward (2008), using data from the pulp and paper industry during the 1990s and 2000s, find that increased expected penalties induced typically complying facilities to lower pollution even further below legally permitted levels. Moreover, facilities that may have been noncompliant reduced discharges to well below permitted levels when expected penalties increased. These empirical results are puzzling when interpreted through the lens of a simple, deterministic, one-pollutant model of the firm. However, Shimshack & Ward (2008) demonstrate that beyond-compliance behavior can be fully rationalized by economic theory. That paper finds practically and economically significant evidence that stochastic pollution and jointness in pollution production drive the results. In periods of high perceived regulatory scrutiny, facilities lower target discharges to reduce the probability of accidental violations from randomness. Similarly, in periods of high regulatory scrutiny, facilities lower target discharges of one pollutant to reduce the probability of a violation for a jointly produced copollutant.

4.2.3. Extensions to the empirical deterrence literature. The environmental deterrence literature increasingly explores the heterogeneity of enforcement responses across facility characteristics. As a general rule, the impact of inspections and sanctions varies across facility size, firm size, firm financial status, industrial sector, community characteristics, permit conditions, and other characteristics (e.g., Alberini & Austin 2002, Carlough 2004, Gray & Shadbegian 2005, Deily & Gray 2007, Earnhart 2009, Hanna & Oliva 2010, Earnhart & Segerson 2013). However, if and when deterrence heterogeneity is systematic or generalizable are not clear.[21]

[21]Murphy & Stranlund's (2007) experimental evidence shows that, as predicted by theory, enforcement responses do not seem to vary significantly with agent characteristics when the regulation is price based.

The impact of environmental monitoring and enforcement activities also varies across instruments. State inspections, federal inspections, state administrative sanctions, federal administrative sanctions, civil penalties, and criminal penalties generate different deterrence effects on average. Laboratory evidence and empirical evidence suggest that marginal changes in sanction magnitudes may impact deterrence more than marginal changes in the probability of detection (Nadeau 1997, Anderson & Stafford 2003, Earnhart 2004c, Shimshack & Ward 2005, Glicksman & Earnhart 2007, Friesen 2012). This result is not universally found, however. Federal actions seem to generate larger deterrence effects than state actions do, and civil penalties seem to generate deterrence impacts at least as large as those stemming from administrative penalties (Earnhart 2004c, 2009; Miller 2005). The evidence comparing deterrence from criminal sanctions with deterrence from other sanctions is sparse, but Miller (2005) finds that DOJ criminal penalties reduced environmental recidivism rates at US companies more than administrative or civil penalties did.

5. DISCUSSION

What have we learned? First, environmental monitoring and enforcement actions are effective on average. Inspections and sanctions directly reduce pollution, deter future violations, and even encourage beyond-compliance behavior at the monitored or sanctioned facilities. Inspections and sanctions spill over to deter violations and to reduce pollution at facilities other than the monitored or sanctioned facility. Second, current environmental monitoring and enforcement practices are unlikely to be fully cost effective. Environmental regulators do not appear to strictly maximize social welfare, and observed regulator behavior often departs from optimal enforcement.

The above lessons notwithstanding, we have a lot left to learn about how—and how well—monitoring and enforcement work. First, how effective are monitoring and enforcement interventions in an international, and especially developing country, context? If and when empirical lessons from the North American experience translate to other contexts are unclear. Second, how do social norms, social dynamics, and economic psychology influence monitoring and enforcement? Environmental economists have been slow to investigate the causes and consequences of behavioral complications, social interactions, and compliance motivations other than through simple utilitarian calculations. Third, how does the practice of monitoring and enforcement match the theory? My sense is that many worthy existing hypotheses remain untested.

We also have a lot left to learn about the social trade-offs involved in monitoring and enforcement. First, are traditional monitoring and enforcement instruments efficient? Although the evidence indicates that enforcement actions get results, how the benefits compare with the administrative and compliance costs is not clear. Second, are monitoring and enforcement instruments cost effective? Ideally, we would understand how the environmental bang per buck from traditional inspections and sanctions compares with the environmental bang per buck from voluntary, cooperative, and information-based alternatives. Similarly, when are alternative policy instruments complements to traditional enforcement, and when are they substitutes for traditional enforcement? Voluntary programs and transparency programs can both leverage and undermine enforcement.[22]

[22]I do not mean to suggest that the topics in the final two paragraphs of this article have not been studied at all. Dasgupta et al. (2001) and Lo et al. (2009) study developing country contexts; May & Winter (2000), Winter & May (2001), and Muehlenbachs et al. (2013) explore social norms and social interactions; Helland (1998a) and Heyes & Rickman (1999) test prominent theories; Cohen (1986) and Magat & Viscusi (1990) perform benefit-cost analyses; Foulon et al. (2002) compare enforcement and transparency; and Innes & Sam (2008) and Toffel & Short (2011) investigate strategic complementarities across compliance instruments.

DISCLOSURE STATEMENT

The author is not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review.

ACKNOWLEDGMENTS

I thank Michael Ward and Wayne Gray, as many of the ideas in this article came out of joint work. Jon Silberman and Dinah Koehler provided helpful discussions of related work.

LITERATURE CITED

Alberini A, Austin DH. 1999. Strict liability as a deterrent in toxic waste management: empirical evidence from accident and spill data. *J. Environ. Econ. Manag.* 38:20–48

Alberini A, Austin D. 2002. Accidents waiting to happen: liability policy and toxic pollution releases. *Rev. Econ. Stat.* 84:729–74

Almer C, Goeschl T. 2010. Environmental crime and punishment: empirical evidence from the German penal code. *Land Econ.* 86:707–26

Almer C, Goeschl T. 2013. The Sopranos redux: the empirical economics of waste crime. *Reg. Stud.* doi:10.1080/00343404.2013.854323

Anderson LR, Stafford SL. 2003. Punishment in a regulatory setting: experimental evidence from the VCM. *J. Regul. Econ.* 24:91–110

Ashenmiller B, Norman CS. 2011. Measuring the impact of anti-SLAPP legislation on monitoring and enforcement. *B.E. J. Econ. Anal. Policy* 11:1–17

Ayres I, Braithwaite J. 1992. *Responsive Regulation: Transcending the Deregulation Debate*. Oxford, UK: Oxford Univ. Press

Becker GS. 1968. Crime and punishment: an economic approach. *J. Polit. Econ.* 76:169–217

Becker GS, Stigler GJ. 1974. Law enforcement, malfeasance, and compensation of enforces. *J. Legal Stud.* 3:1–18

Bentham J. 1789. *An Introduction to the Principles of Morals and Legislation*. Oxford, UK: Clarendon

Billiet CM, Rousseau S. 2014. How real is the threat of imprisonment for environmental crime? *Eur. J. Law Econ.* 37:183–98

Bressman LS, Vandenbergh MP. 2006. Inside the administrative state: a critical look at the practice of presidential control. *Mich. Law Rev.* 105:47–99

Burby RJ, Paterson RG. 1993. Improving compliance with state environmental regulations. *J. Policy Anal. Manag.* 12:753–72

Carlough L. 2004. *General deterrence of environmental violation: a peek into the mind of the regulated public*. Rep., Dep. Environ. Qual., State Or.

Coase RH. 1960. The problem of social cost. *J. Law Econ.* 3:1–44

Cohen MA. 1986. The costs and benefits of oil spill prevention and enforcement. *J. Environ. Econ. Manag.* 13:167–88

Cohen MA. 1987. Optimal enforcement strategy to prevent oil spills: an application of a principal-agent model with moral hazard. *J. Law Econ.* 30:23–51

Cohen MA. 1992. Environmental crime and punishment: legal/economic theory and empirical evidence on enforcement of federal environmental statutes. *J. Crim. Law Criminol.* 82:1054–108

Cohen MA. 1999. Monitoring and enforcement of environmental policy. *Int. Yearb. Environ. Resour. Econ.* 3:44–106

Dasgupta S, Hettige H, Wheeler D. 2000. What improves environmental compliance? Evidence from Mexican industry. *J. Environ. Econ. Manag.* 39:39–66

Dasgupta S, Laplante B, Mamingi N, Wang H. 2001. Inspections, pollution prices, and environmental performance: evidence from China. *Ecol. Econ.* 36:487–98

Deily ME, Gray WB. 1991. Enforcement of pollution regulations in a declining industry. *J. Environ. Econ. Manag.* 21:260–74

Deily ME, Gray WB. 2007. Agency structure and firm culture: OSHA, EPA, and the steel industry. *J. Law Econ. Organ.* 23:685–709
Delmas MA, Toffel MW. 2008. Organizational responses to environmental demands: opening the black box. *Strateg. Manag. J.* 29:1027–55
Dion C, Lanoie P, Laplante B. 1998. Monitoring of pollution regulation: Do local conditions matter? *J. Regul. Econ.* 13:5–18
Doonan J, Lanoie P, Laplante B. 2005. Determinants of environmental performance in the Canadian pulp and paper industry: an assessment from inside the industry. *Ecol. Econ.* 55:73–84
Duflo E, Greenstone M, Pande R, Ryan N. 2013. Truth-telling by third-party auditors and the response of polluting firms: experimental evidence from India. *Q. J. Econ.* 128:1499–545
Earnhart D. 2000. Environmental "citizen suits" in the Czech Republic. *Eur. J. Law Econ.* 10:43–68
Earnhart D. 2004a. The effects of community characteristics on polluter compliance levels. *Land Econ.* 80:408–32
Earnhart D. 2004b. Panel data analysis of regulatory factors shaping environmental performance. *Rev. Econ. Stat.* 86:391–401
Earnhart D. 2004c. Regulatory factors shaping environmental performance at publicly-owned treatment plants. *J. Environ. Econ. Manag.* 48:655–81
Earnhart D. 2009. The influence of facility characteristics and permit conditions on the effectiveness of environmental regulatory deterrence. *J. Regul. Econ.* 36:247–73
Earnhart D, Segerson K. 2013. The influence of financial status on the effectiveness of environmental enforcement. *J. Public Econ.* 96:670–84
Eckert H. 2004. Inspections, warnings, and compliance: the case of petroleum storage regulation. *J. Environ. Econ. Manag.* 47:232–59
Eckert H, Eckert A. 2010. The geographic distribution of environmental inspections. *J. Regul. Econ.* 37:1–22
Epple D, Visscher M. 1984. Environmental pollution: modeling occurrence, detection, and deterrence. *J. Law Econ.* 27:29–60
Foulon J, Lanoie P, Laplante B. 2002. Incentives for pollution control: regulation or information? *J. Environ. Econ. Manag.* 44:169–87
Friesen L. 2003. Targeting enforcement to improve compliance with environmental regulations. *J. Environ. Econ. Manag.* 46:72–85
Friesen L. 2012. Certainty of punishment versus severity of punishment: an experimental investigation. *South. Econ. J.* 79:399–421
Friesen L, Gangadharan L. 2013. Environmental markets: What do we learn from the lab? *J. Econ. Surv.* 27:515–35
Garvie D, Keeler A. 1994. Incomplete enforcement with endogenous regulatory choice. *J. Public Econ.* 55:141–62
Giles C. 2013. Next generation compliance. *Environmental Forum*, Sept.–Oct., pp. 22–25
Glicksman RL, Earnhart DH. 2007. Comparative effectiveness of government interventions on environmental performance in the chemical industry. *Stanf. Environ. Law J.* 26:317
Grant LE, Grooms K. 2012. *Do non-profits encourage compliance? Watershed groups and the US Clean Water Act*. Work. Pap., Dep. Econ., Univ. Wis., Milwaukee
Grant LE, Langpap C. 2013. *Private provision of public goods: evidence from the effect of environmental groups on water quality*. Work. Pap., Dep. Econ., Univ. Wis., Milwaukee
Grau MV, Groves T. 1997. The oil spill process: the effect of coast guard monitoring on oil spills. *Environ. Resour. Econ.* 10:315–39
Gray WB, Deily ME. 1996. Compliance and enforcement: air pollution regulation in the US steel industry. *J. Environ. Econ. Manag.* 31:96–111
Gray WB, Shadbegian RJ. 2004. "Optimal" pollution abatement—whose benefits matter, and how much? *J. Environ. Econ. Manag.* 47:510–34
Gray WB, Shadbegian RJ. 2005. When and why do plants comply? Paper mills in the 1980s. *Law Policy* 27:238–61
Gray WB, Shadbegian RJ. 2007. The environmental performance of polluting plants: a spatial analysis. *J. Reg. Sci.* 47:63–84

Gray WB, Shimshack JP. 2011. The effectiveness of environmental monitoring and enforcement: a review of the empirical evidence. *Rev. Environ. Econ. Policy* 5:3–24
Grooms KK. 2012. *Enforcing the Clean Water Act: the effect of state-level corruption on compliance*. Work. Pap., Dep. Econ., Univ. Calif., Santa Barbara
Hanna RN, Oliva P. 2010. The impact of inspections on plant-level air emissions. *B.E. J. Econ. Anal. Policy* 10:1–31
Harford JD. 1991. Measurement error and state-dependent pollution control enforcement. *J. Environ. Econ. Manag.* 21:67–81
Harford JD. 1993. Improving on the steady state in the state-dependent enforcement of pollution control. *J. Environ. Econ. Manag.* 24:133–38
Harford JD, Harrington W. 1991. A reconsideration of enforcement leverage when penalties are restricted. *J. Public Econ.* 45:391–95
Harrington W. 1988. Enforcement leverage when penalties are restricted. *J. Public Econ.* 37:29–53
Harrison K. 1995. Is cooperation the answer? Canadian environmental enforcement in comparative context. *J. Policy Anal. Manag.* 14:221–44
Helland E. 1998a. The enforcement of pollution control laws: inspections, violations, and self-reporting. *Rev. Econ. Stat.* 80:141–53
Helland E. 1998b. Environmental protection in the federalist system: the political economy of NPDES inspections. *Econ. Inq.* 36:305–19
Helland E. 1998c. The revealed preferences of state EPAs: stringency, enforcement, and substitution. *J. Environ. Econ. Manag.* 35:242–61
Heyes AG. 1994. Environmental enforcement when "inspectability" is endogenous: a model with overshooting properties. *Environ. Resour. Econ.* 4:479–94
Heyes A. 2000. Implementing environmental regulation: enforcement and compliance. *J. Regul. Econ.* 17:107–29
Heyes A, Rickman N. 1999. Regulatory dealing—revisiting the Harrington paradox. *J. Public Econ.* 72:361–78
Hilton GW. 1972. The basic behavior of regulatory commissions. *Am. Econ. Rev.* 62:47–54
Innes R. 1999a. Remediation and self-reporting in optimal law enforcement. *J. Public Econ.* 72:379–93
Innes R. 1999b. Self-policing and optimal law enforcement when violator remediation is valuable. *J. Polit. Econ.* 107:1305–25
Innes R. 2001. Violator avoidance activities and self-reporting in optimal law enforcement. *J. Law Econ. Organ.* 17:239–56
Innes R, Mitra A. 2011. *Parties, politics, and regulation: how Congressmen affect local EPA enforcement of Clean Air laws*. Work. Pap., Cent. Energy Environ. Econ., Univ. Calif., Berkeley
Innes R, Sam AG. 2008. Voluntary pollution reductions and the enforcement of environmental law: an empirical study of the 33/50 program. *J. Law Econ.* 51:271–96
Joskow PL. 1974. Inflation and environmental concern: structural change in the process of public utility price regulation. *J. Law Econ.* 17:291–327
Kagan RA, Gunningham N, Thornton D. 2003. Explaining corporate environmental performance: How does regulation matter? *Law Soc. Rev.* 37:51–90
Kaplow L, Shavell S. 1994. Optimal law enforcement with self-reporting of behavior. *J. Polit. Econ.* 102:583–606
Keohane NO, Mansur ET, Voynov A. 2009. Averting regulatory enforcement: evidence from new source review. *J. Econ. Manag. Strategy* 18:75–104
Kleit AN, Pierce MA, Hill RC. 1998. Environmental protection, agency motivations, and rent extraction: the regulation of water pollution in Louisiana. *J. Regul. Econ.* 13:121–37
Konisky DM. 2007. Regulatory competition and environmental enforcement: Is there a race to the bottom? *Am. J. Polit. Sci.* 51:853–72
Landes WM, Posner RA. 1975. The private enforcement of law. *J. Legal Stud.* 4:1–46
Landsberger M, Meilijson I. 1982. Incentive generating state dependent penalty system: the case of income tax evasion. *J. Public Econ.* 19:333–52
Langpap C. 2007. Pollution abatement with limited enforcement power and citizen suits. *J. Regul. Econ.* 31:57–81

Langpap C, Shimshack JP. 2010. Private citizen suits and public enforcement: substitutes or complements? *J. Environ. Econ. Manag.* 59:235–49
Laplante B, Rilstone P. 1996. Environmental inspections and emissions of the pulp and paper industry in Quebec. *J. Environ. Econ. Manag.* 31:19–36
Leaver C. 2009. Bureaucratic minimal squawk behavior: theory and evidence from regulatory agencies. *Am. Econ. Rev.* 99:572–607
Linder SH, McBride ME. 1984. Enforcement costs and regulatory reform: the agency and firm response. *J. Environ. Econ. Manag.* 11:327–46
Livernois J, McKenna CJ. 1999. Truth or consequences: enforcing pollution standards with self-reporting. *J. Public Econ.* 71:415–40
Lo CWH, Fryxell GE, van Rooij B. 2009. Changes in enforcement styles among environmental enforcement officials in China. *Environ. Plan. A* 41:2706–23
Magat WA, Viscusi WK. 1990. Effectiveness of the EPA's regulatory enforcement: the case of industrial effluent standards. *J. Law Econ.* 33:331–60
Malik AS. 1990a. Avoidance, screening and optimum enforcement. *Rand J. Econ.* 21:341–53
Malik AS. 1990b. Markets for pollution control when firms are noncompliant. *J. Environ. Econ. Manag.* 18:97–106
Malik AS. 1993. Self-reporting and the design of policies for regulating stochastic pollution. *J. Environ. Econ. Manag.* 24:241–57
May PJ. 2005. Regulation and compliance motivations: examining different approaches. *Public Adm. Rev.* 65:31–44
May P, Winter S. 2000. Reconsidering styles of regulatory enforcement: patterns in Danish agro-environmental inspection. *Law Policy* 22:143–73
Miller A. 2005. *What makes companies behave? An analysis of criminal and civil penalties under environmental law.* **http://papers.ssrn.com/sol3/papers.cfm?abstract_id=471841**
Mintz JA. 2012. *Enforcement at the EPA: High Stakes and Hard Choices*. Austin, TX: Univ. Tex. Press. Revis. ed.
Mookherjee D, Png IP. 1994. Marginal deterrence in enforcement of law. *J. Polit. Econ.* 102:1039–66
Muehlenbachs L, Staubli S, Cohen MA. 2013. *The effect of inspector group size and familiarity on enforcement and deterrence*. Discuss. Pap. 13-36, Resour. Future, Washington, DC
Murphy JJ, Stranlund JK. 2006. Direct and market effects of enforcing emissions trading programs: an experimental analysis. *J. Econ. Behav. Organ.* 61:217–33
Murphy JJ, Stranlund JK. 2007. A laboratory investigation of compliance behavior under tradable emissions rights: implications for targeted enforcement. *J. Environ. Econ. Manag.* 53:196–212
Nadeau LW. 1997. EPA effectiveness at reducing the duration of plant-level noncompliance. *J. Environ. Econ. Manag.* 34:54–78
Naysnerski W, Tietenberg T. 1992. Private enforcement of federal environmental law. *Land Econ.* 68:28–48
Niskanen WA. 1971. *Bureaucracy and Representative Government*. Piscataway, NJ: Transaction
Oljaca N, Keeler AG, Dorfman J. 1998. Penalty functions for environmental violations: evidence from water quality enforcement. *J. Regul. Econ.* 14:255–64
Peltzman S. 1976. Toward a more general theory of regulation. *J. Law Econ.* 19:211–24
Polinsky AM, Shavell S. 2000. The economic theory of public enforcement of law. *J. Econ. Lit.* 38:45–76
Rousseau S. 2007. Timing of environmental inspections: survival of the compliant. *J. Regul. Econ.* 32:17–36
Scarlett L, Fraas A, Morgenstern R, Murphy T. 2011. *Regulating and enforcing environmental, health, and safety risks: a comparative assessment of the Minerals Management Service and other agencies*. Discuss. Pap. 10-64, Resour. Future, Washington, DC
Scholz JT. 1984. Voluntary compliance and regulatory enforcement. *Law Policy* 6:385–404
Segerson K, Tietenberg T. 1992. The structure of penalties in environmental enforcement: an economic analysis. *J. Environ. Econ. Manag.* 23:179–200
Shavell S. 2004. *Foundations of Economic Analysis of Law*. Cambridge, MA: Harvard Univ. Press
Shimshack JP, Ward MB. 2005. Regulator reputation, enforcement, and environmental compliance. *J. Environ. Econ. Manag.* 50:519–40

Shimshack JP, Ward MB. 2008. Enforcement and over-compliance. *J. Environ. Econ. Manag.* 55:90–105
Sigman H. 2009. Environmental liability and redevelopment of old industrial land. *J. Law Econ.* 53:289–306
Smith KM. 2004. Who's suing whom? A comparison of government and citizen suit environmental enforcement actions brought under EPA-administered statutes, 1995–2000. *Columbia J. Environ. Law* 29:359–414
Spence DB. 2001. The shadow of the rational polluter: rethinking the role of rational actor models in environmental law. *Calif. Law Rev.* 89:917–98
Stafford SL. 2002. The effect of punishment on firm compliance with hazardous waste regulations. *J. Environ. Econ. Manag.* 44:290–308
Stafford SL. 2003. Assessing the effectiveness of state regulation and enforcement of hazardous waste. *J. Regul. Econ.* 23:27–41
Stafford SL. 2006. Rational or confused polluters? Evidence from hazardous waste compliance. *B.E. J. Econ. Anal. Policy* 5:1–31
Stafford SL. 2014. Will additional federal enforcement improve the performance of pipelines in the US? *Int. Rev. Law Econ.* 37:137–46
Stigler GJ. 1971. The theory of economic regulation. *Bell J. Econ. Manag. Sci.* 2:3–21
Stranlund J. 2011. *A brief review of the economics of enforcing environmental policies*. Work. Pap. 1-15, Dep. Resour. Econ., Univ. Mass., Amherst
Stranlund J. 2013. Enforcement. In *Encyclopedia of Energy, Natural Resource, and Environmental Economics*, Vol. 3: *Environment*, ed. J Shogren, pp. 150–54. Amsterdam: Elsevier
Stranlund J, Dhanda KK. 1999. Endogenous monitoring and enforcement of transferable emission permit system. *J. Environ. Econ. Manag.* 38:267–82
Telle K. 2013. Monitoring and enforcement of environmental regulations: lessons from a natural field experiment in Norway. *J. Public Econ.* 99:24–34
Thornton D, Gunningham NA, Kagan RA. 2005. General deterrence and corporate environmental behavior. *Law Policy* 27:262–88
Toffel MW, Short JL. 2011. Coming clean and cleaning up: Does voluntary self-reporting indicate effective self-policing? *J. Law Econ.* 54:609–49
Tosun J. 2012. Environmental monitoring and enforcement in Europe: a review of empirical research. *Environ. Policy Gov.* 22:437–48
Uhlmann DM. 2009. Environmental crime comes of age: the evolution of criminal enforcement in the environmental regulatory scheme. *Utah Law Rev.* 4:1223–52
Winter SC, May PJ. 2000. Reconsidering styles of regulatory enforcement: patterns in Danish agro-environmental inspection. *Law Policy* 22(2):143–73
Winter SC, May PJ. 2001. Motivation for compliance with environmental regulations. *J. Policy Anal. Manag.* 20(4):675–98
Woods ND. 2006. Interstate competition and environmental regulation: a test of the race-to-the-bottom thesis. *Soc. Sci. Q.* 87:174–89