Securing Property Rights

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A central challenge in securing property rights is the subversion of justice. We present a model of a polluter whose discharges harm multiple owners, and we compare property rules, liability rules, and regulation on efficiency grounds. We provide conditions under which property

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rules are preferred to liability rules, thus verifying the Calabresi-Melamed conjecture. Regulation that enforces partial abatement may be preferred to either of the extreme rules. An empirical analysis of water quality in the United States before and after the Clean Water Act shows that the effects of regulation are consistent with several predictions of the model.

> The question I have to decide is, whether the appeal to me by the defendant to deprive the plaintiff of his right of way and give him money damages instead, can be entertained. I think it cannot. [If it were,] of course that simply means the Court in every case, at the instance of the rich man, is to compel the poor man to sell him his property at a valuation. . . . I am quite satisfied nothing of the kind was ever intended, and that if I acceded to this view . . . I should add one more to the number of instances which we have from the days in which the Bible was written until the present moment, in which the man of large possessions has endeavoured to deprive his neighbour, the man with small possessions, of his property, with or without adequate compensation. (Krehl v. Burrell, 7 Ch. D. 553 [1878])

> The whole point of a property regime is to restrain the strong from resorting to their strength. . . . The weak are no longer vulnerable to unrestrained depredations, and they now have the chance of becoming rich without becoming strong. . . . The only thing that is certain to be certain under property is effective protection of the weak against violent dispossession by the strong, and vice versa. (Kennedy and Michelman 1980, 723)

I. Introduction

Economists since Montesquieu (1748) and Smith (1776) have seen protection of property rights as essential for growth and prosperity.[1] Yet property in much of the world today remains insecure. Even in the developed world, exposure to dangerous pollution and trespass by hunters or neighbors' cattle are common concerns. In the developing world, the land and property of the weaker members of society are vulnerable to outright takings by the stronger ones—be they tribal chiefs, powerful neighbors, or even men taking from women (Ali, Deininger, and Goldstein 2014; Ali et al. 2014). People everywhere fear expropriation by the state through

[1] For the aggregate evidence in favor of this consensus, see, e.g., Barro (1990), De Long and Shleifer (1993), and Acemoglu, Johnson, and Robinson (2001). For micro evidence, see Besley (1995), De Soto (2000), Field (2005, 2007), Goldstein and Udry (2008), Dell (2010), and Hornbeck (2010).

eminent domain without just compensation (Munch 1976; Chang 2010; Singh 2012; Somin 2015). At the heart of insecurity of property is the belief that institutions of law and order—such as the police and the courts—fail to protect the weak in conflicts with the strong.

We provide some evidence that such subversion of justice is a major concern for people in developing countries today. We then show theoretically that several key aspects of securing property can be understood from this perspective. Using a model of a "strong" water polluter who can influence a court in its determination of damages and multiple "weak" affected property owners who cannot, we compare the efficiency of alternative legal rules, including property rules, liability rules, and regulation. The assumption of a strong polluter who can subvert the determination of damages is a central innovation of our model. The assumption of multiple victims is a standard way to model the limits of bargaining.

In this model, the upside of a property rule relative to a liability rule is that it grants land owners protection that is invulnerable to subversion by the polluter. The downside is that it relies on bargaining to attain efficiency, and when bargaining fails, it stops efficient pollution. Regulation can address these inefficiencies by mandating abatement up to a prespecified level and enforcing this mandate with stark penalties like those of a property rule. Intuitively, regulation is thus equivalent to a partial property rule.

Both regulation and the property rule have the upside of reducing harm when courts are subverted and the downside of being relatively inflexible. Regulation, however, does not fully stop pollution when bargaining fails. It is a crude instrument, like the property rule, but nonetheless avoids both extremes of no pollution or unabated pollution. Therefore, it can do better than either pure legal rule. We then apply our approach to water pollution across US counties, showing how historically court-enforced liability rules failed to protect private property from externalities, especially in the more corrupt places, and how regulation through the 1972 Clean Water Act (CWA) has improved water quality.

The World Justice Project (WJP) conducts surveys of around 1,000 households in each of 102 countries. For countries with population above 50 million, we aggregated over the surveyed households in each country responses to the following question: "In your opinion, most judges decide cases according to: (single answer) 1. What the government tells them to do; 2. What powerful private interests tell them to do; 3. What the law says." The basic fact that motivated our analysis is that in the median country, over half of respondents think that courts decide cases according to the preferences of private interests and the state rather than the law. That figure is over 80% in Mexico. Judges, according to most respondents, cater to the government and the strong. Experts from many countries surveyed by the WJP, especially the developing ones, agree that courts are swayed by corruption and political influence and that the poor are at a substantial disadvantage in court.

In this world of uncertain justice, many people fear that the government will take their property without compensation. About 40%–50% of WJP respondents in most countries say that it is "unlikely" or "very unlikely" that homeowners will "be fairly compensated by the government" if "the government decides to build a major public works project in your neighborhood (such as a railway station or a highway), and . . . the construction of this public works project requires the demolition of private homes in your community/neighborhood." The justice system disproportionately fails the weak.

The subversion of justice by the strong and by the state suggests a new lens for asking how best to secure property from takings or nuisances such as pollution. This is extensively charted territory, but it is largely under the assumption that courts enforce the law or make only random errors. Take the case of pollution. Should those who pollute the property of others pay compensation for harm caused to the owners—a liability rule? Alternatively, should property be protected through a property rule that always deters polluters from emitting? And why would regulation, such as the CWA, ever be needed?

Many scholars see liability rules that make victims whole as more efficient on the grounds that such rules provide missing "prices" to potential violators (e.g., Cooter 1984; Ayres and Talley 1995; Kaplow and Shavell 1996). When polluters must fairly compensate victims for harm, they will take these costs into account. Yet many societies use injunctions to stop pollution, as well as even harsher measures, such as legally permissible self-defense, to stop trespass (Smith 2004). The epigraphs at the top of the paper suggest that such ways of securing property have received wide support, particularly from those who believe that liability rules fail to protect the poor. At the same time, in many situations such as pollution, property rules have increasingly been replaced by regulation, often combined with liability.

We revisit these debates in a model of multiple owners and a polluter. We assume throughout that the owners' property right to uncontaminated land is established and undisputed, although this question has also been examined by courts. Our question instead is how best to secure this existing property right. We further assume that interference with this property right is also indisputable—in our case because there is only one potential polluter—and first compare the liability rule and the property rule. In this framework, the case without any subversion of justice yields the conclusions of the Coase theorem, so property and liability rules are equivalent. However, when the polluter can subvert damage awards by influencing courts, property and liability rules are not equivalent. Property rules have the advantage of stopping the polluter even when courts can be subverted, but they heavily rely on bargaining and stop even efficient pollution when bargaining fails. Our analysis explains the dominance of property rules as the means of securing property rights when there is only one (or a couple) potential victims—so bargaining can work—and when courts cannot be relied on to assess damages fairly.

But what if the courts are vulnerable to subversion and, as in the case of modern pollution, there are many potential victims, so bargaining is likely to fail? An alternative to the two legal rules is government regulation, whereby the polluter is required to abate his emissions beyond a regulated level and to install at some cost a monitoring system that measures compliance. The violation of these limits is punished by criminal or other heavy penalties that are independent of the harm done, as with a property rule. Within regulated limits, pollution is governed by a liability regime instead. This is not the only way to model regulation, but it captures the essential features of the CWA. We show that while such regulation rarely achieves full efficiency, it can do better than either the property or the liability rule, because it successfully enforces some (though not necessarily efficient) abatement when the subverted liability rule limits pollution too little and when the property rule without bargaining limits it too much.

In section V, we test the predictions of our model on the history of water pollution in the United States. We summarize the evidence pointing to the failure of courts to stop water pollution. The legal literature following Horwitz (1973, 1977) argues that nineteenth-century courts moved from a property-rule approach to water pollution ("ancient use") to a liability-rule approach ("reasonable use") because bargaining among riparian owners became impossible when large-scale polluters impacted increasingly crowded waterscapes (Rose 1990; Paavola 2002). In practice, however, courts often failed to impose standard damages on large-scale polluters because, as the Pennsylvania Supreme Court ruled in 1886, "trifling inconveniences to particular persons must sometimes give way to the necessities of a great community" (*Pennsylvania Coal Co. v. Sanderson*, 6 Atl. 453). Government regulation, starting with the states and followed by the federal CWA, was a response to this failure.

We use micro data on water quality from Keiser and Shapiro (2019) to show how the CWA, by restricting emissions directly rather than focusing on the harm they cause, improved water quality. We show that the effects of the CWA were particularly pronounced in industrial (as opposed to agricultural) counties, because the CWA did not directly enforce abatement of emissions from farms, and in the more corrupt states, where court enforcement of the earlier liability regime was presumably weaker. The results suggest that in this instance, regulation enforced by property-rule penalties worked in the ways suggested by our model.

Our analysis relates to several ideas and debates in law and economics. Glaeser and Shleifer (2003) argue that the transition from litigation to regulation in the United States was driven by concerns with subversion of justice; our analysis uses a different model and applies it to a broader set of issues, including alternative legal rules. It speaks to a long-standing debate on the relative merits of liability and property rules as ways of enforcing property rights (Calabresi and Melamed 1972; Polinsky 1979; Kaplow and Shavell 1996; Bebchuk 2001). In particular, our model portrays subversion as a systematic downside of fact-intensive rules, such as liability rules, and it shows that property rules and regulation are less vulnerable to subversion. As such, it delivers in a unified framework the Coase (1960) theorem, the Kaplow-Shavell (1996) result that liability rules are preferred to property rules when courts make only random errors but bargaining can fail, and the related and influential Calabresi-Melamed (1972) hypothesis that property rules are crucial complements to bargaining.

Our perspective reflects the classic view of bright-line rules as a way to economize on enforcement costs (Kaplow 1992; Mookherjee and Png 1992, 1994) but shifts the focus from direct administrative costs to the indirect cost of subversion. Our approach to court subversion is related to the work of Milgrom (1988) and Milgrom and Roberts (1988) on influence in organizations, although we do not focus on the problem of obtaining information from self-interested litigants or on the "influence costs" they waste to manipulate such information. Also related are the classic findings of Weitzman's (1974) study of price and quantity regulation and Cooter's (1984) study of legal prices and sanctions.

II. A Model

Our model contains multiple land owners and one polluter who may harm the owners' enjoyment of their property. The model also applies to other forms of interference with private property, such as trespass or outright takings. We focus on the optimal means of protecting private property, where optimality is defined as maximizing the sum of benefits to the owners and the polluter. We compare property rules, liability rules, and regulation using this definition of optimality.

In comparing alternative rules, our analysis turns crucially on the question of which facts are disputable. We assume throughout that the owners' property right itself is indisputable. Because we consider only one polluter, we are also assuming that his interference with that property right is indisputable. With multiple polluters, disputable responsibility becomes a further realistic complication, which strengthens the case for regulation, as we discuss in appendix 2.2 (apps. 1–3 are available online). On the other hand, we assume that the precise level of harm suffered by the owners as a result of pollution is disputable.

The standard approach in law and economics is to assume that even if some facts are disputable, the court will establish them, perhaps with random error but without a predictable, systematic bias in favor of a litigant (Coase 1960; Kaplow and Shavell 1996). Instead, we see indisputable facts as obvious to outsiders, so if the court misrepresented these facts its malfeasance would also be indisputable. Disputable facts are not obvious to outsiders, so the court's bias and misrepresentation go unchecked.

This implies that when the relevant legal rule depends only on indisputable facts, such as the polluter's interference with the owners' property rights, a court always applies that rule faithfully. In contrast, when the legal rule requires the court to assess disputable facts, such as the level of harm, a powerful polluter can subvert the court and distort the application of the rule. We assume for starkness that a subverted court simply rules in favor of the strong polluter, by assessing harm to be negligible. The essence of subversion of justice is judicial discretion when facts are disputable.[2] We examine the implications of this assumption for optimal legal rules and then evaluate them empirically.[3]

In our model, a polluter P can take an action that yields him a private benefit but imposes costs on a set of owners O_i, for $i = 1, 2, \ldots, N$. For example, a factory might dump runoff waste in a nearby river that impacts riverfront properties. The polluter can also pay a cost to adopt an abatement technology that reduces the social costs of his action. All agents' payoffs are normalized to zero if the polluter takes no action. If P acts without abatement, his payoff is $b > 0$ and each owner suffers harm $c/N > 0$. Abatement reduces P's benefit to $(1 - \rho_b)b$ and each O_i's harm to $(1 - \rho_c)c/N$, for $0 < \rho_b < \rho_c < 1$.[4] We are particularly interested in the two extreme cases of $N = 1$ (which corresponds to a classic trespass case) and large N (which corresponds to complex pollution cases).

The private benefit b of the activity is deterministic. The social cost of action c is stochastic with cumulative distribution $F(c)$ with a minimum value of $0 < b$. Sometimes unabated pollution—or for that matter taking—is efficient. The realization of c for owners in a particular case is known by the polluter P and every owner O_i. We assume for simplicity that harm from P's action is certain for each case and merely heterogeneous across cases, but in appendix 2.1 we show how our model naturally extends to the case of inadvertent harm, with residual ex ante uncertainty in a particular case.

[2] Judicial discretion is central to the analysis of legal rules (Frank 1932; Posner 2005). Courts' ability both to bias their interpretation of the law and to distort their findings of fact is a crucial factor driving the evolution of tort law and liability (Gennaioli and Shleifer 2007, 2008; Ponzetto and Fernandez 2008; Fernandez and Ponzetto 2012), as well as the development of contract law and the evolving structure of privately optimal contracts (Gennaioli 2013; Gennaioli and Ponzetto 2017).

[3] Our distinction between disputable and indisputable facts is different from that between verifiable and nonverifiable facts used as a foundation of incomplete contracts (Hart and Moore 1988). The idea there is that facts that can be verified will be verified honestly. For our model, it is easiest to think of all facts as verifiable, but a court can nevertheless choose to find such facts that are disputable in favor of the strong. The better the institutional environment, the lower likelihood of such a biased finding.

[4] We disregard the simpler case in which $\rho_c < \rho_b$; then abatement is a dominated option.

We consider three legal rules that aim to discourage inefficient action and to allow efficient action: a property rule, a liability rule, and regulation. Each rule specifies penalties that are enforced on the basis of facts assessed by a court. The court observes everything and with probability $1 - \delta$ assesses all facts honestly. With probability δ, the court is subverted by a powerful polluter. If the court is subverted, it assesses indisputable facts honestly but misrepresents disputable facts to improve the polluter's payoff.

We assume that whether P acted and therefore interfered with the property rights of the O_i's is indisputable. With one pollutant, the fact of his discharge into a river is obvious to all. However, the exact realization of harm c suffered by the owners is disputable. Experts hold different assessments of the actual damage suffered from any one pollutant. In the fraction δ of cases in which P subverts the court, harm is assessed at zero irrespective of its true realization c.

We assume that abatement is not automatically indisputable. However, the legislator can mandate that P invest in a monitoring technology, which costs m per polluting action and makes abatement indisputable. For instance, the Environmental Protection Agency's (EPA) National Pollutant Discharge Emission System (NPDES) "sets technology-based effluent limitations (TBELs) that the agency deems to be the best performing and affordable technology available to control the pollutant" (Shabman and Stephenson 2012, 210). The EPA specifies a pollution-abating technology for an industry, such as a particular form of filtration, and monitoring confirms that the technology has been adopted. The EPA enforces compliance through inspections and heavy penalties for violations of prespecified conditions. EPA monitoring rules enforce technology adoption more than they regulate quantity because "if the EPA technology proves ineffective, and the source can show it has properly installed and operated the prescribed technology, that source will still be in compliance with its permit" (Shabman and Stephenson 2012, 211).[5]

The timeline of the model follows.

Stage 0.—The legislator sets the legal rule protecting the owners and chooses whether to mandate a monitoring system to indisputably measure abatement.

Stage 1.—The social cost c and P's ability to subvert the court are realized and privately observed by P and each O_i. The parties have a chance to bargain and write a contract, but each O_i is unable to join the bargaining table with probability β. The ability to bargain is drawn independently across owners. Bargaining is otherwise efficient among the parties able to join the negotiation.

[5] Regulation often takes the form of mandates on technology that are then monitored by testing the levels of pollution outcomes. For example, emissions tests on automobiles evolved out of a regulatory system that began in 1960 when California required cars sold in the state to have positive crankcase ventilation.

Stage 2.—Polluter P chooses whether to act and, if he acts, whether to abate.

Stage 3.—If P acts, the court assesses facts and penalties are enforced.

In stage 3, the court assesses facts about the polluter's action, which may have different implications for penalties depending on the contract written in stage 1. For example, if all owners sign a contract allowing P to damage their property, then the court will not punish P for damaging their property. We consider the choice between different regimes for protecting property from harm, but with respect to contracts we assume that the only remedy for breach, in line with the common law practice, is the award of damages to the injured party proportional to the harm assessed by the court.[6]

A. *Rules*

In stage 0, the legislator chooses one of three rules: the property rule, the liability rule, or regulation.[7] Each of these rules also allows the possibility of contracts between P and the owners, which we turn to below. We first discuss the implications of each rule in the absence of contracts.

Under the property rule, every owner is entitled to be spared from the polluter's harmful activity. Hence, if P acts, he suffers a fixed penalty $f > b$, which could be a monetary fine, imprisonment, or physical harm. Whatever form it takes, the penalty f is large and relies only on the indisputable fact that the polluter acted; it does not depend on any fact-intensive verification of harm, abatement, or the number of owners whose right is violated. This penalty cannot be subverted by a powerful polluter.

Under the liability rule, every owner is entitled to compensation for any harm suffered as a result of the polluter's action. Hence, if P acts, he must pay damages to each O_i equal to assessed harm. If he cannot subvert the court, P's total payment equals the social cost of his action. This cost equals c if he acted without abatement or $(1 - \rho_c)c$ if he acted with abatement. If P can subvert the court, it assesses negligible harm so that P pays negligible damages. Damage awards that differ from assessed harm would serve no purpose in our model; they are irrelevant when the court is subverted and only distort behavior when it rules correctly.[8]

[6] This rule could be optimal averaging across all contracts, even though in a particular case such as the one we consider it might be optimal to instead allow parties to specify a fixed, punitive penalty for breach of contract. General common law principles make all such contractual penalties unenforceable in the United States.

[7] In our model, it is always preferable for the owners' property rights to be protected at least by the liability rule rather than not at all.

[8] Subversion in the assessment of harm means that the cost of pollution to P becomes independent of legal rules raising damages above the court's estimate of harm, such as double and treble damages. Polluter P's action can be deterred only by a penalty for action irrespective of harm—the property rule. On the other hand, damages equal to actual harm align the cost of pollution to P with its social cost when courts are not subverted.

Under regulation, every owner is entitled to be spared from action without abatement. This is an absolute entitlement protected by property-rule remedies. Acting without abatement is deterred by the threat of a certain, fixed penalty $f > b$. The CWA requires factories to adopt abatement technologies and makes violations punishable with criminal penalties. On the other hand, regulation protects owners with only liability-rule protection against action with abatement. If P documents abatement through the indisputable monitoring technology, the owners are entitled only to fair compensation for any harm suffered.[9] Assessed damages will then be negligible if P can subvert the court.

Abatement plays a different role under each rule. Under the property rule, abatement plays no role in the absence of a contract. The property rule deters any and all action that is not authorized by all the owners. Under the liability rule, abatement plays only an indirect role. Abatement reduces the harm suffered by the owners and thus the damages paid by P if he cannot subvert the court. However, the liability rule focuses exclusively on the level of harm, and the courts are not independently concerned with how P caused that harm. Liability penalties do not distinguish between an unabated action with intrinsically low social costs and an intrinsically higher-cost action that was abated.

Under regulation, abatement plays a crucial direct role. Action without abatement is deterred by property-rule penalties, irrespective of the harm caused. Action with abatement is allowed, subject only to liability-rule damages.

B. Contracting

In stage 1, the parties can bargain and write two kinds of Coasian contracts. The polluter can promise to refrain from acting, or the owners can permit the polluter's activity. In both cases, the contract can be conditional on abatement: the polluter can promise to refrain from unabated action, retaining the right to act with abatement, or the owners can permit abated action, retaining the right to stop action without abatement.

Under the liability rule, only the first kind of contract is meaningful. Polluter P never needs to buy the permission of the O_i's: whenever they are willing to sell it, courts will identically provide it. Conversely, some O_i's could pay P to refrain from acting. Since contracts are enforced with court-assessed damages, however, a powerful polluter would then subvert the court and pay minimal damages after breaching the contract. As a consequence, no O_i is willing to pay P not to pollute when he can subvert

[9] In some cases, a regulatory standard creates a safe harbor against tort, but there would be no advantage of such a safe harbor in this case unless there were powerful owners who engaged in nuisance lawsuits.

the court. If P cannot subvert the court, a liability rule obviates any need for contracting, since it already induces P to pollute only when his benefit exceeds the cost to the owners.[10]

Under the property rule, only the second kind of contract is meaningful. Sanctions perfectly deter P from acting, so he has nothing to sell to the O_i's. Conversely, all the O_i's could collectively allow P to act in exchange for a payment. The polluter who signs a contract permitting him to act actually does so, and the court simply recognizes that every owner has indisputably relinquished her entitlement to block his activity. If any O_i fails to join the bargaining table, then no contract can be written because P is still subject to the full penalty f for violating a single owner's rights without her consent.

If P cannot subvert the court, the owners can also sign a more nuanced contract permitting him to act but requiring him to abate. However, this contract turns into an all-out permission to act if P can subvert the court. By signing the contract, the owners forego their right to property-rule protection and become entitled to damages only for breach of contract if the polluter does not abate. If P can subvert the court, he will breach the contract, pollute without abatement, and pay negligible damages.[11]

Since regulation combines liability-rule remedies for pollution with abatement and property-rule protection against action without abatement, both contracts that stop action and contracts that permit pollution are possible under regulation. Just as with the pure liability rule, however, a contract that stops action with abatement is useless. If the court is subverted, then breach of contract is not punished and the contract is unenforceable. If the court is not subverted, then liability-rule remedies eliminate the need for such a contract. Just as with the pure property rule, it is instead possible in theory for all the owners to collectively write an enforceable contract that allows action without abatement. Yet when the number of owners N is large, this somewhat implausible possibility becomes vanishingly rare.

III. Efficient Rules

We begin with the textbook case in which the court's fact-finding cannot be subverted. In this case, full compensation of the actual social cost of action is mandated under the liability rule. Alternatively, the property rule is enforced by a high fixed penalty $f > b$, such that the polluter never acts without the owners' prior authorization. The monitoring technology is made redundant by the courts, which always correctly assess the social

[10] As the polluter will not pay more than the assessed damages, a contract will simply duplicate the outcomes without a contract and so will be completely redundant.

[11] Subversion of the court's assessment of damages suffices to make this contract unenforceable, whether abatement is disputable or indisputable. Consequently, adopting a monitoring technology cannot expand the contracting space.

costs of pollution and whether P adopted the abatement strategy. All contracts are perfectly enforced. Our framework then embeds the classic Coase theorem (all proofs appear in app. 1).

Lemma 1 (Coase 1960). Suppose that the court can never be subverted ($\delta = 0$) and the polluter can always bargain with all the owners ($\beta = 0$). Then the first-best social surplus is attained under any of the liability rule, the property rule, or regulation, without monitoring.

Under the liability rule, the expectation of unbiased assessment of damages induces P to internalize exactly the expected social cost of his actions. He then chooses to act without abating if $c/b < \rho_b/\rho_c$, to act and abate if $\rho_b/\rho_c < c/b < (1 - \rho_b)/(1 - \rho_c)$, and not to act at all if $c/b > (1 - \rho_b)/(1 - \rho_c)$; these are the efficient choices. Under the property rule, each O_i can simply stop any polluting activity. However, when $\rho_b/\rho_c < c/b < (1 - \rho_b)/(1 - \rho_c)$, P finds it efficient to buy the permission to act while promising to abate, and when $c/b < \rho_b/\rho_c$, he further buys the permission to act without abating. Bargaining restores the first best. Likewise, under regulation the first best is attained through bargaining if $c/b < \rho_b/\rho_c$, and otherwise there is no need to bargain.

Whereas both the property rule and regulation require bargaining to attain efficiency in some situations, the liability rule without any subversion can efficiently replace bargaining. This consideration implies a second classic result that underpins the traditional case for liability rules in law and economics.

Lemma 2 (Kaplow and Shavell 1996). Suppose that the court can never be subverted ($\delta = 0$) but the polluter cannot always bargain with all the owners ($\beta > 0$). Then the liability rule, without monitoring, attains the first-best social surplus, but the property rule and regulation do not.

When bargaining fails but the court cannot be subverted, it is efficient to let judges write ex post the contracts that the parties would have liked to write ex ante. This reasoning does not require court enforcement to be perfect. We have assumed that harm can be assessed exactly if the court is not subverted, but random measurement error is immaterial. Efficiency does require that assessment of damages is free of any predictable systematic bias in favor of either party. When in some fraction $\delta > 0$ of cases a subverted court favors powerful polluters, the liability rule no longer achieves the first best. In this setting, the property rule and the partial property-rule protection granted by regulation reduce or eliminate reliance on court assessment of damages. Their appeal comes from their greater robustness to subversion.

A. Second-Best Rules: Laws without Regulation

We now turn to the simpler two-way comparison of the liability and the property rule, which largely characterized the legal landscape before

World War I. In some cases, the cost of monitoring, captured by m in our model, was just too high to enable adoption of regulation, in part because technology was unavailable. In other cases, regulation may have been delayed because the political process was captured.

Since the adoption of the costly monitoring technology yields no efficiency gains under either the liability or the property rule, for the sake of brevity we now refer to the liability rule without monitoring as "the liability rule" and the property rule without monitoring as "the property rule."

The liability rule generates the first best when the court is not subverted. But if a powerful P knows that he can subvert the court's assessment of harm, then the liability rule leads him to always choose the most profitable and most polluting option: action without abatement. His activity creates social costs of $\Lambda = \int_{b\rho_b/\rho_c}^{b(1-\rho_b)/(1-\rho_c)} (\rho_c c - \rho_b b)\, dF(c) + \int_{b(1-\rho_b)/(1-\rho_c)}^{\infty} (c - b)\, dF(c)$ from inefficient pollution. Consequently, the total expected social loss from a liability regime, relative to the first best, equals $\delta\Lambda$.

The property rule requires all the owners to consent to any action by the polluter. With probability $1 - (1 - \beta)^N$, at least one of the owners is unable to bargain. In that case, the property rule prevents inefficient and efficient action alike, causing the loss of the social value of efficient pollution, which equals $\Pi = \int_0^{b\rho_b/\rho_c} (b - c)\, dF(c) + \int_{b\rho_b/\rho_c}^{b(1-\rho_b)/(1-\rho_c)} [(1 - \rho_b)b - (1 - \rho_c)c]\, dF(c)$.

With probability $(1 - \beta)^N(1 - \delta)$, all the owners can bargain and the court is not subverted. The owners and the polluter can then reach a perfectly efficient contract. If that contract involves the polluter abating harm, this clause is enforced by the court's honest assessment of damages from breach.

With probability $(1 - \beta)^N\delta$, all owners can bargain, but the court is subverted. In this case, the court does not enforce a contract that specifies abatement, and it sets damages for its breach to zero. However, the court does prevent the action if no contract is signed, since this action is indisputable. When the court is subverted, the owners and the polluter must then choose between no contract and no harm or a contract that allows pollution, which also leads to no abatement. They choose the better of these two options, and the resulting social loss is therefore smaller than either the full cost Λ of universal unabated action or the full cost Π of universal inaction. The loss equals $\Lambda - \lambda_P$, where $\lambda_P = \int_b^{\infty} (c - b)\, dF(c) < \Lambda$ denotes the value of switching from unabated action to inaction when that switch increases efficiency.

Under the property rule, the social loss relative to the first best is then $[1 - (1 - \beta)^N]\Pi + (1 - \beta)^N\delta(\Lambda - \lambda_P)$. Proposition 1 compares the liability rule and the property rule in the second-best setting when there is both a chance that the parties cannot bargain ($\beta \geq 0$) and a chance that the court is subverted ($\delta \geq 0$).

PROPOSITION 1. The liability rule yields greater social surplus than the property rule if and only if court subversion is unlikely enough: $\delta < \tilde{\delta} \equiv (\Pi/\Lambda)[1 - (1 - \beta)^N]/[1 - (1 - \beta)^N(1 - \lambda_P/\Lambda)]$.

The downside of the property rule is that it deters all efficient pollution when bargaining is impossible. The upside is that it also deters most inefficient pollution. The liability rule, instead, always allows efficient pollution. However, when the court's assessment of damages can be subverted, the liability rule also allows powerful polluters to act with impunity. This essential trade-off compares insufficient pollution under the property rule and excessive pollution under the liability rule.

Since the downside of the property rule lies in letting the owners prevent all pollution when bargaining is impossible, the liability rule is more attractive when the benefits from efficient pollution (Π) are higher. Since the downside of the liability rule lies in letting the polluter get away with any pollution when the court can be subverted, the liability rule is more attractive when the costs of inefficient pollution (Λ) are lower. Since the property rule effectively enforces inaction but does not induce optimal abatement when the court is subverted, the liability rule is less attractive when a greater share of inefficiency can be eliminated by simple shutdowns (i.e., when λ_P is higher).

More interesting is that the liability rule is favored when the probability of court subversion (δ) is lower. As lemma 2 shows, in the case of unbiased court assessment of damages ($\delta = 0$), the liability rule is always preferred, as it achieves the first best even without bargaining. More generally, there is a unique threshold $\tilde{\delta}$ for court subversion that determines whether the liability or the property rule yields higher social benefits. The liability rule is preferred in more orderly societies. This result may perhaps explain why legal scholars most familiar with experience in developed countries tend to favor liability rules.[12]

The case for the property rule gets unambiguously stronger when bargaining is more likely ($\partial\tilde{\delta}/\partial\beta > 0$). With bargaining, the property rule is optimal even when the benefits from efficient pollution (Π) are much higher than the costs of inefficient pollution (Λ). If bargaining is always possible ($\beta = 0$), the property rule dominates the liability rule. Both systems attain the first best when the court cannot be subverted. When the court can be subverted, bargaining is not perfect with the property rule because the polluter still cannot commit to abatement, but the property rule still eliminates the most egregious cases of inefficient pollution, with social savings λ_P.

[12] The complementarity of the property rule and the risk of court subversion is independent of our assumption that the power to subvert lies with powerful polluters. If instead the court were subverted by powerful owners, it would assess prohibitive damages for any action they have not explicitly authorized, making the liability rule and the property rule identical. Thus, the trade-off between the two rules always depends only on the two cases we consider explicitly: no court subversion and court subversion by *P*.

When N and β are small, the property rule enables the parties to bargain and reach an efficient outcome. An absolute entitlement gives each O_i the power to stop the polluter, but they use that power only to bargain, even with a strong P. In contrast, the liability rule does not facilitate bargaining between weak owners and strong polluters because a strong P cannot credibly commit not to pollute under the liability rule. A strong P literally needs to be stopped unless and until he pays.

These results vindicate Calabresi and Melamed's (1972) original intuition that property rules and bargaining are complements. The Coasian argument to the contrary requires perfect enforcement of contracts, just as the classic argument for liability rules relies on their unbiased enforcement. When contract enforcement is vulnerable to subversion, owners whose entitlement is protected by the property rule can sell it to efficient polluters. In contrast, owners whose entitlement is protected by the liability rule cannot pay off powerful but inefficient polluters, because contracts are not reliably enforced against them.

The complementarity between the property rule and bargaining also means that the liability rule becomes more attractive as the number of owners increases, because a greater number of owners raises the probability that not all of them are able to bargain ($\partial\tilde{\delta}/\partial N > 0$ for all $\beta > 0$). If the liability rule is better than a total shutdown of all activity (i.e., if $\delta < \Pi/\Lambda$), then it yields greater expected social surplus than the property rule if and only if $N > \ln[1 + \lambda_P/(\Pi/\delta - \Lambda)]/|\ln(1 - \beta)|$.

This last result may explain the path of case law around water pollution in nineteenth-century America. Before the Industrial Revolution, riparian rights more closely resembled the property rule discussed above. As Paavola (2002, 298) explains, "the riparians whose land abutted" water enjoyed "a right to receive water in its accustomed (and thus natural) quantity and quality," which was established by the concept of "natural flow" and the maxim of *sic utere tuo ut non alienum laedas.* But over the course of the nineteenth century, the scale of industrial pollution increased and so did the number of people who could plausibly claim that they were harmed by water pollution.

The logic of our model suggests that maintaining the property rule would have shut down most water-related industrial activity, and that may well have generated more harm than good. Courts understood that difficulty and reacted by moving to the liability rule for water pollution, weakening downstream riparian rights. After *Snow v. Parsons* (28 Vt. 459, 1856), many courts embraced the doctrine of "reasonable use," which allowed new users to harm downstream riparian owners as long as the court deemed that the activity did more good than harm. Later water regulation represents an attempt to roll back some of the leeway accorded to water polluters during the nineteenth century and to restore in part an absolute entitlement to clean water for the owners, protected by property-rule remedies.

B. *Second-Best Rules: Law and Regulation*

A costly monitoring technology does not improve the efficiency of either the liability rule or the property rule, but it is critical for regulation. Regulation enforces absolute property-rule protection of the owners against only unabated action while subjecting activity with abatement to a mere liability-rule requirement to compensate for damages. Without monitoring, abatement itself is disputable. Regulation is then dominated by the liability rule because it does not constrain a powerful polluter any more than the liability rule when the court is subverted, while it imposes inefficient constraints when the court is not subverted but not all owners can bargain. Since the adoption of the costly monitoring technology is necessary for regulation not to be a dominated option, for the sake of brevity we now refer to regulation with monitoring as simply "regulation."

When the legislator mandates adoption of the monitoring technology, abatement becomes indisputable. Regulation can then successfully enforce abatement as a default irrespective of P's ability to subvert the court. Two inefficiencies remain.

First, when P cannot bargain with all owners, regulation requires abatement even when unabated action is efficient. This distortion causes a social loss from inefficient abatement but not the loss of the full social value Π of efficient pollution. The loss is instead reduced to $\Pi - \pi_R$, where $\pi_R = \int_0^{b(1-\rho_b)/(1-\rho_c)}[(1-\rho_b)b - (1-\rho_c)c]\, dF(c) < \Pi$ denotes the value of switching from inaction to abated action whenever that switch increases efficiency.

Second, when P can subvert the court, he chooses to act and abate even when inaction is efficient. Contracts, enforced by damage awards, cannot deter him. This distortion causes a social loss from inefficient pollution but not the full cost Λ of inefficient pollution. The loss is instead reduced to $\Lambda - \lambda_R$, where $\lambda_R = \int_{b\rho_b/\rho_c}^{\infty}(\rho_c c - \rho_b b)\, dF(c) < \Lambda$ denotes the value of switching from unabated action to abated action whenever that switch increases efficiency.

Summarizing, regulation yields a social loss $[1-(1-\beta)^N](\Pi - \pi_R) + \delta(\Lambda - \lambda_R) + m$, including the cost m of adopting the monitoring technology. Proposition 2 characterizes the efficiency-maximizing rule whenever $(1-\beta)^N \leq (\Lambda - \lambda_R)/(\Lambda - \lambda_P)$. This is the case of greater empirical interest, since in practice regulation is mainly adopted for activities with a large number of affected owners (N).[13] Appendix 1 shows that the characterization in proposition 2 of the parameter values for which the liability rule is efficiency maximizing is general. The alternative rule that is optimal for marginal changes in parameters away from this region is also

[13] Moreover, the condition holds for any β and N if the efficiency gains from switching from unabated action to abated action whenever desirable are lower than the efficiency gains from switching from unabated action to inaction whenever desirable ($\lambda_R \leq \lambda_P$).

always as described in proposition 2. The condition affects only the relative appeal of the property rule and regulation for high values of court subversion (δ).

PROPOSITION 2. Suppose that $(1-\beta)^N \leq (\Lambda - \lambda_R)/(\Lambda - \lambda_P)$. If adopting the monitoring technology is costly enough that $m > \bar{m} \equiv \Pi[\lambda_R/\Lambda + \pi_R/\Pi - 1 - (1-\beta)^N(1-\lambda_P/\Lambda)(1-\pi_R/\Pi)][1-(1-\beta)^N]/[1-(1-\beta)^N(1-\lambda_P/\Lambda)]$, then the efficiency-maximizing rule is the liability rule if court subversion is rare enough that $\delta < \tilde{\delta}$ and it is the property rule if court subversion is common enough that $\delta > \tilde{\delta}$. If adopting the monitoring technology is cheap enough that $m < \bar{m}$, then the efficiency-maximizing rule is the liability rule if court subversion is rare enough that $\delta < \tilde{\delta}_1 \equiv \{[1-(1-\beta)^N](\Pi - \pi_R) + m\}/\lambda_R$, it is the property rule if court subversion is frequent enough that $\delta > \tilde{\delta}_2 \equiv \{[1-(1-\beta)^N]\pi_R - m\}/[\Lambda - \lambda_R - (1-\beta)^N(\Lambda - \lambda_P)]$, and it is regulation for intermediate levels of court subversion: $\tilde{\delta}_1 < \delta < \tilde{\delta}_2$.

Regulation is distinguished from both the liability rule and the property rule by its unique reliance on monitoring to enforce abatement, even by powerful polluters who can subvert the court. Two intuitive consequences follow. First, regulation is a dominated option when monitoring technology is too costly ($m \geq \bar{m}$). Second, regulation can be attractive only if abatement is useful enough, either because most of the social costs from inefficient pollution can be avoided by requiring abated instead of unabated action (i.e., high λ_R/Λ) or because most of the social value of efficient pollution can be reaped by allowing abated action instead of inaction (i.e., high π_R/Π).[14]

If abatement is useful enough and the monitoring technology cheap enough, so that $0 \leq m < \bar{m}$, the appeal of the liability rule is reduced relative to what we found for a binary rule choice in proposition 1. For intermediate levels of subversion ($\tilde{\delta}_1 < \delta < \tilde{\delta}$), the liability rule is preferable to the property rule, but regulation is most efficient. Regulation likewise replaces the property rule as the second best for some higher levels of subversion ($\tilde{\delta} < \delta < \tilde{\delta}_2$).

The appeal of regulation relative to both the liability rule and the property rule is intuitively greater if monitoring is cheaper ($\partial\tilde{\delta}_1/\partial m < 0 < \partial\tilde{\delta}_2/\partial m$) and if abatement is more useful (i.e., if λ_R or π_R is higher). Just as in proposition 1, a higher chance that all owners can bargain makes liability less appealing ($\partial\tilde{\delta}_1/\partial\beta > 0 > \partial\tilde{\delta}_1/\partial N$).[15]

As a final theoretical point, we have presented our theory in the context of pollution, trespass, or other torts. Yet closely related ideas apply to

[14] Formally, $\bar{m} > 0$ if and only if $\lambda_R/\Lambda + \pi_R/\Pi - (\lambda_P/\Lambda)(\pi_R/\Pi)(1-\beta)^N/[1+(1-\beta)^N] > 1$.

[15] Instead, the impact of bargaining on the relative appeal of the property rule and regulation is ambiguous: $\partial\tilde{\delta}_2/\partial\beta$ has the sign of $\pi_R(\lambda_P - \lambda_R) + m(\Lambda - \lambda_P)$.

contracts and the question of specific performance versus compensatory damages as the remedy for breach. In appendix 2.3, we develop this analysis and show how it can shed light on some debates in the literature on contracts and on the theory of the firm.

IV. Empirical Predictions

The propositions in the above section were largely normative. If rules are chosen optimally or change in response to pressures for efficiency, then these propositions also yield predictions about the evolution of legal regimes. We consider these implications to be our first two empirical predictions. The first prediction is based on proposition 1; the second is based on proposition 2.

Institutional Prediction 1. Property rules tend to be replaced by liability rules as court subversion becomes less prevalent or as the number of impacted owners increases.

Proposition 1 shows that the property rule is particularly valuable when the court is likely to be subverted. This may explain the heavy reliance on property rules in developing countries, where the imbalance of power in legal disputes is substantial. As courts get better with development, the optimal institutional choice implies a movement from property to liability rules. A more interactive and connected economy will also lead to a transition from property to liability rules. When each polluter deals with only one owner, bargaining is easy and the property rule enables efficient bargaining. When a polluter can potentially impact hundreds or thousands of individuals, bargaining is impossible and the case for the liability rule becomes stronger.

Institutional Prediction 2. When pollution impacts a large number of owners and abatement is sufficiently useful to avoid the inefficiencies of no pollution or unconstrained pollution, then liability rules tend to be replaced by regulation as the costs of monitoring fall.

For many activities that pollute the air and water, it is better to let polluters act without constraint than forcing them not to act at all. When the number of owners N is large, the liability rule is preferred to the property rule because the latter essentially forbids all activity that could pollute any large waterway (i.e., $\delta < \lim_{N\to\infty}\tilde{\delta} = \Pi/\Lambda$). Often, however, abatement allows reaping most of the benefits from efficient action while entailing greatly reduced costs of inefficient pollution. As a result, regulation is better than the liability rule—and a fortiori than the property rule—when monitoring costs are low (i.e., $\delta > \lim_{N\to\infty}\tilde{\delta}_1 = (\Pi - \pi_R + m)/\lambda_R$). When monitoring costs are high instead, regulation is prohibitively expensive and the liability rule is the most efficient alternative. Our second prediction is that technology improvements should lead to more regulation in settings where many people can potentially be harmed.

We next turn to predictions that require no assumptions about efficiency-maximizing institutional choices and instead focus on the level of pollution. Proposition 3 looks at the impact of a switch from liability to regulation caused by either an exogenous event or a decline in monitoring costs.

PROPOSITION 3. If a jurisdiction switches from the liability rule to regulation and no parameters change other than the cost of monitoring m, the expected cost of pollution to the owners falls by $\rho_c\{[1-(1-\beta)^N]\int_0^{b\rho_b/\rho_c} c\, dF(c) + \delta\int_{b\rho_b/\rho_c}^{\infty} c\, dF(c)\} \geq 0$. The decline in harm, as a fraction of initial harm under the liability rule, is increasing with the probability of court subversion δ.

Proposition 3 shows that a switch from the liability rule to regulation leads to a reduction in the total costs of pollution and that this reduction is proportionally larger in places where subversion is more common. As we show in appendix 1, the polluter's benefits from pollution also decline, and their decline is also proportionally larger where subversion is more common. This is our third empirical prediction.

EMPIRICAL PREDICTION 3. Pollution declines when liability rules are replaced by regulation, and its decline is larger where court subversion is more prevalent.

The first part of this prediction has essentially been tested already by the large number of studies documenting the fact that environmental regulations, including the CWA and Clean Air Act, have reduced pollution. In almost every case, there was a liability regime in place before the act, and the act replaced that liability regime with a regulation regime that uses property-rule remedies for enforcement.

The second part is more novel. Our model delivers the strong prediction that the liability rule should be more effective, both at enhancing social welfare and at reducing pollution, when the quality of courts is high. The impact of replacing the fact-intensive liability rule with a less nuanced regulatory regime is then larger where subversion is more prevalent.

To derive our final empirical prediction, we start from observing that the CWA distinguishes between pollution from point sources, including most industrial polluters, and nonpoint sources, including most agricultural polluters. This distinction largely reflects differences in monitoring technology. An industrial plant's discharges from an outflow pipe can be monitored much more easily than a farm's emissions leaching from its fields. Our final empirical prediction concerns situations in which a given share of polluters, denoted by α, is agricultural and thus not subject to a requirement for water pollution abatement enforced by property-rule remedies. Our prediction does not depend on the total number of potential polluters since we focus on proportional changes in pollution.

COROLLARY 1. If no parameters change other than the cost of monitoring m and a jurisdiction switches from the liability rule to regulation for a share $1-\alpha$ of polluters, the decline in total harm from pollution, as a fraction of initial harm, is monotone decreasing in the share α of polluters who remain subject to the liability rule.

Polluters facing a switch in enforcement from the liability rule to regulation increase abatement and reduce total harm. Polluters whose rule does not switch do not change their behavior. Theoretically, this simple point underscores the complementarity of technology and regulation. Cheaper monitoring does not reduce pollution unless it is accompanied by regulation. Empirically, the corollary leads to our final testable prediction.

Empirical Prediction 4. The decline in pollution when liability rules are replaced by a regulatory regime is larger in locations that have less agriculture, if the regulatory regime applies property-rule penalties only to nonagricultural polluters.

If the key element of regulation is the enforcement of property rules against industrialists but not against farmers, then its impact will be larger when the share of industrialists is higher and the share of farmers is lower. This would not necessarily be the case if the effectiveness of regulation hinged on other factors instead, such as replacing state with federal authority or courts with administrative agencies.

V. Water Pollution

Water is a shared resource such that actions upstream can reduce the value of riparian land downstream. Riparian rights have long been protected by the common law. Until the nineteenth century, these rights were protected like other forms of property, with violations stopped by injunction. During the nineteenth century, American courts moved closer to a liability standard, citing the social losses from shutting down successful enterprises that happened to pollute the water. As our model suggests, this appears to have allowed much more pollution. In 1972, the CWA imposed regulations that were once again enforced with property-rule remedies. Our model predicts that water pollution fell when the liability rule was replaced by regulation. It further predicts that regulatory enforcement should reduce pollution where it is applied and binding, and that pollution reductions should be particularly large in more corrupt places. We first briefly describe the history of water pollution control in the United States and then describe the pollution data collected by Keiser and Shapiro (2019) and present our analysis.

A. *Legal History of Water Pollution Control*

Paavola (2002, 297) documents that, before the Industrial Revolution, "the early courts construed water uses, and the water quality they depended on, as private property." Horwitz (1973, 252) explains that "a late eighteenth century New Jersey case (*Merritt v. Parker*, 1 N.J.L. 526) clearly expressed the prevailing conception" when it ruled that "when a man purchases a piece of land through which a natural water-course flows, he has a right to make use of it in its natural state, but not to stop or divert it" and that the water flow "cannot legally be diverted from its course without the consent of all who have any interest in it." The need for "consent of all" suggests the bargaining challenge highlighted by our model. The court also affirmed large penalties for violating this property rule: "I should think a jury right in giving almost any valuation which the party thus injured should think proper to affix to it." Rose (1990, 271) explicitly links bargaining and these property-rule riparian arrangements, which "simply look like a way of specifying rights between neighbors so that negotiations could take place and the resources could flow to the one who most valued them."

As opportunities for exploiting America's water resources increased during the nineteenth century, courts increasingly saw the property rule as an inefficient limitation on industrial expansion. As Horwitz (1977, 34) writes, "the evolving law of water rights had a greater impact than any other branch of law on the effort to adapt private law doctrines to the movement for economic growth." As the industrial riverscapes grew denser, the conflict between a single mill owner and his neighbor, which could be handled through property rights and negotiation, was replaced by "new water use conflicts that involved a number of injured downstream riparians" (Paavola 2002, 301). Rose (1990, 286) explains that "both upstream and downstream mill owners effectively claimed an exclusive right to control the entire current of the river," and consequently, "to adopt either of these positions, in the large-numbers context of controlling the entire river current, might well freeze the use of the river for all users since no reallocation could be negotiated easily among all those affected riparians."

In a series of cases including *Palmer v. Mulligan* (3 Cai. R. 307; NY 1805), *Tyler v. Wilkinson* (24 F. Cas. 472; RI 1827), *Snow v. Parsons,* and *Pennsylvania Coal Co. v. Sanderson,* the courts increasingly embraced the doctrine of reasonable use, which replaced the old property rule with a liability rule (institutional prediction 1). But as our approach argues, the courts often failed to impose damages for actions that were deemed to be "reasonable." As Chief Justice Redfield wrote in his opinion in *Snow v. Parsons*: "Within reasonable limits, those who have a common interest in the use of air and running water must submit to small inconveniences to afford a disproportionate advantage to others." When the State Supreme Court of Pennsylvania rejected any damages owed to a riparian owner who claimed that "acid mine drainage had spoiled a brook's water, killed all the fish, and corroded a new water distribution at his farm," the court ruled that "to encourage the development of the great natural resources of a country trifling inconveniences to particular persons must some times give way to the necessities of a great community" (Paavola 2002, 305–6).

This transformation technically left riparian owners and other water users with common-law remedies for pollution, such as the notions of trespass and nuisance (Percival et al. 2017). None of the nineteenth-century cases mentioned above reject the liability rule that damages should be awarded if it can be proven that an upstream polluter did great harm to a downstream riparian. Yet pollution posed challenges for common law, because establishing liability requires that a plaintiff both show that pollution caused harm and attribute the level of harm to the specific polluter (Hines 1966). Such attribution becomes very challenging, especially with multiple polluters.[16] Following the logic of the Pennsylvania Supreme Court, judges reduced damage awards or even denied any liability for damages because they did not want to burden American industry (Lewin 1989; Goldstein 2010).

Several states responded to the limitations of the common-law liability rule with regulations that set quality standards for a given body of water, but enforcement was limited. According to Lazarus (2004, 74), "the experience of regulators prior to 1972 was that there were so many factors that influenced the actual impact of pollutants on water quality, including temperature, flow, volume, and the presence of other pollutants, that regulation tied to such determinations would quickly become mired in protracted factfinding and scientific uncertainty." In many states, these programs were also voluntary, partially because regulators were checked by the political forces aligned with the polluters (Andreen 2003a).

The CWA shifted the focus of regulation from water quality to compliance with emissions permits administered by the EPA (Andreen 2003b) and enforced that compliance with property-rule penalties. The EPA issues permits that require measurement and limit discharges of pollution from a "point source" into "a water of the United States." Although the Supreme Court held that the CWA does not preempt common-law claims of nuisance (*International Paper Co. v. Ouellette*, 479 U.S. 481 [1987]), state court cases alleging trespass or nuisance from environmental harm fell 75% from the early 1970s to the early 1990s. Federal court cases dealing with trespass or nuisance fell by 21% over the same time period (Green 1998). The CWA shifted water pollution control from the liability rule enforced by the common law to regulation enforced with fixed penalties (institutional prediction 2).

[16] Many jurisdictions even barred recovery when liability could not be divided among multiple polluters (e.g., *Walters v. Prairie Oil & Gas Co.*, 204 P. 906, Okla. 1922). A related issue was the delay between when pollution is emitted and when its effects became clear (Lazarus 2004). In *Globe Aircraft Corp. v. Thompson* (203 S.W.2s 865, Tex. Civ. App. 1947), the court overturned a jury damage award for a farmer whose cows had allegedly been poisoned by water pollution because the plaintiff could not demonstrate that pollution had been emitted for the entire time the cows were harmed.

The general finding is that water quality in the United States improved after the passage of the CWA, although there are some questions of attributing this improvement to the CWA rather than to general trends (Olmstead 2009; Mehan 2010). Keiser, Kling, and Shapiro (2018) review many of the cost-benefit analyses of the CWA and find that costs often appear to exceed benefits. Keiser and Shapiro (2019) provide the most comprehensive study of the CWA and national water quality, using data on nearly 50 million pollution readings dating back to the 1960s. They find that nearly all of the pollutants they study have declined since the passage of the CWA, but the trends in the reduction of several pollutants appear to have slowed after the enactment of the CWA.

A central feature of the CWA is the disparate treatment of point-source pollution—produced primarily by industrial activity—and non-point-source pollution produced by agriculture. The CWA requires point-source polluters to have a permit, and failure to comply with a permit is punished by property-rule penalties, such as injunction and criminal prosecution.[17] Point-source polluters can also be sued for damages under the common law. Non-point-source polluters do not require permits but can be sued for damages. The differential impact of the CWA on point-source and non-point-source pollution provides a test of whether the regulatory permitting and the associated property-rule remedies mattered or whether other changes in the legal and regulatory environment drove changes in water pollution levels. Our empirical analysis focuses on the distinction between point-source and non-point-source regulation because the differential impact of the CWA on point-source pollution enables us to estimate the impact of regulation holding common-law remedies and national trends constant (empirical prediction 4).

B. Data

Keiser and Shapiro (2019) collected source material from the EPA's STORET Legacy database. This database records measures of water pollution in the United States since the 1960s. Keiser and Shapiro (2019) describe their data in detail. They conduct much of their analysis of water pollution trends at the monitor-by-hour-by-pollutant level. We aggregate this hourly monitor data to the county-by-year level by taking an annual average of the individual station readings for each pollutant in each county, since our covariates and our treatment are at the county level. We restrict the years in the sample to 1962–85 and follow Keiser and Shapiro (2019) in analyzing data on pollution only in rivers and lakes.

[17] Point-source pollution is much easier to attribute to a source than non-point-source pollution, but it is today a less important source of water pollution. Bingham et al. (2000) suggests that reducing point-source pollution to zero would substantially improve only 10% of the river miles in the United States.

For each pollutant in the sample, we calculate a *Z* score by county by year as the difference between the level of pollutant in the county during a year and the average level of that pollutant across all county-by-year observations in our sample divided by the standard deviation of that level across the sample. For each county, we sum *Z* scores across all pollutants by year to get an annual pollution *Z* score. We present results using the *Z* score for pollutants that the CWA defines as "conventional" as well (see app. 3). Keiser and Shapiro (2019) examine individual pollutants, but for us the aggregate suffices.

We use data compiled by Keiser and Shapiro (2019) on the date and location of the permits issued by the EPA for facilities through the NPDES.[18] The enforcement of the CWA was delayed for both administrative and political reasons (Jerch 2019). The first NPDES permits were issued in 1973 and set limits consistent with the "best professional judgement" of the permit writer about what emission levels would reduce water pollution (USEPA 1973).

To measure whether a switch from common-law liability rules to regulation induces an overall reduction in pollution, as predicted by the first part of our empirical prediction 3, we define counties that contain a facility that received an NPDES permit in either 1973 or 1974 as being treated by regulation. These counties should include all areas that had any point source of pollution at the beginning of the CWA era. In our primary analysis, we drop counties in which the first regulated facility receives its permit after 1974 and before 1986. We do not include data from 1973 or 1974 in our analysis except to assign treatment.[19] As we are conditioning on the presence of a point-source polluter in 1973 and 1974, we cannot be sure that the county had such a polluter during all of the years before the passage of the CWA, but this issue is likely to be minor, since our treated counties do not experience a statistically discernible increase in water pollution in the years before the CWA.

The CWA requires NPDES permits only for polluters who convey a pollutant into a water of the United States from a defined point, such as an outflow pipe. Most agricultural polluters were excluded from regulation under the NPDES system because pollution from agriculture is typically runoff from fertilized fields that does not enter water bodies at any defined point. In practice, this meant that the EPA did not enforce pollution reduction requirements on agricultural polluters (or most other non-point-source polluters) until the early 1990s (Owen 2015). If regulation reduces pollution by replacing the liability-rule tort remedies with

[18] These permits are recorded in the Permit Compliance System (later the Integrated Compliance Information System). Keiser and Shapiro (2019) received access to this data through a Freedom of Information Act request.

[19] In app. 3, we present robustness checks retaining 1973 and 1974, retaining counties that receive a permit between 1975 and 1985, and using a time-varying measure of treatment.

property-rule sanctions for noncompliance with permits, we would expect the CWA to entail a larger decline in pollution for nonagricultural counties (empirical prediction 4).

We define a county as agricultural if its share of employment in agriculture in the 1972 County Business Patterns is greater than the 75th percentile of the distribution of the agricultural employment share across all counties.[20] While we distinguish between agricultural and nonagricultural counties because of the expected differences in how the NPDES regime influenced water pollution in each type of county, our classification of agricultural counties does not depend on NPDES permits in any way.

Another implication of our theory, predicted by the second part of our empirical prediction 3, is that both property rules and regulation should reduce harm more, relative to a liability rule, where court subversion is more common. We proxy for court subversion with measures of corruption at the state level. We expect that areas that are more corrupt will have higher levels of pollution before the CWA and that the impact of regulation will be higher in more corrupt areas. To test these predictions, we follow Glaeser and Saks (2006) and use the number of federal, state, and local public officials convicted of a corruption-related federal crime in each state, from the Department of Justice's (DOJ) "Report to Congress on the Activities and Operations of the Public Integrity Section."[21] We calculate the number of convictions over the state's population. We then assign the average of the state's annual conviction rate from 1976 (the earliest year in the DOJ data) to 1985 (the last year in our sample) to each county in a state. We create an indicator for corrupt counties as those in states where the conviction rate is above the mean. In appendix 3, we also provide comparable results based on newspapers per capita (Gentzkow, Shapiro, and Sinkinson 2011), which provides a noisy measure of the level of public scrutiny.[22]

C. *Empirical Approach*

We begin by estimating the standard difference-in-differences model:

$$y_{ijt} = \beta_0 + \beta_1\ CWA_{it} + \pi X_{it} + \gamma_i + \varphi_t + \delta_j t, \tag{1}$$

[20] In app. 3, we show that our results are robust to using a continuous measure of agricultural employment as well as various other employment thresholds for whether a county is agricultural. We also consider a definition of agricultural counties based on the number of agricultural establishments rather than the employment share.

[21] For details on what the DOJ considers a corruption-related crime, see Glaeser and Saks (2006).

[22] Our measure of the number of per capita newspapers in 1972 uses Gentzkow, Shapiro, and Sinkinson's (2011) digital record of newspaper circulation in presidential election years from 1872 to 2004. We calculate the per capita number of subscriptions as the total state circulation over the population of the state in 1972.

where y_{ijt} represents the summed Z score across all pollutants in county i in state j and year t, CWA_{it} is an indicator that takes on a value of one for years after 1974 for those counties in which the CWA became enforceable because the EPA issued a permit in 1973 or 1974, X_{it} is a vector of time-varying controls for economic conditions in county i (e.g., total employment), γ_i represents a county fixed effect, φ_t represents a year fixed effect, and δ_j represents a state-specific linear time trend. In equation (1), β_1 provides a test of the first part of empirical prediction 3 by estimating how pollution changes in counties in which the CWA becomes enforceable relative to counties in which the CWA does not become enforceable in our sample.

To measure the differential effect of the CWA on agricultural and nonagricultural counties, we estimate the following variant of equation (1):

$$y_{ijt} = \beta_0 + \beta_1\ CWA_{it} + \beta_2\ CWA_{it} \times Nonag_i + \pi X_{it} + \gamma_i + \varphi_t + \delta_j t, \quad (2)$$

where the common terms are as before and $Nonag_i$ is an indicator for whether county i is a nonagricultural county. In equation (2), β_2 provides a test of empirical prediction 4 by estimating the differential impact of the CWA becoming enforceable in nonagricultural counties relative to agricultural counties. We again define treatment as an indicator variable for whether the county had a permit in 1973 or 1974. Agricultural counties that did not contain a facility that received a permit for point-source pollution are in the nontreated group. Roughly 3% of our counties are nontreated agricultural counties. In estimating equations (1) and (2), we cluster standard errors at the county level.

Finally, to measure the differential effect of the CWA in corrupt and noncorrupt states, we estimate

$$y_{ijt} = \beta_0 + \beta_1\ CWA_{it} + \beta_2\ CWA_{it} \times Corrupt_j + \pi X_{it} + \gamma_i + \varphi_t + \delta_j t, \quad (3)$$

where the common terms are as before and $Corrupt_j$ is an indicator for whether county i is located in a state j that we consider corrupt (i.e., one with a conviction rate above the mean in the sample). In equation (3), β_2 provides a test of the second part of empirical prediction 3 by estimating the differential impact of the CWA becoming enforceable in counties that are in corrupt states relative to noncorrupt states, as measured by the average per capita number of federal, state, and local convictions. These corruption measures are available only at the state level, so in estimating equation (3) we cluster standard errors at the state level.

D. Results

In table 1, we present a comparison of the average level of pollution before and after the passage of the CWA in all counties for which we have

TABLE 1
PRE- AND POST-CWA AVERAGE POLLUTION LEVELS BY COUNTY TYPE

	Pre-CWA		Post-CWA		Difference in Means	
	Mean	Standard Deviation	Mean	Standard Deviation	$\mu_{post} - \mu_{pre}$	t Statistic
All counties	.48	4.37	−.05	4.51	−.53	−9.07
Nonagricultural counties	.45	4.31	−.27	4.26	−.72	−11.22
Agricultural counties	.60	4.54	.69	5.17	.09	.64
Treated counties	.40	4.34	−.24	4.33	−.64	−10.64
Nontreated counties	.98	4.47	1.31	5.39	.33	1.81
Noncorrupt counties	.04	4.26	−.20	4.77	−.24	−3.15
Corrupt counties	1.38	4.44	.28	3.83	−1.10	−11.73

NOTE.—Statistics are reported for the summed Z score of pollution. The Z scores are calculated for each pollutant in each year (negative Z scores indicate lower than average pollution), and then Z scores for all pollutants are summed by county-year. "All counties" reports the statistics across all the counties in our sample. "Agricultural counties" are those whose share of employment in agriculture in 1972 was above the 75th percentile of its distribution across all counties. Results using agricultural establishments instead of employment are similar. "Treated counties" are those that contain a facility that receives an NPDES permit in 1973 or 1974, while "Nontreated counties" are those that do not contain a facility that receives an NPDES permit from 1972 to 1985. Counties that contain facilities that receive a permit from 1975 to 1985 are dropped. "Noncorrupt counties" ("Corrupt counties") are those in states where the average number of federal convictions per 10,000 state residents is below (above) the mean. Conviction rates are calculated as the average of the annual number of convictions per capita over the years 1976–85. The reported t statistic is from a paired t-test showing that the means before and after passage of the CWA in 1972 are the same.

data. The first row provides the basic evidence that pollution fell after the passage of the CWA by more than half of a standard deviation relative to previous years. This difference in means is highly significant.

Figure 1 shows the annual trend in pollution levels for the treated counties compared with those where the CWA does not become enforceable before 1985 ("nontreated counties"). Pollution levels in nontreated counties have a slight upward trend over the sample period and no noticeable trend change after the passage of the CWA. Before the passage of the CWA, treated counties have pollution levels that are roughly half of a standard deviation lower than nontreated counties. As we report in table 1, after the passage of the CWA, treated counties reduce their pollution levels by 0.64 standard deviations while nontreated counties remain roughly constant, increasing the difference between treated and nontreated counties to 1.5 standard deviations. Consistent with the first part of empirical prediction 3, our findings indicate that water pollution declined with the enforcement of regulation under the CWA and not simply with the passage of time.

Figure 2 displays the annual trend in pollution levels in treated nonagricultural counties compared with treated agricultural and nontreated

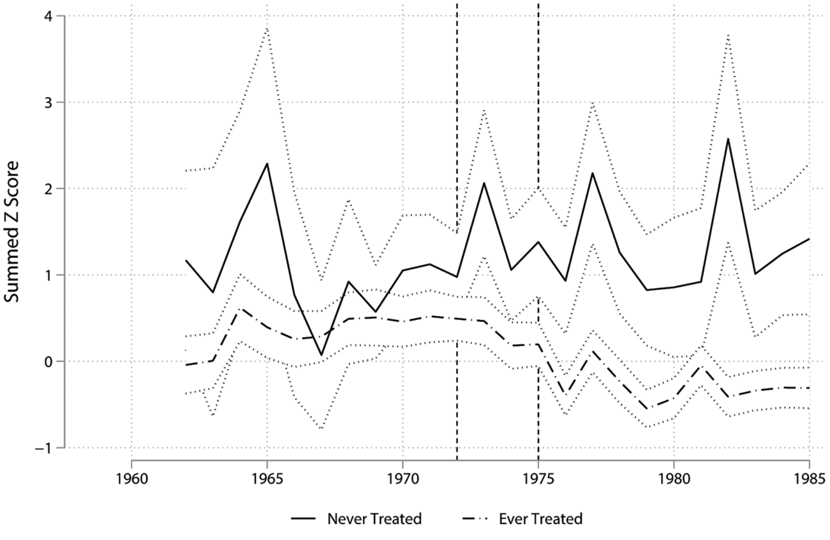

Fig. 1.—Pollution trends. The figure shows the annual trend in the average summed *Z* score of water pollution for treated and nontreated counties. The *Z* scores are calculated for each pollutant in each year (negative *Z* scores indicate lower than average pollution), and then *Z* scores for all pollutants are summed by county-year. Averages across counties are calculated by year. Treated counties are those that contain a facility that received an NPDES permit in 1973 or 1974. Counties that contain a facility that received a permit after 1974 are dropped. Nontreated counties do not contain a facility that received an NPDES permit between 1972 and 1985. Dotted lines indicate the 95% confidence interval for the average summed *Z* score.

counties. Both treated agricultural and treated nonagricultural counties have lower pollution levels than nontreated counties before and after the passage of the CWA. Consistent with our predictions, treated nonagricultural counties see a noticeable downward trend in pollution levels relative to years before 1972. Treated agricultural counties display no such trend. Table 1 shows that the average level of pollution in treated nonagricultural counties falls by roughly 0.70 standard deviations after 1972 relative to the pre-1972 average. Treated agricultural counties, in contrast, see a 0.09 standard deviation increase in average pollution levels. This difference bears out empirical prediction 4.

The analysis so far does not control for pretrends, which we take up next. Table 2 presents the results of the difference-in-differences specifications described in equations (1) and (2). Conditional on the assumption of parallel trends in the pre-CWA period, these equations identify the impact of the CWA becoming enforceable in the treated counties. In appendix 3, we present evidence for the absence of pretrends in the full sample and various subsamples. This finding differs from the trends that Keiser and Shapiro (2019) find for the subset of pollutants they examine.

FIG. 2.—Pollution trends: agricultural and nonagricultural. The figure shows the annual trend in the average summed *Z* score of water pollution for treated agricultural and nonagricultural counties and all nontreated counties. The *Z* scores are calculated for each pollutant in each year (negative Z scores indicate lower than average pollution), and then *Z* scores for all pollutants are summed by county-year. Averages across counties are calculated by year. Treated counties are those that contain a facility that receives an NPDES permit in 1973 or 1974. Counties that contain a facility that receives a permit after 1974 are dropped. Nontreated counties do not contain a facility that received an NPDES permit between 1972 and 1985. Agricultural counties are those whose share of employment in agriculture in 1972 was above the 75th percentile of its distribution across all counties. Nontreated agricultural and nontreated nonagricultural counties are pooled in the nontreated group. Dotted lines indicate the 95% confidence interval for the average summed *Z* score. We plot confidence intervals only for the period after 1976 to aid readability. Before 1976 the confidence intervals largely overlap.

They find that across most of the individual pollutants they examine, levels are declining in the years preceding 1972. The difference seems to stem from our inclusion of all the available pollutant data in each year rather than focusing on individual pollutants. We show in appendix 3 that we can replicate the pattern of trends they report when we focus on the same subset of pollutants.

When we consider the simple difference between treated and nontreated counties after the passage of the CWA in column 1, the results indicate that pollution in treated counties fell by between 0.5 and 1 standard deviation more than in nontreated counties. The impact of treatment is robust to the inclusion of both year fixed effects and state-specific linear time trends. It is also robust to inclusion of time-varying controls for measures of industry that might be correlated with pollution (e.g., total employment in mining). The magnitude of our treatment effect is substantially larger than

TABLE 2
Difference-in-Differences Results

	(1)	(2)	(3)	(4)
CWA enforceable	−.689***	−.683***	−.846***	−.475
	(.129)	(.128)	(.272)	(.334)
CWA enforceable × nonagricultural				−.485**
				(.224)
Observations	25,455	25,455	25,455	25,455
R^2	.55	.55	.56	.56
County fixed effects	Yes	Yes	Yes	Yes
Year fixed effects			Yes	Yes
State-specific linear time trend	Yes	Yes	Yes	Yes
Controls		Yes	Yes	Yes

Note.—The table reports the results of two specifications. Columns 1–3 report the difference-in-differences specification described in eq. (1) with and without year fixed effects and with and without controls. Column 4 reports the additional difference between agricultural and nonagricultural counties described in eq. (2). We consider the CWA enforceable starting in the year that the first facility in a county receives its first NPDES permit if that is before 1975. Counties that contain only facilities that receive their first permit between 1975 and 1985 are dropped. We consider the CWA nonenforceable in counties that do not contain a facility that receives a permit by 1985. Agricultural counties are those whose share of employment in agriculture in 1972 was above the 75th percentile of its distribution across all counties. Controls include total employment, manufacturing employment, and mining employment. Standard errors are clustered at the county level.
** $p < .05$.
*** $p < .01$.

the average change in pollution levels across all counties before and after passage of the CWA reported in table 1 and confirms that the decline in water pollution since 1972 was concentrated in treated counties (first part of empirical prediction 3).

Column 4 of table 2 shows the additional difference between the impact of treatment in agricultural and nonagricultural counties. Nonagricultural counties show a decline in pollution that is roughly 0.5 standard deviations larger than agricultural ones. The impact of treatment in nonagricultural counties accounts for roughly 70% of the overall treatment effect estimated in columns 1–3.

This difference-in-differences model not only helps control for nationwide time trends in pollution but also provides evidence specifically supporting the mechanism predicted by our theory, as highlighted by empirical prediction 4. Our model implies that regulation is effective when it relies on monitoring simple, indisputable facts and enforcing abatement with property-rule remedies. The CWA treatment of point sources (hence, nonagricultural counties) fits this model. Its treatment of nonpoint sources (hence, agricultural counties) does not. The evidence confirms that the effectiveness of the CWA resulted precisely from the adoption of bright-line rules and not from, for example, simply setting uniform nationwide environmental standards or, more generally, replacing state with federal bureaucracy.

We also made a pair of predictions about the relationship between pollution and corruption. First, pollution levels should be higher in more corrupt places under a liability regime, and second, regulation should reduce pollution more in such places, as in the second part of empirical prediction 3. Figure 3 indicates that both of these predictions hold in our data. In figure 3, we show the level of pollution in treated corrupt and treated noncorrupt counties. As predicted, pollution levels in corrupt counties are substantially higher before 1972 than in noncorrupt ones. Moreover, levels in corrupt counties fall precipitously after 1972 and are substantially closer to levels in noncorrupt counties by the late 1970s. Table 1 confirms the findings in figure 3 and shows that they are statistically highly significant.

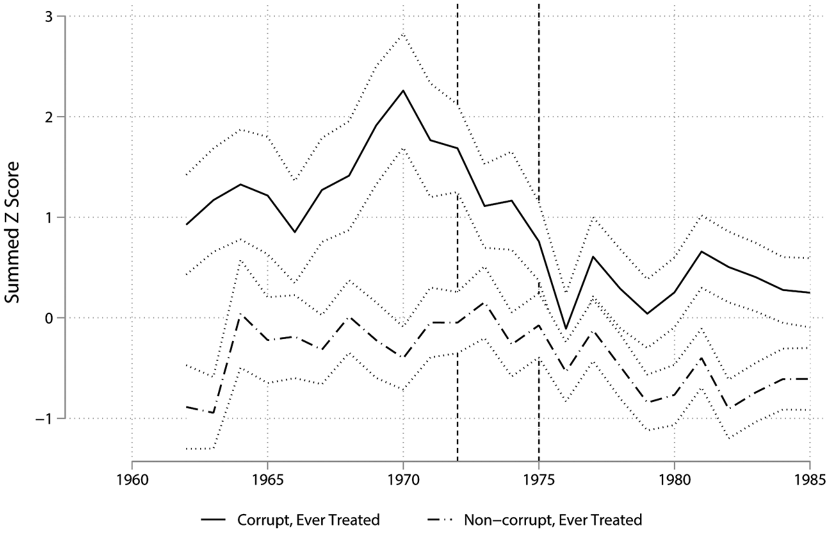

FIG. 3.—Pollution trends: corrupt and noncorrupt. The figure shows the annual trend in the average summed *Z* score of water pollution for corrupt and noncorrupt counties that are treated. The *Z* scores are calculated for each pollutant in each year (negative *Z* scores indicate lower than average pollution), and then *Z* scores for all pollutants are summed by county-year. Averages across counties are calculated by year. Treated counties are those that contain a facility that receives an NPDES permit in 1973 or 1974. Counties that contain a facility that receives a permit after 1974 are dropped. Nontreated counties do not contain a facility that received an NPDES permit between 1972 and 1985. Corrupt counties are those in states where the average number of federal convictions per 10,000 state residents is above the mean. Conviction rates are calculated as the average of the annual number of convictions per capita over the years 1976–85. Dotted lines indicate the 95% confidence interval for the average summed *Z* score.

TABLE 3
Impact of the CWA in Corrupt Counties

	(1)	(2)
Corrupt	1.334**	
	(.656)	
CWA enforceable		−.587***
		(.217)
CWA enforceable × corrupt		−.922**
		(.439)
Observations	9,106	25,455
R^2	.04	.56
County fixed effects		Yes
Year fixed effects	Yes	Yes
State-specific linear time trend		Yes
Controls	Yes	Yes

Note.—The table reports the results of two specifications. Column 1 reports $y_{ijt} = \beta\, Corrupt_j + \psi_t$. Column 2 reports $y_{ijt} = \beta\, CWA_{it} + \omega\, CWA_{it} \times Corrupt_j + \gamma_i + \delta_j t + \psi_t$. The variable y_{ijt} represents the summed Z score across all pollutants in county i in state j and year t, and CWA_{it} is an indicator for whether the CWA was enforceable in county i in year t. We consider the CWA enforceable starting in the year that the first facility in a county receives its first NPDES permit if that is before 1975. $Corrupt_j$ is an indicator for whether a county is in a corrupt state (1 = yes). Corrupt states are those where the number of federal convictions per 10,000 state residents is above the mean. Conviction rates are calculated as the average of the annual number of convictions per capita over the years 1976–85. Controls include total employment, manufacturing employment and mining employment at the county level, and rates of college attendance at the state level. The parameter γ_i represents a county fixed effect, ψ_t represents a year fixed effect, and δ_j represents a state-specific linear time trend. Standard errors are clustered at the state level.
** $p < .05$.
*** $p < .01$.

To test whether regulation is more effective in counties in corrupt states, we turn to the specification in equation (3). Table 3 shows that the introduction of the CWA had a substantially larger impact in more corrupt locations. Column 1 confirms the results in table 1 that corrupt states have substantially more pollution before the CWA: levels of pollution are 1.3 standard deviations higher before 1972. Column 2 confirms that counties in corrupt states saw greater reductions in pollution than noncorrupt counties. We define corrupt states here as those with more than the average number of convictions. The corrupt locations see a decline in pollution levels 0.9 standard deviations larger than noncorrupt ones.

VI. Summary and Implications

We have started with the puzzle that, while the law and economics approach typically stresses the benefits of liability rules to protect property rights, most jurisdictions use very different strategies—including property rules such as injunctions, regulation, and even criminal law—to achieve this goal. We have taken the efficiency perspective on the question of which approach is likely to prevail in a community.

The central mechanism whose consequences we explored is the subversion of justice by the strong. When particular legal facts are disputable, a strong litigant may have the power to get a favorable court ruling on these facts. Focusing on the case of water pollution by a factory that affects multiple adjacent land owners, we examined the case in which the polluter's interference with the owners' property right is indisputable, but the precise extent of harm they suffer because of it is disputable. We showed that the upside of a property rule relative to a liability rule is that it stops inefficient pollution when the strong polluter can subvert the court's assessment of damages. The downside of a property rule is that it relies on bargaining to reach efficient solutions, which can fail when there are many victims. In this situation, regulation that limits but does not eliminate pollution can work better than either legal rule, because the partial mandated abatement of pollution cannot be effectively subverted. Our model predicts when alternative forms of securing property rights are more efficient.

We then examined pollution trends across US counties before and after the CWA. We discuss how American courts replaced property rules with liability for pollution in the nineteenth century and how CWA legislation then replaced the liability rules with regulation restricting emissions, enforced by stark property-rule sanctions. Both transitions are consistent with the predictions of our model for optimal rules under changing conditions. We further showed that the CWA reduced pollution, especially in counties where it was enforced through direct monitoring of permitted emissions—namely, in manufacturing rather than agricultural counties. Finally, we showed that more corrupt states generally had higher levels of water pollution before the passage of the CWA but also sharper subsequent reductions in pollution. Both findings confirm the empirical predictions of our model.

The key message of our findings is to suggest the conditions under which liability rules, property rules, and regulation are likely to be the most efficient method of securing property rights, starting with the perspective that the subversion of justice is a central feature of property rights enforcement. Perhaps other features of the systems of law enforcement both across space and over time can be understood through this general lens.

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